Regional Review Workshops on Completed Research Activities

Proceedings of Review Workshop on Completed Research Activities of Crop Protection Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia 15-20 Nov 2021 and 31 Oct-04 Nov 2022

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Edited by: Kedir Wako, Tafa Jobie and Addis Shiferaw

Oromia Agricultural Research Institute

P.O.Box 81265, Finfinnee, Ethiopia

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Contents

Effect of Fungicide Application Rate and Frequency against Major Diseases of Faba Bean (Vicia Faba L.) on Grain Yield and Yield Components in Southeastern Oromia, Bale

[1]Ermias Teshome and [2]Dagne Kora
Oromia Agricultural Research Institute, Sinana Agricultural Research Center (SARC). P.O.Box: 208; Bale-Robe, Ethiopia. Corresponding Author: ermiastafa@gmail.com

ABSTRACT

An experiment was conducted for three years (2017/18, 2018/19 and 2019/20) at SARCand Agarfa sub-site to determine the application frequency and rate of a fungicide, Matico WP. RCBD with three replicationswas used to layout the experiment. Severity of chocolate spot, rust and ascochyta blight diseaseswas scored based on 1-9 scale. Area under disease progress curve (AUDPC) and apparent disease progress rate (r) were calculated from percent disease severity index (PSI). Logistic model (ln[y/ (1-y)]) was employed to estimate the disease progress and data were analyzed using SAS Software. The relationship of disease severity with yield and yield traits was assessed using Correlation and Regression analysis. The economic analysis was done to see the financial profitability of Faba bean diseases management. ANOVA for disease severity, AUDPC and r have shown significant differences ($p \leq 0.05$) between treatments.The highest Chocolate spot rust and ascochyta blight diseases severity of 53.55%, 44.44% and 42.59%, respectively were recorded from unsprayed and plots sprayed with lower rates and frequency. The lowest disease severity for all diseaseswas recorded from plot sprayed four times at the rate of 2.5 kg/ha. The lowest AUDPC and r for the three diseases were recorded from plots sprayed four times at the rate of 2.5 kg/ha. ANOVA for yield and yield-related traits have shown significant variations ($P \leq 0.05$) among treatments.The highest number of pods per plant (21), TKW (664.7g) and grain yield (3319.4kg/ha) were recorded from plots sprayed four times at 2.5 kg/ha.The lowest number of pods per plant (7), TKW (340g) and grain yield (1075 kg/ha) were recorded from plots sprayed once at 1kg/ha and unsprayed plots. Simple Linear Regression between grain yield anddiseases severity revealed significant association ($P \leq 0.0001$). The Correlation of grain yield with diseases severity has depicted significant negative correlation. The economic analysis showed thatthe highest marginal benefit (43109.8ha^{-1} ETB) was obtained from plots sprayed by MATICO WP three times at 2.5kg/ha. Whereas, the Maximum Marginal Rate of Return (MRR) of 2126.31% and 2021.13%were obtained from plots sprayed twice and once at 2.5kg/ha, respectively. Therefore, one to two times foliar application of MATICO WP at the rate of 2.5 kg/ha is recommended for the management of Faba bean diseases.

Key words: *Faba bean, Botrytis fabae, Uromyces viciae-fabae,Ascochyta fabae*

Disease severity index, AUDPC, and Disease progress curve

INTRODUCTION

Faba bean (*Vicia faba* L.) also known as broad bean, horse bean and field bean is among the earliest domesticated food legume crops (Metayer, 2004). In Ethiopia, it is one of the most important pulse crops produced. According to some reports, Faba bean has covered 437, 106.04 ha of land and a total production volume of 921,761.54t yr^{-1}washarvested (CSA, 2018). Its high nutritive value, both in terms of energy and protein contents (24-30%) has madeFaba beanone of the most important food legumes in the world. It is an excellent nitrogen fixer and Ethiopian farmers are aware of its role in improving soil health and fertility by fixing atmospheric nitrogen, and widely useit in rotation with cereals (Sahile *et al*., 2008). However, its national average yield under small holder farmers in Ethiopia is as low as 2.1t ha^{-1} (CSA, 2018), despite the availability of varieties which can yield up to 4t ha^{-1} (MoA, 2018). This is largelybecause of the fact that Ethiopian farmers cultivate low yielding cultivars, diseases, Weeds and insect pests (Yohannes, 2000). The most important diseases are chocolate spot (*Botrytis fabae*), rust (*Uromyces viciae-fabae*), black rot (*Fusarium solani*) and Aschochyta blight (*Ascochyta fabae*). The most important parasitic weeds are *Orobanchespp.*and *Phelipanchespp.*;black bean aphid (*Aphis fabae*) isalsoan important faba bean insect pestthat can cause yield reduction(Mussa *et al*., 2008; Ahmed *et al*., 2010).

Diseases are among the major yield constraining biotic factors challenging faba bean production in Ethiopia.The environmental conditions in the faba bean growing areas of Bale highlands are highly favorable for disease development. This necessitates to have well developed management options against major Faba bean diseasesto reduce the yield losses. The work done so far focuses only on the application of fungicide atits highest rate without considering the crop growth stage, althoughthe flowering stage is identified to be highly susceptible to disease infection. Therefore, this work was undertaken to find out the effect of reduced fungicide application rate and frequency at flowering stageof chocolate spot development and progress.

MATERIALS AND METHODS

Description of Experimental Site

The experiment was conducted for three years - from 2017/18 to 2019/20at Agarfa sub-site and Sinana Agricultural Research Center (SARC). The locations represent the major faba bean production areas of Bale highlands and are characterized by high rainfall.They are characterized by bimodal pattern of rainfall where the short rainy season is from March to June locally known as "*Ganna (Belg)"* and the main season is from August to December which is called *"Bona (Meher)"*. The two seasons are locally termed after the time of crop harvest. These areasarealso suitable environments (hot spot) for majority of faba bean diseasesdevelopment. SARC is located at 7^{o}7' N (latitude) and 40^{o}10' E (longitude) at about 2400 m.a.s.l. SARC receives a mean annual rainfall of 875mm and the annual temperature range of 9–21 ^{o}C (Nefo *et al*., 2008). The dominant soil type of Sinana is pellic vertisol and slightly acidic (Dagne *et al.*, 2016). Agarfa is locate at an altitude range of 2328-2505 m.a.s.l and receives a mean annual rainfall of 907 mm. The annual temperature range of Agarfa area is10-24 ^{o}C andthe dominant soil type is vertisol (Eshetu *et al.*, 2018).

Treatments and Design

The experimentwas conducted using Randomized Complete Block Design (RCBD)in three replications. An improved faba bean variety known asMosisa was used as test variety. A fungicide Matico WP was sprayed in four frequencies (one times, two times, three times and four times sprays) and five application rates (0 kg/ha, 1 kg/ha, 1.5 kg/ha, 2 kg/ha and 2.5 kg/ha) at 7-10 days interval (Table 1).The plots size were 3m × 2.4 m having a total of 6 seeding rows out of which four rows were harvested for yield and thousand kernel weight measurements. Space between rows, plots and replicationswere of 0.4m, 2m and 2m, respectively. Disease infection gradients were created by spraying a fungicide Matico WP at different application rates and frequencies at flowering stage (Table 1). Unsprayed control was included as negative control for treatment comparison. Fungicide application was started at about flowering stage. Seed rate (125 kg/ha for small seeded varieties), fertilizer rate (100 kg/ha NPS), weeding and other all agronomic packages are applied as per the recommendation for the Faba bean.

Table 1: Treatment Combination

Treatment No.	Application rate	Frequency of spray
1	No spray	0
2	1 kg/ha	1
3	1 kg/ha	2
4	1 kg/ha	3
5	1 kg/ha	4
6	1.5 kg/ha	1
7	1.5 kg/ha	2
8	1.5 kg/ha	3
9	1.5 kg/ha	4
10	2 kg/ha	1
11	2 kg/ha	2
12	2 kg/ha	3
13	2 kg/ha	4
14	2.5 kg/ha	1
15	2.5 kg/ha	2
16	2.5 kg/ha	3
17	2.5 kg/ha	4

Data Management and Statistical Analysis

Logistic, [ln [(Y/1-Y)], (Vander Plank, 1963) and Gompertz, -ln[-ln(Y)], (Berger, 1981) models were compared for estimation of disease parameters. Goodness of the fit of the models was tested using coefficient of determination (R^2) and Logistic model was found to fit best to the data. Therefore, variables for field experiment data under different treatments were analyzed using logistic model, ln[y/ (1-y)] with the SAS Procedure (SAS Institute, 1998). Diseases were scoredbased on 1-9 scoring scale, where 1= No disease symptoms or very small specks; 3= few small discrete lesions; 5= some coalesced lesions with some defoliation; 7= large coalesced sporulating lesions, 50% defoliation and some dead plant; and 9= Extensive lesions on leaves, stems and pods, severe defoliation, heavy sporulation, stem girdling, blackening and death of more than 80% of plants (Bernier *et al*., 1993), and converted to percentage severity index (PSI) (Wheeler (1969). LSD technique at 95% confidence interval was used for mean separation.Area UnderDisease Progress Curve (AUDPC)rate of disease progress (r) were calculated for each treatment (Shaner and Finney, 1977). ANOVA was performed for PSI, AUDPC and r using SAS version 9.1.3.The association between disease parameters yield was assessed via Correlation and regression analysis.

$$\text{PSI} = \frac{\text{Sum of Numerical Ratings X 100}}{\text{Number of Plants Scored X Maximum Score on Scale}} \ldots\ldots\ldots\ldots\ldots 1 \text{ (Wheeler, 1969)}$$

$$\text{AUDPC} = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2 \text{ (Shaner and Finney, 1977)}$$

Where, X_i= the PSI of disease at the i^{th} assessment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

ECONOMIC ANALYSIS

The total cost of production and marginal benefitsfrom each treatment were calculated using the partial budget analysis method. Similarly, the Marginal Rate of Return (MRR) was computed considering the total variable costs in each treatment. The sum costs of fungicide, water, sprayer rent, labor for spraying, labor of water supply and labor for cleaning equipment were considered as total variable cost. The grain yield and economic data were collected to calculate MRR and compare the advantage of fungicide sprayat flowering stage for the management of chocolate spot disease over unsprayed plot. MRR was used to measure the effect of additional investment on net returns (CIMMYT, 1988). MRR provides the benefit value obtained as a function of the additional investment.

$$\text{MRR} = \frac{\text{DNI}}{\text{DIC}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3 \text{ (CIMMYT, 1988)}$$

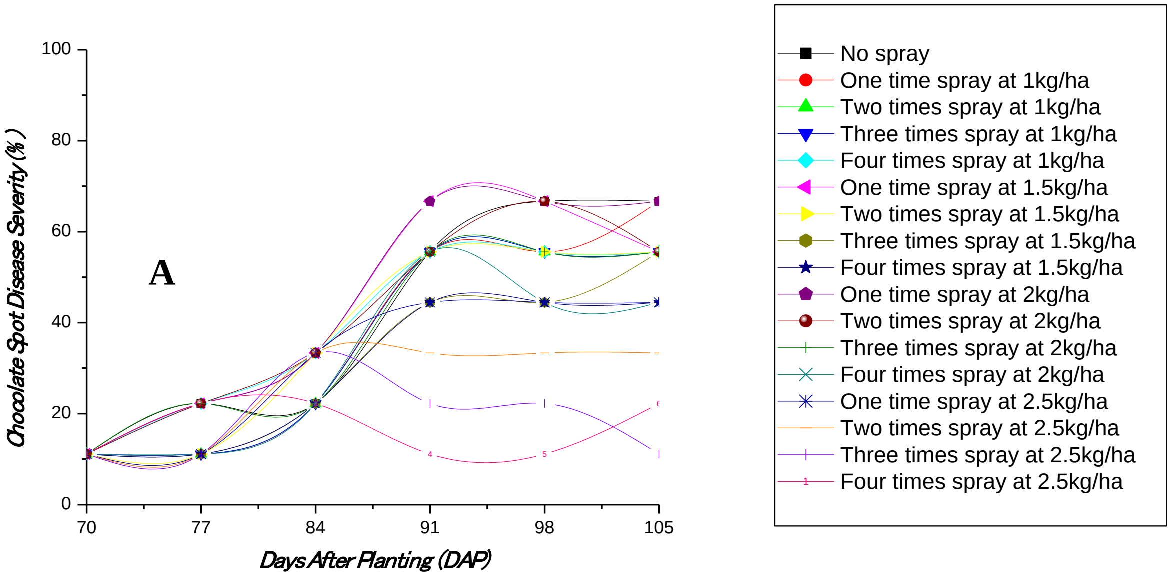
Where: - MRR- Marginal Rate of Return,

DNI-Difference in Net Income compared with control, DIC- Difference in Input Cost compared with control.

RESULTS AND DISCUSSION

The combined Analysis of Variance over years and locations showed statistically significant differences (*P<0.0001*) between treatments for disease parameters and yield and yield components. The highest chocolate spot (53.55%), rust (44.44%) and ascochyta blight (42.59%) diseases severities were recorded from untreated control, plot sprayed once at 1 kg/ha and plot sprayed once at 1.5 kg/ha, respectively. The lowest chocolate spot (14.20%), rust (11.11%) and ascochyta blight (16.67%) disease severities were recorded from plots sprayed four times at 2.5 kg/ha (Figure 1;Table 2).In line with this finding, Sahile *et al.,* (2008) reported thatmean disease severity ranging from 25 to 46.6% in sprayed plots, in comparison with 56.7% in unsprayed plots.Similarly, Ermias and Addisu (2013) reported lower disease severity from sprayed plots and higher disease severity for unsprayed plots.The highestchocolate spot AUDPC (2350.4%-days), rust AUDPC (1555.56%-days) and ascochyta blight AUDPC (1578.63 %-days) were recorded from unsprayed plot, plot sprayed once at 1kg/ha and plot sprayed once at 1.5kg/ha, respectively.

Apparent infection rates of 0.01458, 0.01458 and0.07150units^{-1} day were calculated from unsprayed plot and plot which received one time application at 1kg/ha, respectively. This finding agrees with Samuel *et al.,* (2018) who reported that application of fungicide reduced r and disease severity.Whereas, the lowestChocolate spot AUDPC (238.3%-days) and r(-0.00063units^{-1}) were calculated from plotsprayed four times at 2.5kg/ha.The lowest Rust (408.72%-days) and Ascochyta blight (570.37%-days) AUDPC were recorded from plot sprayed four times at 2.5 kg/ha and the lowest r of -0.00245units^{-1} day for rust and -0.00729units^{-1} day for ascochyta blight were recorded from plots sprayed three times at a rate of 2.5 kg/ha. Fungicide spray affects the development and progress of faba bean diseases severity andAUDPC (Emeran *et al.,* 2011; Samuel *et al.,* 2018).


Chocolate Spot Disease Severity (%)
Days After Planting (DAP)
A
No spray
One time spray at 1kg/ha
Two times spray at 1kg/ha
Three times spray at 1kg/ha
Four times spray at 1kg/ha
One time spray at 1.5kg/ha
Two times spray at 1.5kg/ha
Three times spray at 1.5kg/ha
Four times spray at 1.5kg/ha
One time spray at 2kg/ha
Two times spray at 2kg/ha
Three times spray at 2kg/ha
Four times spray at 2kg/ha
One time spray at 2.5kg/ha
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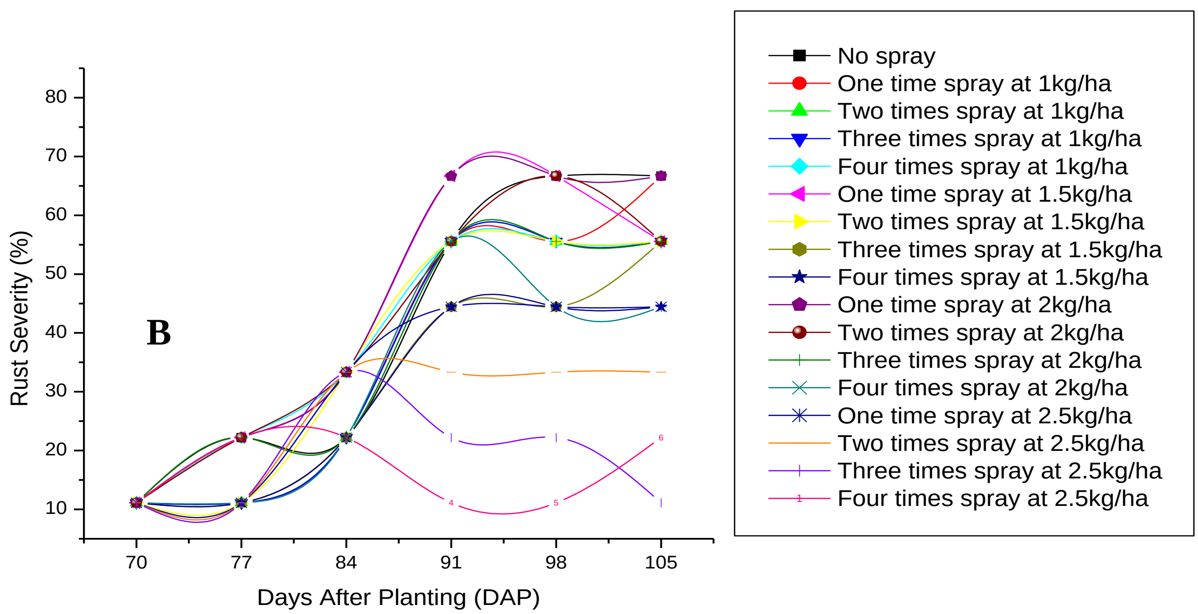
Four times spray at 2.5kg/ha


Rust Severity (%)
Days After Planting (DAP)
B
No spray
One time spray at 1kg/ha
Two times spray at 1kg/ha
Three times spray at 1kg/ha
Four times spray at 1kg/ha
One time spray at 1.5kg/ha
Two times spray at 1.5kg/ha
Three times spray at 1.5kg/ha
Four times spray at 1.5kg/ha
One time spray at 2kg/ha
Two times spray at 2kg/ha
Three times spray at 2kg/ha
Four times spray at 2kg/ha
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Three times spray at 2.5kg/ha
Four times spray at 2.5kg/ha

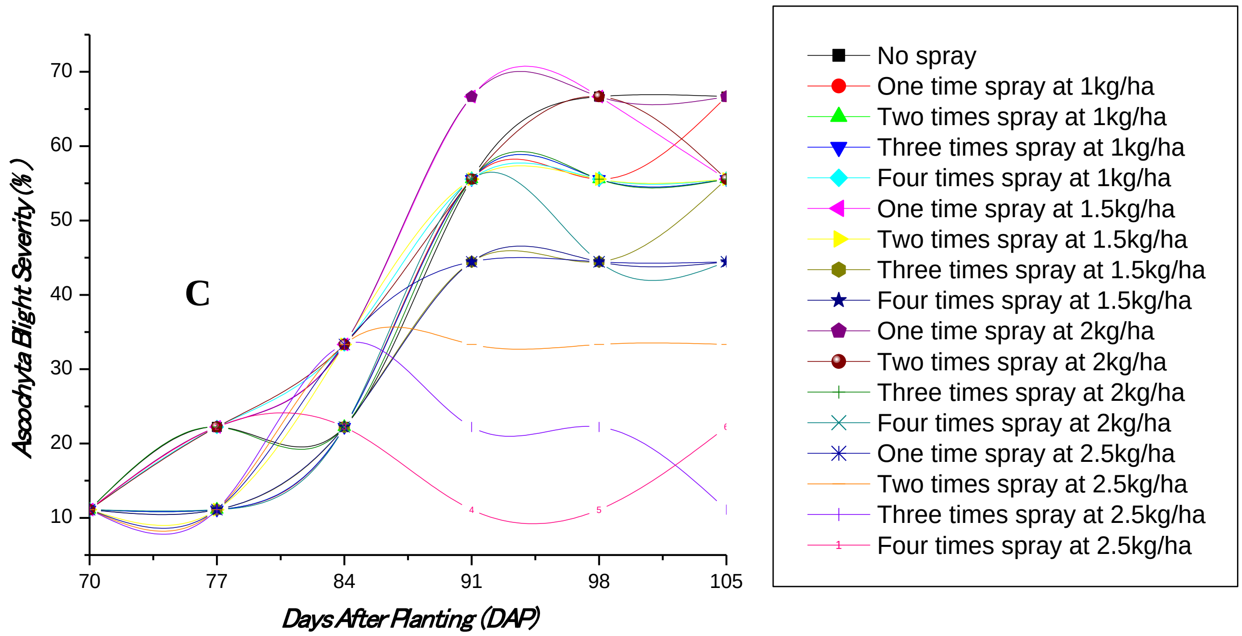


Figure 1: Influence of fungicide application rate and frequency on Chocolate spot (A), Rust (B)and Ascochyta blight (C) diseases development and progress over time

Table 2: Effects of fungicide spray rate and frequency on disease severity, AUDPC and r of Chocolate spot, Rust and Ascochyta blight diseases

Treatment	Chocolate spot (%)	Choc. spot-AUDPC	Choc. spot-r	Rust (%)	Rust AUDPC	Rust-r	Asco. blight (%)	Asco. blight AUDPC	Asco. blight -r
No spray	53.55	2350.4	0.01458	41.95	1450.81	0.14793	40.70	1438.11	0.05368
1 times X 1kg/ha	48.67	2058.8	0.01348	44.44	1555.56	0.14410	37.04	1283.33	0.07150
2 times X 1kg/ha	47.49	1850.01	0.00687	38.89	1361.11	0.07491	36.40	1269.98	0.02508
3 times X 1kg/ha	43.37	1526.6	0.00546	34.54	1217.48	0.03478	35.76	1268.56	0.02534
4 times X 1kg/ha	39.59	568.9	0.01147	32.08	1114.04	0.04127	38.89	1400.00	0.02165
1 times X 1.5kg/ha	47.05	1854.8	0.00547	41.33	1490.22	0.03054	42.59	1555.56	-0.00590
2 times X 1.5kg/ha	42.59	1514.4	0.00348	41.96	1451.07	0.06416	37.04	1322.22	0.02296
3 times X 1.5kg/ha	42.58	1513.5	0.00325	42.51	1436.94	0.02688	31.48	1088.89	0.04211
4 times X 1.5kg/ha	41.36	1485.1	0.00311	29.63	1050.00	0.01937	29.60	1049.48	0.01427
1 times X 2kg/ha	40.74	1448.3	0.00425	35.17	1243.67	0.03821	44.35	1578.63	0.04630
2 times X 2kg/ha	43.79	1532.4	0.00589	30.17	1033.93	0.04148	40.72	1477.00	0.00637
3 times X 2kg/ha	35.8	458.6	0.00241	27.78	972.22	0.02427	37.62	1346.59	0.01957
4 times X 2kg/ha	32.05	365.4	0.00112	30.80	1087.07	0.01293	31.48	1127.78	0.00722
1 times X 2.5kg/ha	38.27	547.6	0.00254	32.67	1190.91	0.00670	32.09	1140.48	0.01173
2 times X 2.5kg/ha	30.26	359.4	-0.00098	29.59	1022.91	0.01825	25.90	932.30	0.00565
3 times X 2.5kg/ha	20.96	289.4	-0.00086	18.72	666.17	-0.00245	19.12	712.70	-0.00729
4 times X 2.5kg/ha	14.20	238.3	-0.00063	11.67	408.72	0.00031	16.05	570.37	0.00328
CV(%)	15.1	19.5	11.34	12.23	15.99	13.72	18.24	17.76	16.77
$LSD_{(0.05)}$	9.29	586.4	0.00114	3.43	115.54	0.0231	1.2604	35.34	0.0064

Note: AUDPC- Area Under Disease Progress Curve, r- apparent infection rate, Choc. Spot- Chocolate spot, Asco.blight- Ascochyta blight.

Regarding agronomic performance, analysis of variance depicted that there was statistically significant difference ($P<0.05$) among treatments. ANOVA for number of seeds per plant has showed no significant difference ($P\leq 0.05$). In contrary, ANOVA for number of Pods per Plant, Thousand Kernel Weight (TKW (g)) and grain yield (kg/ha) showed statistically significant difference ($P<0.05$) among treatments (Table 3). The highest number of pods (21), TKW (664.67g) and Grain yield (3319.4kg/ha) were recorded from plot sprayed four times at 2.5kg/ha (Table 3).

Table 3: Effect of fungicide spray rate and frequency on Faba bean yield and yield components

Treatment	No. Pod/plant	No. Seed/pod	TKW (g)	Grain Yield (kg/ha)
No spray	7.67	3.00	350.00	1075.00
1 times X 1kg/ha	7.00	2.67	340.00	1091.7
2 times X 1kg/ha	8.00	3.00	365.00	1097.7
1 times X 1.5kg/ha	10.00	3.33	406.00	1158.3
2 times X 2kg/ha	14.00	2.00	386.33	1729.2
3 times X 1kg/ha	8.00	3.00	395.00	1276.4
2 times X 1.5kg/ha	10.67	3.00	405.00	1179.2
3 times X 1.5kg/ha	8.00	3.00	392.67	1273.6
4 times X 1.5kg/ha	9.00	2.00	489.00	4548.6
1 times X 2kg/ha	10.00	2.00	365.00	1737.5
4 times X 1kg/ha	9.00	2.00	405.00	1381.9
1 times X 2.5kg/ha	16.00	4.00	593.00	1958.3
3 times X 2kg/ha	14.33	3.00	456.00	1819.4
4 times X 2kg/ha	17.00	3.00	556.00	2265.3
2 times X 2.5kg/ha	15.00	3.67	601.00	2929.2
3 times X 2.5kg/ha	18.67	3.00	645.00	3204.2
4 times X 2.5kg/ha	21.00	4.00	664.67	3319.4
CV (%)	18.65	11.74	9.74	18.26
LSD $_{P\leq 0.05}$	7.01	NS	265.62	808.64

CORRELATION AND REGRESSION ANALYSIS

Correlation Analysis

Simple pair wise Pearson Correlation analysis was performed to determine the relationship between chocolate spot, rust and ascochyta blight disease parameters and yield parameters. ANOVA showed statically significant relationship ($P<0.005$) between disease parameters and yield parameters. Similarly, some of the yield parameters showed very strong positive influence on grain yield.

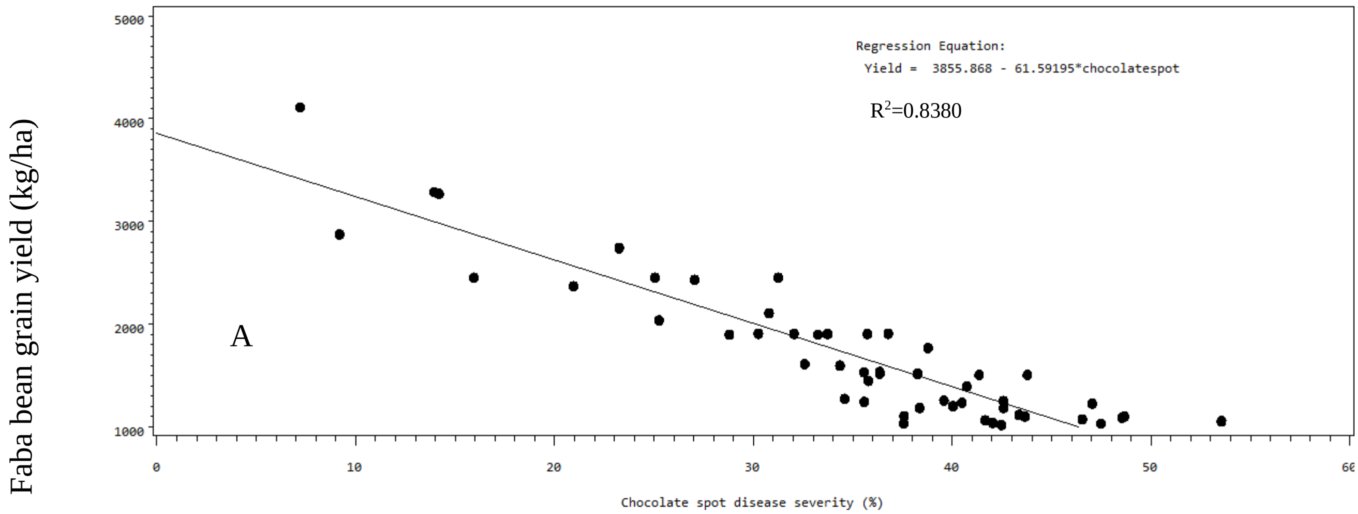
Chocolate spot, Rust and Ascochyta blight diseases severity have significant and highly strong negative correlation with number of pods per plant (r=-0.84324, $P\leq 0.0001$; r= -0.81568, $P\leq 0.0001$ *and* r= -0.68554, $P\leq 0.0001$), TKW (r= -0.85503, $P\leq 0.0001$; r= -0.79667, $P\leq 0.0001$ *and* r= -0.86229, $P\leq 0.0001$) and grain yield (r= -0.91540, $P\leq 0.0001$; r= -0.83911, $P\leq 0.0001$ *and* r= -0.72643, $P\leq 0.0001$), respectively. Similarly, number of pods per plant (r= 0.85612, $P\leq 0.0001$) and TKW (r= 0.83312, $P\leq 0.0001$) showed strong positive correlation with grain yield (Table 4).

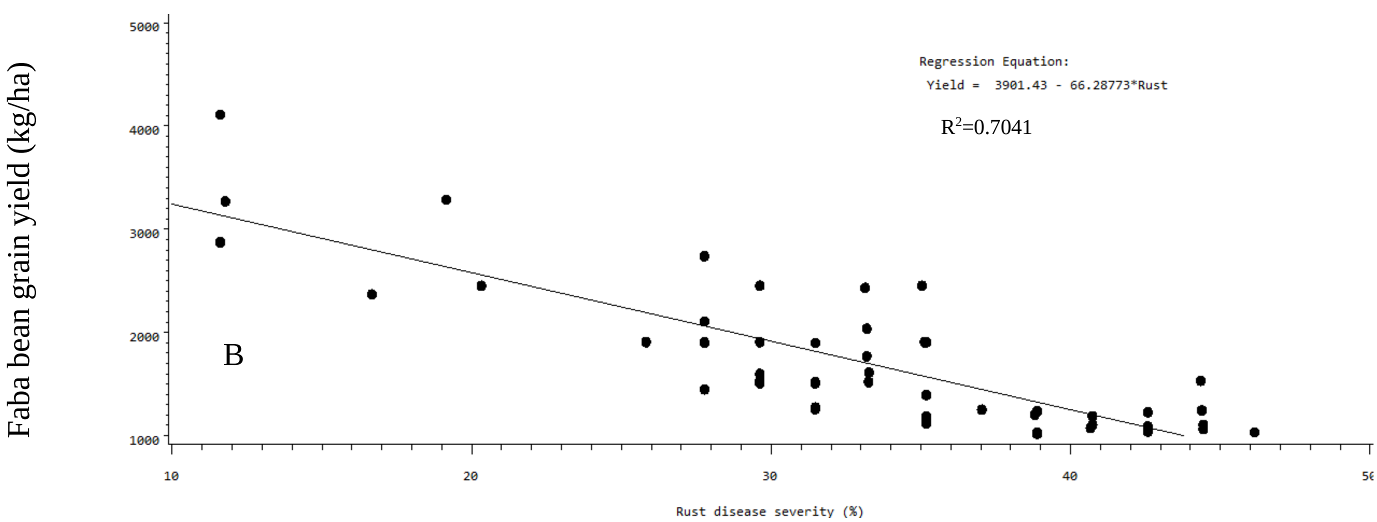
Table 4: Correlation between Chocolate spot, Rust, Ascochyta blight diseases parameters,yieldand yield Components of Faba bean

	Chocolate spot (%)	Rust (%)	Ascochyta blight (%)	number of pods/plant	TKW (g)	Grain yield (kg/ha)
Chocolate spot (%)						
Rust (%)	0.84133**					
Ascochyta blight (%)	0.79993**	0.72691**				
Number of pods/plant	-0.84324***	-0.81568***	-0.68554***			
TKW (g)	-0.85503***	-0.79667***	-0.86229***	0.88284***		
Grain yield (kg/ha)	-0.91540***	-0.83911***	-0.72643***	0.85612***	0.83312***	

Regression Analysis

Simple linear regression analysis was undertaken in order to assess the association between chocolate spot, rust and ascochyta blight diseases severity and faba bean grain yield. The regression analysis result has revealed statistically significant associations ($P\leq 0.0001$)between chocolate spot, rust and ascochyta blight diseases and grain yield. The estimated slope of the regression line obtained for chocolate spot disease severity, rust and ascochyta blight diseases were -61.59, -66.28 and -64.95, respectively. These estimatesindicatethat for each unit increase in percent chocolate spot, rust and ascochyta blight severity, there will befaba bean grain yield loss of 61.59 kg/ha, 66.28 kg/ha and 64.95 kg/ha, respectively (Figure 2A, B, C). The coefficient of determination (R^2) values calculated for each disease has confirmed that for chocolate spot, rust and ascochyta blight, the equations explained83.8%, 70.4% and 52.8% of losses in faba bean grain yield was occurred due to chocolate spot, rust and ascochyta blight diseases, respectively (Figure 2A, B, C).





R^2=0.5278

C

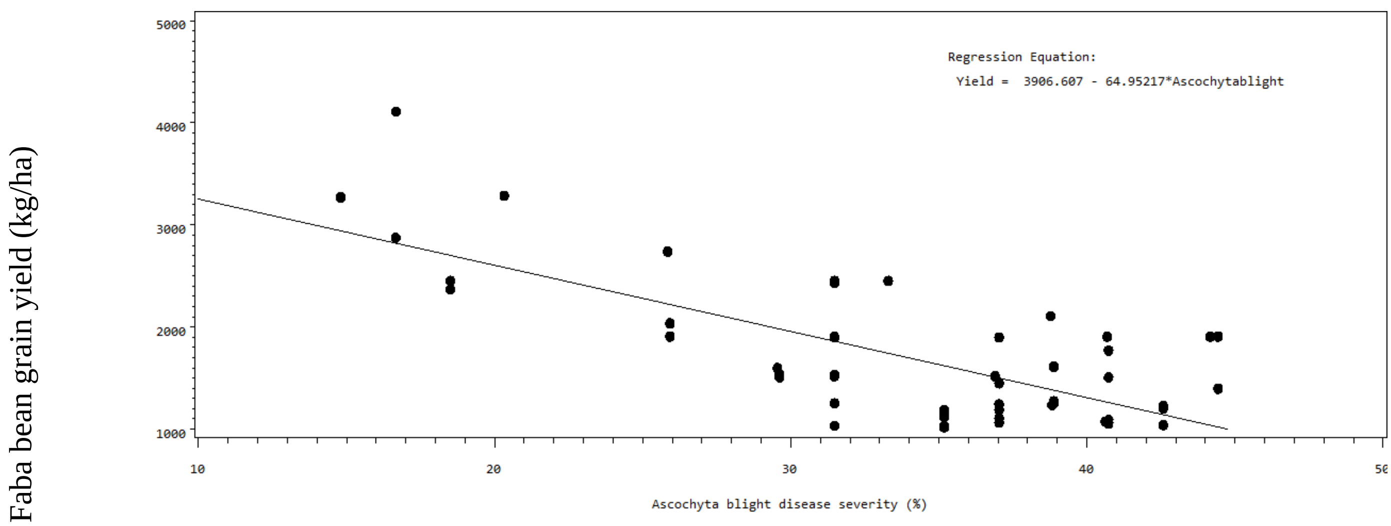


Figure 2: Association between losses in Faba bean grain yield and Chocolate spot(A), Rust (B) and Ascochyta blight diseases severity (C)

Economic Analysis

The partial budget analysis method was employed to carry out economic analysis to determine the profitability of the treatments. The total variable costs in each treatment were taken in to account to do the analysis. The sale revenue, marginal cost, marginal benefit and marginal rate of return (MRR) were computed for each treatment (Table 6). The total income from each treatment was obtained as sale revenue (SR) from the produce in a rate of 14 ETB per kilogram of Faba bean. The marginal cost (MC) was computed as a total sum of all production costs that varied and marginal benefit (MB) was calculated as a difference of sale revenue and marginal cost (Table 5 and Table 6). The highest marginal benefit (43109.8ha^{-1}ETB)was recorded from plots sprayed with a fungicide MATCO WPthree times in week's interval at a rate of 2.5 kg/ha which is followed by 42123.6ha^{-1}ETB and 39842.8ha^{-1}ETB from plots sprayed four times and two times at 2.5 kg/ha, respectively. The lowest marginal benefit of 15000.8ha^{-1}ETB was recorded from plots sprayed once at a rate of 1kg/ha (Table 6).

The highest MRR (ETB 2126.31 %) was recorded from plots sprayed twice at a rate of 2.5 kg/ha. This indicates that for every ETB 1.00 invested on MATCO WP to spray against Faba bean diseases, there will be a gain of about ETB 21.26 ha^{-1} season^{-1}. The second and third highest MRR of 2021.13% and 1604.33% were calculated from plots sprayed once and three times at a rate of 2.5kg/ha, respectively. Which implies that for every ETB 1.00 invested on a fungicide MATCO, the return will be ETB 20.21 and 16.04, respectively ha-^{1} season^{-1}(Table 6).

Therefore, from the economic profitability viewpoint, production of moderately resistant Faba bean variety Mosisa sprayed MATCO PW one to two times at flowering stage at a rate of 2.5kg/ha is the most profitable Faba bean diseases management practice for small holder farmers' at the current Faba bean market price.

Table 5:Total variable cost of fungicide application and costs associated with it for protected plots at Sinana in 2013/14, 2014/15 and 2015/16 GC main cropping season

Treatment	List of items and activities as a source of costs (Ethiopian Birr)								
	Fungicide			Sprayer rent	Labor cost tospray	Labor cost for water supply	Cleaning equipment	Cost of water	Total variable cost
	Rate (kgha^{-1})	Frequency	Cost (ETH Birr)						
No spray	0	0	0	0	0	0	0	0	0
1 times × 1kg/ha	1	1	200	20	35	15	5	8	283
2 times × 1kg/ha	1	2	400	40	70	30	10	16	566
1 times × 1.5kg/ha	1.5	1	300	20	35	15	5	8	383
2 times × 2kg/ha	2	2	800	40	70	30	10	16	966
3 times × 1kg/ha	1	3	600	60	105	45	15	24	849
2 times × 1.5kg/ha	1.5	2	600	40	70	30	10	16	766
3 times × 1.5kg/ha	1.5	3	900	60	105	45	15	24	1149
4 times × 1.5kg/ha	1.5	4	1200	80	140	60	20	48	1548
1 times × 2kg/ha	2	1	400	20	35	15	5	8	483
4 times ×1kg/ha	1	4	800	80	140	60	20	48	1148
1 times × 2.5kg/ha	2.5	1	500	20	35	15	5	8	583
3 times × 2kg/ha	2	3	1200	60	105	45	15	24	1449
4 times × 2kg/ha	2	4	1600	80	140	60	20	48	1948
2 times × 2.5kg/ha	2.5	2	1000	40	70	30	10	16	1166
3 times × 2.5kg/ha	2.5	3	1500	60	105	45	15	24	1749
4 times × 2.5kg/ha	2.5	4	4000	80	140	60	20	48	4348

Table 6: Cost-benefit assessment of fungicide application frequency against Chocolate spot of Faba bean at Sinana in 2013/14,014/15 and 2015/16 GC main cropping season

Treatment	Fungicide ($kgha^{-1}$)	Yield $kgha^{-1}$	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
No spray	0	1075.0	15050	0	15050.0	
1 times × 1kg/ha	1	1091.7	15283.8	283	15000.8	-17.39
2 times × 1kg/ha	2	1097.7	15367.8	566	14801.8	-43.85
1 times × 1.5kg/ha	1.5	1158.3	16216.2	383	15833.2	204.49
2 times × 2kg/ha	4	1729.2	24208.8	966	23242.8	848.12
3 times × 1kg/ha	3	1276.4	17869.6	849	17020.6	232.11
2 times × 1.5kg/ha	3	1179.2	16508.8	766	15742.8	90.44
3 times × 1.5kg/ha	4.5	1273.6	17830.4	1149	16681.4	141.98
4 times × 1.5kg/ha	6	1548.6	21680.4	1548	20132.4	328.32
1 times × 2kg/ha	2	1737.5	24325	483	23842.0	1820.29
4 times × 1kg/ha	4	1381.9	19346.6	1148	18198.6	274.27
1 times × 2.5kg/ha	2.5	1958.3	27416.2	583	26833.2	2021.13
3 times × 2kg/ha	6	1819.4	25471.6	1449	24022.6	619.23
4 times × 2kg/ha	8	2265.3	31714.2	1948	29766.2	755.45
2 times × 2.5kg/ha	5	2929.2	41008.8	1166	39842.8	2126.31
3 times × 2.5kg/ha	7.5	3204.2	44858.8	1749	43109.8	1604.33
4 times × 2.5kg/ha	10	3319.4	46471.6	4348	42123.6	622.67

SR = Sales revenue; MC = Marginal cost; MB = Marginal benefit; MRR = marginal rate of return

CONCLUSION AND RECOMMENDATION

The application of a fungicide MATICO WP influencedchocolate spot, rust and ascochyta blight diseases development and progress over time. Similarly, the agronomic performance of Faba bean was influenced by the application rate and frequency of the fungicide. For the disease parameters, the highest diseases severity, AUDPC and r were recorded from unsprayed plots and plots which received lower rates and frequency of applications. Whereas, the lowest diseases severity, AUDPC and rare recorded from plots which have received four times application of a fungicide MATICO WP at the rate of 2.5kg/ha. This indicates that theapplication of fungicideMATICO WPis an important Faba bean production package.

The highest grain yield of 3319.4 kg/ha and 3204.2 kg/ha were achieved from plots sprayed four times and three timesby a fungicide MATICO at the rate of 2.5kg/ha, respectively.While the lowest grain yield of 1075 kg/ha and 1091.7 kg/ha were recorded from unsprayed plot and plot sprayed once at 1 kg/ha. Economic analysis depicted that the maximum marginal benefit (MB) of 43109.8 ETB ha^{-1} and 42123.6 ETB ha^{-1}were computed from plots sprayed three times and four times at a rate of 2.5 kg/ha, respectively. The lowest marginal benefit (MB) of 15000.8 ETB $ha^{-1}$and 15050 ETB ha^{-1}werecalculated from unsprayed plot and plots sprayed once at 1 kg/ha. Whereas, the highest marginal rate of return (MRR) 2126.31% and 2021.13% were obtained from sprayed twice and once at thr rate of 2.5kg/ha. On the other hand, the lowest MRR of -43.85% and -17.39 were calculated from plots sprayed twice and once at a rate of 1kg/ha, respectively.

Therefore, based on the result of biological study and economic analysis, 1-2 times spray of a fungicide MATICO WP at the rate of 2.5 $kgha^{-1}$at flowering stage of the crop is recommended for the management offaba bean Chocolate spot, rust and ascochyta blight diseasesto optimize financial benefit fromfaba bean production.

REFERENCES

Agegnehu, G., Ghizaw, A., Sinebo, W., 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. Eur. J. Agron. 25, 202–207.

Berger, R.D. 1981. Comparison of the Gompertz and Logistic equation to describe plant disease progress.*Phytopathology*. 71: 716-719.

Bernier, C.C., S.B. Hanounik, M.M. Hussein and H.A. Mohamed, 1993.Field manual of common faba bean diseases in the Nile Valley.International Center for Agricultural Research in the Dry Areas (ICARDA) Information Bulletin No. 3.

CSA (Central Statistical Authority), 2011.Agricultural sample survey. Report on area and

production of crops (private peasant holdings, meher season). Statistical Bulletin Vol. 1.

Addis Ababa, Ethiopia.

CSA (Central Statistical Authority), 2018.Agricultural sample survey. Report on area and

production of crops (private peasant holdings, meher season). Statistical Bulletin Vol. 1.

Addis Ababa, Ethiopia.

CIMMYT (International Maize and Wheat Improvement Center), 1988. From Agronomic data to farmers' recommendations: An Economic training manual. Completely revised edition. CIMMYT, Mexico, D.F.

Dagne Kora, Temam Hussein and Seid Ahmed, 2016. Epidemiology of chocolate spot (*Botrytis fabae* Sard.) on faba bean (*Vicia faba* L.) in the Highlands of Bale, Sinana district, Southeastern Ethiopia. Vol. 4 (1), pp. 131-138.

Dereje, G., 1993. Studies on the epidemiology of chocolate spot (*Botrytis fabae* Sard.) of faba beans (Vicia faba L.). Msc Thesis, Alamaya University, Alamaya, Ethiopia, 152pp.

Dereje, G., Beniwal, S.P.S., 1988. Yield loss in faba beans (*Vicia faba* L.) caused by chocolate spot (Botrytis fabae Sard). Plant Pathol.News Lett.13 (1), 16.

Dereje, G., Yaynu, H., 2001. Yield loss of crops due to plant diseases in Ethiopia. *Pest Manage. J. Ethiop*. 5, 55–67.

Emeran A.A., J.C. Sillero, M. Fernández-Aparicio and D. Rubiales, 2011.Chemical control of faba bean rust *(Uromyces viciae-fabae*). *Crop Protection*.Vol. 30. Pp. 907-912.

Ermias.Teshome and Addisu Tagegn, 2013.Integrated management of Chocolate spot (Botrytis fabae Sard.) of Faba bean (*Vicia faba* L.) at highlands of Bale, south eastern Ethiopia. Res *J Agric. Environ Manage*. Vol. 2: p. 011-014.

Eshetu G., Bimrew Y., and Shifa, H., 2018. Association of Chocolate Spot and Faba Bean Rust Epidemics with Climate Change Resilient Cultural Practices in Bale Highlands, Ethiopia.*Advances in Agriculture.*Vol. 1, P. 13. doi:10.1155/2018/6042495

Metayer. 2004. *Vicia faba* breeding for sustainable agriculture in Europe. Gie feverole.

MoA (Ministry of Agriculture), 2018. Plant variety release, protection and seed quality control directorate. Crop variety register. Issue No. 21. Addis Ababa, Ethiopia. pp. 104-108.

Nefo, Kedir; Geleto, Tilahun; and Aman, Allo (eds.), 2008. Fifteen years achievements: Oromia Agricultual Research Institute, Sinana Agricultural Research Center, Bale-Robe, Southeast Ethiopia.

SAS Institute. 1998. SAS/STAT guide for personal computers, version 6.12 edition. Cary, NC: SAS Institute.

Shaner, G., Stromberg, E.L., Lacy, G.L., Barker, K.R. and Pirone, T.P. 1992.Nomenclature and concepts of pathogenicity and virulence.*Annual Review of Phytopathology*.30:47-66.

Sahile Samuel, Chemeda Fininsa, P.K.Sakhuja and Seid Ahmed. 2008. Effect of mixed cropping and fungicides on chocolate spot *(Botrtyis fabae* L.*)* of faba bean *(vicia faba)* in Ethiopia. *Crop Protection*.27:275-282.

Samuel Woldemariam Sahile, Zewdu Teshome & Mulugeta Kibret, 2018. Integrated management of faba bean chocolate spot caused by *Botrytisfabae* inGondar, Ethiopia, Archives of Phytopathology and Plant Protection, 51:9-10, 461-484, DOI:10.1080/03235408.2018.1482648.

Torres, A.M., Roman, B., Avila, C.M., Satovic, Z., Rubiales, D., Sillero, J.C., Cubero, J.I., Moreno, M.T., 2004. Faba bean breeding for resistance against biotic stresses: towards application of marker technology. Euphytica 147, 67–80.

Van der Plank, J.E. 1963. Epidemiology of Plant Disease.New York and London Academic publishers. 206p.

Wheeler B.E.J., 1969. An introduction to plant diseases. Wiley sons, london, P. 347.

Yohannes Degago, 2000. Faba Bean (*Vicia fabae*) in Ethiopia.Institute of Biodiversity, conservation and Research (IBCR), Addis Ababa, Ethiopia, 43pp.

Survey of Striga (striga hermonthica (Del.) Benth) Infestation on Maize and Sorghum Fields in East Wollega zone

Megersa Debela[1*], Gudeta Bedada[1], Megersa Kebede[1]
[1] Bako Agricultural Research Center
[*]Corresponding author

Abstract

Striga weed, ***Striga hermonthica*** *is a devastating parasitic weed in the Sub-Saharan Africa. Studies have shown that Striga can reduce crop yield almost to zero often leading farmers to abandoning the fields when they are no more productive. This study assessed the infestation level of striga in East Wollega Zone to identify incidence, crop damage and farmers' management practices. The survey was conducted on farmers' fields in five districts for two consecutive years. Most of the farmers' fields were prevalent to striga weeds. Significant difference was observed in terms of striga infestation by crop type, survey years, and study districts. Accordingly, the highest mean value of striga incidence and mean crop damage score on sorghum (13.2 and 4.8, respectively) and Maize crop (8.9 and 3.4, respectively) were recorded in Guto Gida district. Most of the farmers (33%) practiced hand weeding to control striga. This study indicated that while the extent of striga infestation is high, striga control methods available are poorly understood and are rarely practiced by farmers. The current Maize and sorghum variety under production in the study areas do not show resistance/tolerance for striga infestation. Therefore it needs immediate action from all stakeholders to reduce the extent of striga infestation into striga-free districts. Enhancing the technical knowledge of farmer, Development Agents and development workers on the available striga control methods is of paramount importance.*

Key words: striga, incidence, infestation, sorghum, maize

Introduction

Striga hermonthica (Del.) Benth and *Striga asiatica* (L.) Kuntze are obligate root parasites that cause severe yield losses in sorghum and other cereal crops including rice (*Oryza glaberrima* Steudel and *O. sativa* L.), pearl millet (*Pennisetum glaucum* L.) and maize (*Zea mays* L.) (Riches 2003; Rodenburg *et al*. 2015)

In sub-Saharan Africa (SSA) the parasitic weeds in the genus striga are serious constraint to the productivity of staple cereal crops such as maize and sorghum causing yield losses ranging from 20% to 80% - even total crop failure in cases of severe infestation are quite common (Ejeta 2007).

As much as 21% of the total maize area in East Africa is infested by *striga* and it is considered to be extra severe there as well (Parker, 2009).

Striga is under control in mechanized, high-input agricultural systems such as in the southeastern USA (Sand *et al*., 1990), but the weed has not been appreciably controlled yet in sub-Saharan Africa. In Africa, farmers lack the resources to purchase and apply inputs that are common in developed countries: optimum fertilizers, herbicides, mechanical tillage equipment, etc. These farmers still await discoveries that will be relevant to their needs and capacities. Smallholder farmers are the most affected since they cannot afford expensive striga control mechanisms currently available on the market. These farmers often resort to hand weeding aimed at reducing the striga seed bank within the soil, which is unsustainable. This problem is aggravated by the viability of striga seeds in the soil for up to 20 years and their complex potential to spread *via* both mechanical and cultural processes (Khan *et al*., 2002).

On-farm striga control technologies require spatio-temporal information on the weed to precisely prioritize sites for intervention and applications of such technologies. Usually, ground-based surveys and inspection methods are used to detect striga-infested farms. (Mutanga *et al*., 2017).

High striga infestation was mainly observed in the northern and eastern parts of the country based on the evidence from different assessments (Atsbha G. *et al.*, 2016). Currently, in the western part in general and the East Wollega zone in particular, this invasive weed poses a great risk tomaize and sorghum production. No formal survey was conducted to identify and quantify the striga prevalence and infestation level in the East Wollega zone. This showed a gap in delivering reliable information for users. Therefore, this study was conducted with the aim to deliver information on striga infestation, pest pressure, damage it poses on the host plant and also to indicate farmers' management practices. Thus the information assists to make a decision for future risk prediction and to set the management strategies.

Materials and methods

Survey site selection

Districts (Guto Gida (31), Gida Ayana (27), Diga (5), Limu(9) and Sasiga (29) and kebeles from East wollega zone were purposively selected based on the history of striga infestation. Thirty six and sixty farmer's fields were assessed on the first and second assessment years, respectively. Structured disease survey protocol was prepared and used.

Field assessments

Field assessment was conducted during the main season when the strigawas at peak growth stage mainly at grain filling stage for maize. Farmers' fields were assessed randomly by making stops every 5-10km intervals as found suitable. Each field was assessed in a‘W’ pattern and at each spot quadrant was thrown.

Data were collected focusing mainly on land history, striga incidence (number of striga above ground shoot count from 10 plants on each spot of the field), crop damage score in terms of Striga syndrome rating (plant damage on 1-9 scale) and field prevalence based onmanual developed by International Institute of Tropical Agriculture (IITA).

Data analysis

Data was analyzed usingSPSS software. Simple statistics were used to compute means, percentage and frequencies. Mean comparison was computed by one way ANOVA and independent sample t-test.

Results and discussion

Striga infestation by crop type and assessment years

There was no significant difference (P>0.05) observed on striga infestation between the survey years. However, the damage score of striga showed significant differences (P ≤0.05) between the two survey years (Table 1). Higherstriga infestation and crop damage score (CDS) were recorded in the 2018 assessment year.

Table 1. Mean of strigaweed infestation and CDS as influenced by survey year and crop type

Factors		N	mean	STD	F-value
Year*Incidence	2018	36	11.45	10.692	0.292
	2019	60	7.15	11.326	
Year*CDS	2018	36	3.83	2.894	0.022
	2019	60	3.4	2.413	
Crop type*incidence	Maize	50	6.7	8.405	0.007
	Sorghum	45	11.26	13.445	
Crop type*CDS	Maize	50	3.23	2.443	0.384
	Sorghum	45	4.02	2.701	

Striga infestation was significantly (P ≤ 0.05) higher on sorghum than maize crop (Table 1). Esilaba *et al*. (2000) reported that the emergence of striga is positively associated with increased root surface area due to extensive root systems of sorghum and the subsequent release of germination stimulants. However, the damage of striga oncrops doesn’t show significant differencebetween sorghum and maize crops.

Striga infestation by survey routes and districts

There were no significant differences observed on survey routes and study districts for the striga incidence and damage score on maize crop (Table 2). Low Striga shoot count (incidence) was recorded in the current study districts compared to the highest (190/m2) record in the northern part of Ethiopia (Atsbha *et al*., 2016). However, significant difference (P<0.05) was observed in crop damage scores by survey routes and districts on sorghum crop.

Table 2.Strigainfestation on maize and sorghum crops by district and survey routes

Factors	Sorghum				Maize			
	N	Mean	Mean square	t-value	N	Mean	Mean square	t-value
Incidence by districts	44	11.163	356.898	0.145	50	6.7	53.135	0.48
CDS by districts	44	3.982	46.626	0.01	50	3.232	1.519	0.78
Incidence by Routes	44	11.163	185.8	0.375	50	6.7	5.26	0.931
CDS by Routes	44	3.982	22.95	0.041	50	3.232	5.166	0.43

Accordingly, the highest mean value of striga incidence and damage score on sorghum (13.2 and 4.8) and Maize crop (8.9 and 3.4) were recorded in Guto Gida district (fig 1&2). Moreover, the highest mean value of striga incidence and damage score on sorghum (13.9 and 4.9) and Maize crop (6.3 and 3.9) were recorded along the Uke-Oda Gudina survey route which is located in the Guto Gida district (fig 1&2).

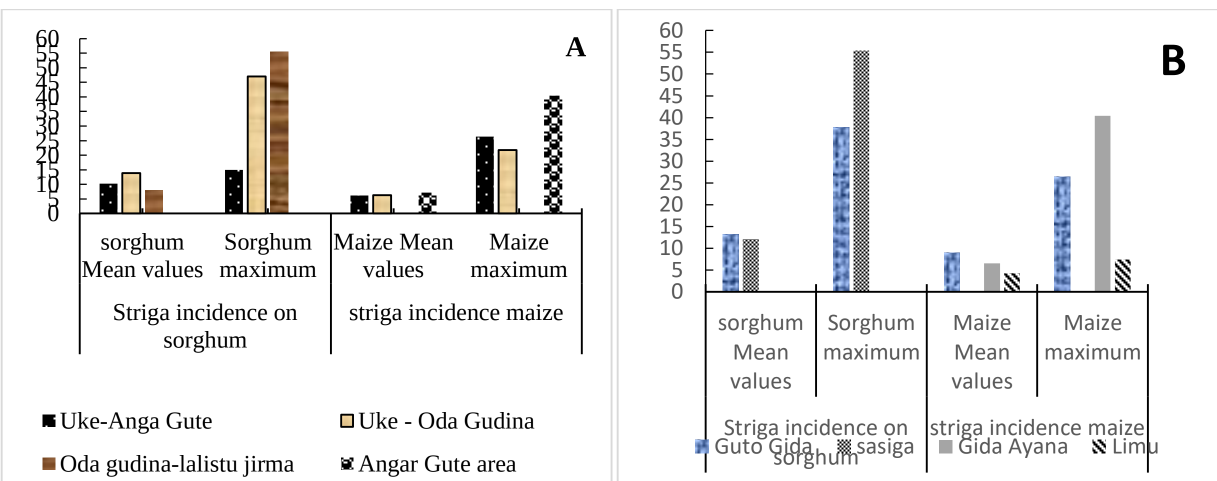


Fig 1. Mean and Maximum Striga above ground shout count by survey routes (A) and Study Districts (B)

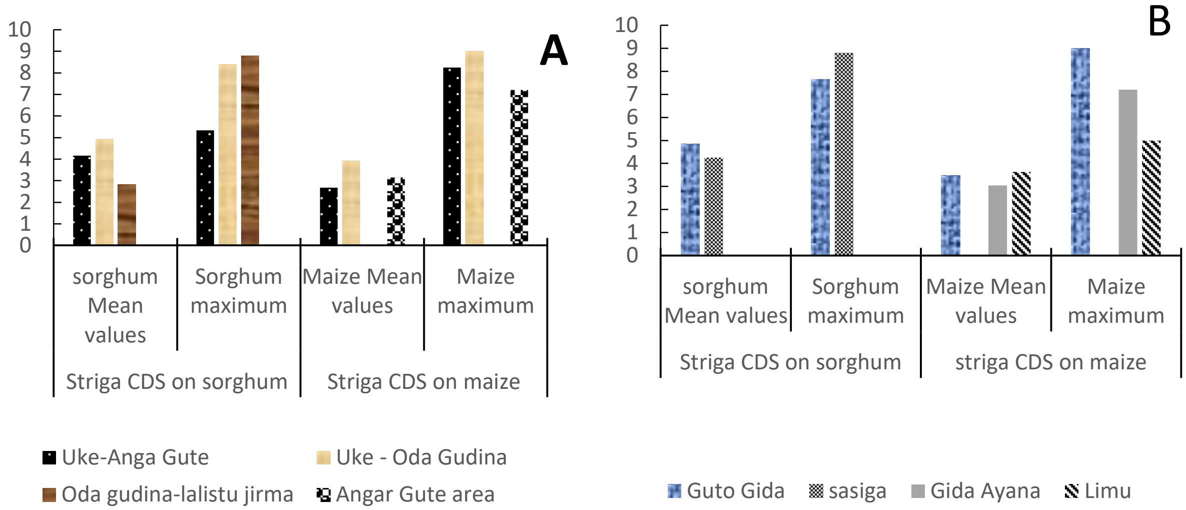


Fig 2. Mean and Maximum Striga CDS by survey routes (A) and Study Districts (B)

Farmers'striga management practices

Most of the farmers (33%) practice hand weeding to control striga which is the same practice applied to control other weeds. However based on their experiences, they know the fact that using Farm Yard Manure (FYM) suppresses the germination of striga seed. Few farmers, on the other hand, practice push-pull technologies (use of desmodium) with the support of district Agricultural and Natural Resource Offices (fig 3). In general, farmers depend only on hand weeding and supplement with other striga management methods. However, most of the farmers start weeding after striga has already caused damage to crops or even after the weed starts flowering. This causes challenges for sustainable striga management practices eventually in the subsequent years. The *S. hermonthica* problem has persisted with limited adoption of recommended control methods owing to farmers' reluctance to adopt such methods and unfavorable biological and socioeconomic conditions (Oswald, 2005). Effective *S. hermonthica* control technologies should target reducing the seed bank, limiting the production of new seeds and their spread from infested to non-infested soils, improving soil fertility and methods that fit within the farmers' cropping system, all of which should result in good crop yield (Ejeta 2007; Khan *et al*., 2006).

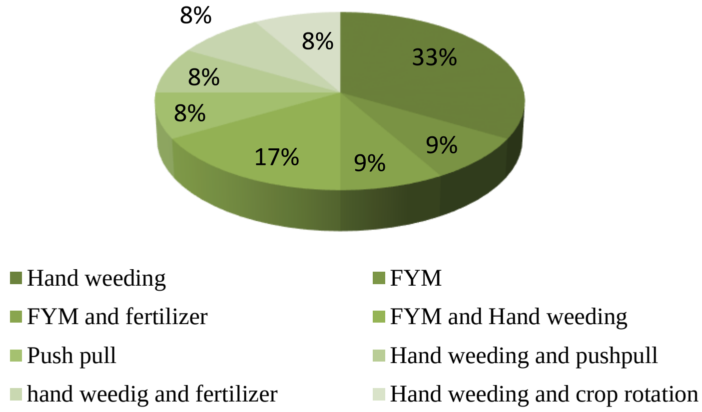


Fig 3.Striga management practices by farmers in the study areas.

Conclusion

Striga weed is currently a gowing possible threat for maize and sorghum production and even for other crops grown in the study area. The potential maize (Angar Gute and Guto Gida) and Sorghum (Sasiga) production areas in East Wollega are the most infested areas which may reduce area production and productivity in near future. This study indicates that while the extent of striga infestation is high, striga control methods available are poorly understood and rarely practiced by farmers. The current maize and sorghum varieties under production in the study areas are not resistant to striga infestation. Therefore it needs immediate action from all stakeholders to reduce the extent of striga infestation into striga-free districts. Enhancing the technical knowledge of farmers on the available striga control methods is of paramount importance. Searching and testing adaptability of early maturing sorghum striga tolerant varieties with compromising high bird attack observed (cluster and large area farming) in the study area is important. Maize research for those areas should have to be focused on the Striga resistant/tolerant variety development and deployment.

References:

Atsbha Gebreslasie, Taye Tessema, Ibrahim Hamza and Demeke Nigussie (2015).Abundance a

nd distribution of Striga (*Striga hermonthica* (Del.) Benth.) infestation in selectedsorghum (*Sorghum bicolour* L. Moench) growing areas of Tigray Region, Ethiopia.*African Journal of Agricultural Research*.11(45):4674-4682. https://doi.org/10.5897/AJAR2015.10060.

Ejeta G (2007) The Striga scourge in Africa: a growing pandemic. Pages 3–16 in Ejeta G, Gressel J, eds. Integrating New Technologies for Striga Control: Towards Ending the Witch-Hunt. Singapore: World Scientific

Esilaba AO, Fasil R, Ransom JK, Wondimu B, Gebremehdin W, Beyenesh Z (2000). Integrated nutrient management strategies for soil fertility improvement and Striga control in northern Ethiopia. *Afr.Crop Sci. J.* 8(4):403-410.

IITA (1997) Striga Research Methods.D.K. Berner, M.D. Winslow, A.E., K.F. Cardwell, D.R. Mohan Raj, and S.K. Kim.*eds.* The IITA Striga Research Group for the Pan African Striga Control Network (PASCON) International Institute of Tropical Agriculture. PMB 5320, Ibadan, Nigeria.81pp

Khan ZR, Pickett JA, Wadhams LJ, Hassanali A, Midega CAO (2006) Combined control of Striga hermonthica and stemborers by maize Desmodium spp. intercrops. *Crop Prot*. 25:989–995

Khan, Z.R., Hassanali, A., Overholt, W., Khamis, T.M., Hooper, A.M., Pickett, J.A., Wadhams, L.J., Woodcock, C.M., (2002). Control of witchweed *Striga hermonthica* by intercropping with Desmodium spp., and the mechanism defined as allelopathic. *J. Chem. Ecol.* 28:1871–1885. https://doi.org/10.1023/A:1020525521180

Mutanga, O., Dube, T., Galal, O (2017). Remote sensing of crop health for food security in Africa: potentials and constraints. Remote Sens. *Appl. Soc. Environ*. 8:231–239. https://doi.org/10.1016/j.rsase.2017.10.004

Oswald A (2005) Striga control: technologies and their dissemination. *Crop Prot.* 24:333–342

Parker, C. (2009).Observations on the current status of *Orobanche* and *Striga* problems worldwide.*Pest Management Science. 65*:453-459. http://dx.doi.org/10.1002/ps.1713.

Riches C. (2003).Integrated Management of Striga Species on Cereal Crops in Tanzania. Dfid Crop Protection Program, Final Technical Report, Project R7564. Natural ResourcesInstitute, University of Greenwhich, Chatham, Kent, UK.

Rodenburg J, Cissoko M, Kayeke J, Dieng I, Khan Z R, Midega C A O, Onyuka E A, Julie D, Scholes J D. (2015). Do NERICA rice cultivars express resistance to *Striga hermonthica* (Del.) Benth and *Striga asiatica* (L.) Kuntze under field conditions.*Field Crops Research*, 170:83–94.

Sand, P. F., Eplee, R. E., and Westbrooks, R. G. (eds) (1990). Witch weed research and control in the United States. Monograph series of the Weed Science Society of America, Number 5, *Weed Science Society of America*, 309 W. Clark St., Champaign, IL 61820, U.S.A. 154 pp

Field Evaluation of Commonly Used Synthetic Insecticides againstChickpea Pod Borer (*Helicoverpa armigera* Hubner) (*Lepidoptera:* Noctudae) on Chickpea (*Cicer arietinum* L) in the Midlands of Bale Zone

Dagne Kora* and Ermias Teshome

Sinana Agricultural Research Center, P.O.Box-208, Bale-Robe, Ethiopia

Corresponding author:* Email:*dagnekor@gmail.com***,

Abstract

Chickpea (Cicer arietinumL.) is the world's second most important grain legume after common bean (Phaseolus vulgaris L.). Ethiopia is considered as a secondary center of genetic diversity for chickpea. The current field experiment was conducted on farmers' field and research sub-site of SARC in Goro district for two years with the objective to test the comparative efficacy of different insecticides for management of chick pea pod borer. The experiment was conducted using one chick pea varietiy, Arerit and nine insecticides.Results showed that all the insecticides significantly reduced the pod borer larval population.The reduction percentage of larval population over check was the highest for Profit 72 % EC (97.52) sprayed plots followed by Karate 5%EC (83.37) and Helerat 5 % EC (83.37) spayed plots.The maximum percent of seed yield was increased over check for Helerat treatment with 73.62% followed by Karate 5%EC with 71.87% and Selecron 720 EC with 70.6% yield incensements. From the present study, we recommend that insecticide Helerat and Karate 5% EC were found to be the most effective against the pod borer as compared to the tested insecticides.Besides, all the insecticides tested in addition to thetwo for the management of pod borer of chickpea at the right time and optimum dose are promising. Hence, farmers/growers can use choices of insecticides available in the absence of the other as an option/alternatives to increase their productivity even if they have different degrees of efficacy.

Key words: Insecticides, Pod Borer, Chickpea, Infestation

Introduction

Chickpea is the world's second most important grain legume after common bean (*Phaseolus vulgaris*L.) among food legumes grown for production worldwide (Guar *et al.*, 2012). Currently, it is one of the most widely produced crops at the global level on over 12 million hectares of land from which 10.9 million tons of grain is produced every year (FAOSTAT, 2012). Ethiopia is considered as a secondary center of genetic diversity for chickpea and the wild relative of cultivated chickpea is found in Tigray region of Ethiopia (Yadeta and Geletu, 2002; Kanouni *et al.*, 2011). Ethiopia shares 2% among the most chickpea producing countries next to India (64%), Turkey (8%) and Pakistan (7%) (ICRISAT,2004).

Two types of chickpeas are cultivated in Ethiopia -Desi with pink flower and Kabuli with white flower types. Chickpea is good source of dietary protein containing 17 - 23 % protein, maintain and restore soil fertility (can fix up to 60 kg N /ha/year) and chickpea offers high potential for domestic and export markets.On an average, chickpea yield in Ethiopia on farmers field is usually below 1t/ha although its potential is more than 5 t/ha (Jagdish*et al.,* 1995;Melese, 2005). This is attributed to many factors of whih susceptibility of landraces to frost, drought, waterlogging and poor cultural practices; low or no protection measures against weeds, diseases and insect pests (Tilaye*et al.,* 1994; Bejiga*et al.,* 1994) are the major ones. Chickpea is susceptible to a number of insect pests, which attack on roots, foliage and pods. Chickpea pod borer (*Helicoverpaarmigera*Hubner) (Lepidoptera*:* Noctuidae) is a major field insect pest affecting chickpea in several agro-ecological zones. It is also listed among pests, which are medium priority in research on chickpea, field pea and faba bean at national level. Besides pulse crops, pod borer also affects fiber crops, vegetables, cereals and oil crops in Ethiopia (Tadesse, 1989). This pest is the major constraint in chickpea production causing severe losses of up to 100% even in spite of several rounds of insecticide applications. Sometimes in serious cases, there may be a complete crop failure. The pod borer, *H.armigera,* is the most serious pest in causing economic loss to the chickpea crop (Singh &Yadav, 2006). It is a highly polyphagous pest, feeding on a wide range of food, oil and fiber crops. Due to its wider host range, multiple generations, migratory behavior, high fecundity and insecticide resistance, it has become one of the difficult pests to manage. It selectively feeds upon growing points and reproductive parts of the host resulting in significant yield loss. In chickpea, it feeds on buds, flowers and young pods of the growing crop; the crop often fails to recover and provides pooryieldr. The pest status of this species has increased steadily over the last 50 years due to agro-ecosystem diversification by the introduction of host crops such as chickpea (Knights *et al.,* 1980; Passlow, 1986).Commercial chickpea crops are important sources of *Helicoverpa*species (White *et al.,* 1995). Sequeira*et al.*(2001) reported that chickpea is attractive for oviposition of *Helicoverpa*moths from as early as 14 days after planting and throughout the growth period. Of all *Helicoverpa*species larvae recorded from the entire samples and crop combinations, 98.3% were found on chickpea.

These days, there are so many recommended insecticides found on the market to manage this pest most of which are imported. Every pesticide imported should be tested for its efficacy and registered before they reache to the users. But most pesticides supplied by local pesticide dealers are mostly ineffective according to the information obtained from the users. Therefore farmers, investors and local seed producer cooperatives are confused to select among these pesticides because they are many and not effective for the management of intended pests.

They complain local pesticide dealers for their supplying such pesticides and they are also vulnerable to unnecessary cost to buy pesticide. Therefore, they are asking for the effective pesticide for the management of pests to increase their crop productivity. In line with this the objective of this study was to investigate comparative efficacy of different insecticides for management of chick pea pod borer.

Materials and Methods

In order to recommend effective insecticidesfor management of *H. armigera*in chickpea,all available insecticides were evaluated for their efficacy.All chemicals were purchased from thelocal pesticide dealers. Alarge seeded chickpea varietyAreritwas used in this experiment.

The experiment was laid out in RCBD with three replicationsandconducted at Goro both on farmers' field and research sub-site for three years.The plot size was 5.4m^2(3m × 1.8m) having 6 rows that are 0.3m apart;the space between blocksas well as between plots was 1.5m.Recommended agronomic practices were applied. Insecticideswere applied during the crop-growing season following the appearance of pod borer and continued as necessary.

Table1. List of insecticides tested against chickpea pod borer at Goro district, 2018 cropping season

Trade Name	Common Name	Rate (ml/ha)
Highway 50% EC	Lambda-cyhalothrin	400 ml
Modan 5% EC	lambda –cyhalothrin 5% EC	400 ml
Nimbicidine	Azadirachtin	3000 ml
Agro-plus 175 SC	Imidacloprid125g/l + Lambda-cyhalothrin 50g/l Sc	400 ml
Helerat 5 % EC	lamdacyhlothrin	250-400 ml
Diazinon 60 %EC	Diazinon	1200 ml
Karate 5%EC	Lambda-cyhalothrin	200-500 ml
Selecron 720 EC	Profenofos "Q" 720 g/l	500-750 ml
Profit 72 % EC	Profenofos	1000 ml

Data collected

Data on pod borer population before and after insecticide application were recorded from five randomly selected plants in each plot at the seedling stage after the appearance of the pod borer. The number of larval population per plant from five randomly selected plants in each plotbefore and after first spray of insecticides was recorded. The reduction percentage of larvae was recorded by counting of larval population over check. This was repeated at 15 days interval. Data on pod damage (visual damage) and grain yield were also recorded. At harvest, the data on pod damage due to pod borer was recorded from samples taken at random. The samples were assessed for pod borerdamage visually based on the number of healthy and damaged pods and seeds per 10 plants to work out % pod damage at maturity. Data was also recorded on grain yield.Pod damage was computed as:

$$\% \text{ Pod damage} = \frac{\text{Total number of pod produced per plant} - \text{Number of undamaged Pods} * 100}{\text{Total number of pods produced}}$$

Larval reduction was calculated as:

$$\% \text{ Larval reduction} = \frac{\text{Total number of larval population} - \text{Number of larval population after spray } X\ 100}{\text{Total number of larval population}}$$

Data recorded werestatistically analyzed. Data one Larval population, pod damage and grain yield were analyzed separately. Data were subjected to the analysis of variance using GLM Procedure SAS software (SAS 2002). The mean were compared using Duncan's multiple range test (DRMT) (Duncan, 1955) at 0.05 probability level. Insect counts and damage percentages were subjectedto square root and arcsine transformation, respectively before analysis as found necessary needed.

Results and Discussion

Reduction of larval population

Results showed that all the insecticides significantly reduced the pod borer larval population. The maximum mortality was recorded in plots treated with Profit (95.65%) and Karate 5%EC (72.28%) that were found to be statistically at par, followed by Nimbicidine (61.73%),Selecron 720 EC (59.54%) and Modan 5%EC (58.64%).No mortality was observed in the untreated plots.Thus, it is evident that Profit and Karate 5%EC were the most effective insecticides to give high mortalityof pod borer on chickpea under field conditions.The highest reduction percentage of larval population over check was recorded from Profit (97.52), followed by Karate 5%EC (83.37) and Helerat (83.37), whereas Agro-plus (59.55) resulted in the minimum reduction percentage over check (Table 2)

Table 2: Mean comparison of mortality of gram pod borer on chickpea after treatment

Treatment	Before spray	After spray	% Larval Reduction	% Larval reduction over check or % efficacy
Highway50% EC	1.23b	0.80cb	33.33a	80.15
Modan 5%EC	2.46ba	1.00cb	58.64a	75.19
Nimbicidine	2.90ba	1.10cb	61.73a	72.70
Agro-plus 175 SC	3.90a	1.63b	58.41a	59.55
Helerat5%EC	2.10ba	0.67cb	56.97a	83.37
Diazol 60 EC	1.76b	0.90cb	48.72a	77.67
Karate 5%EC	2.0b	0.67cb	72.28a	83.37
Selecron 720 EC	2.33ba	0.90cb	59.54a	77.67
Profit	2.00b	0.10c	95.65a	97.52
Control	2.10ba	4.03a	-91.43b	
LSD%	1.85	1.36	70.72	

Tukey's Studentized Range (HSD) Test, Means with the same letter are not significantly different.

Reduction of pod damage

The results of reduction percentage of pod damage over untreated check are presented in Table 3.The application of Diazol 60% ECwas more effective in the reduction ofpercentage poddamage over untreated check. It resulted in pod damage of 87.34%, followed by Highway50% EC that had pod damage reduction of 83.06% andProfitwith pod damage reduction percentage of 80.77%, respectively.Selecron 720 EC also resulted in pod damage reduction of 77.91% over untreated check.

Table 3. Average Seed yield and Yield parameters of chickpea at Goro district in 2017/2019 cropping season

Treatment	% pod damage	Reduction % age over check	No. of Pod /plt	HSW	Yield (kg/ha)	Increment of yield over control (kg/ha)	Percent yield increased over control
Highway 50% EC	5.93b	83.06	35.67a	211.73a	1595.5dc	661.1	41.43
Modan 5% EC	11.46b	67.26	46.10a	199.13a	1965.6bdac	1031.2	52.46
Nimbicidine	9.70b	72.28	49.80a	209.17a	1756.3bdc	821.9	46.8
Agro-plus 175 SC	8.33b	76.2	56.47a	190.13a	1458.2d	523.8	35.92
Helerat 5%EC	8.70b	75.14	48.00a	205.73a	3542.7a	2608.3	73.62
Diazol 60% EC	4.43b	87.34	39.33a	218.87a	2108.3bdac	1173.9	55.68
Karate 5% EC	8.40b	76	51.77a	214.40a	3321.9ba	2387.5	71.87

Selecron 720 EC	7.73b	77.91	56.43a	216.87a	3178.1bac	2243.7	70.6
Profit	6.73b	80.77	47.77a	223.53a	1445.6d	511.2	35.36
Control	35.00a		45.53a	208.37a	934.4d		
LSD%	10.88		57.59	101.52	1695.4		

Tukey's Studentized Range (HSD) Test,Means with the same letter are not significantly different.

Grain yield and yield components of chickpea

The data of seed yield (kg/ha) and increment percent over check is presented in Table 3.The results showed significant differences in terms of grain yield and yield components among the treatments.InsecticideHelerat resulted in the maximum seed yield of3542.7 kg/ha,followed by Karate 5%EC that resulted in grain yield of3321.9 kg/ha and Selecron 720 EC 3178.1 kg/ha, respectively.The minimum seed yield of 1445.6kg/ha was recorded from Profit treatment.Similarly, the maximum percent of seed yield was increased over check by application of Helerat with 73.62% increment followed by Karate 5%EC that resulted in 71.87% yield incensement. Selecron 720 EC resulted in 70.6% yield increment, whereas the lowest yield increment (35.36%) was recorded from Profit treatment.

Cost-benefit analysis

The results showed that Helerat 5% EC sprayed plot provided the highest gross returns (ETB 121,144.00/ha) whereas the lowest gross return of ETB 31,920.00/ha was computed from the untreated check. The plot sprayed with Helerat 5% EC gave the maximum net return of ETB 101,987.6/ha and also gave the highest benefit cost ratio (5.32). Karate 5%EC sprayed plots also provided higher gross returns (ETB 113,582.00/ha) next to Helerat 5% EC and gave higher net return of ETB 93,945.3/ha as well as higher benefit cost ratio (4.78). The highest marginal rate of return of ETB 462.61 and 410.34 were obtained from Helerat 5% EC and Karate 5%EC treated plots, respectively. In other words, for every ETB 1.00 investment in Helerat 5% EC and Karate 5%EC cost and spraying, there was a gain of ETB 4.63 and4.10, respectively (Table 4). Therefore the most economic benefit for pod borer management in chick pea was obtained from spraying either Helerat 5% EC or Karate 5%EC.

Table 4: Return and Benefit Cost Ratio of Treatment for the Control of pod borer on chickpea during 2017/19 GC Season at Goro Districts.

Treatment(Insecticides)	Yield obtained (Qt/ha)	AdjustedYield (Qt/ha)	Sale price (ETB/Qt)	Total Variable Cost (ETB/ha)	Gross Return(Price x Qt)	Net Return (GR-TVC)	Benefit cost ratio (GMP/TVC)	MRR %
Highway50% EC	15.95	14.36	3800	19190.8	54,568.00	35377.2	1.84	114.69
Modan 5%EC	19.65	17.69	3800	19290.7	67,222.00	47931.3	2.48	179.17
Nimbicidine	17.56	15.8	3800	20124	60,040.00	39916	1.98	131.92
Agro-plus 175 SC	14.58	13.12	3800	19153.6	49,856.00	30702.4	1.60	90.50
Helerat 5% EC	35.42	31.88	3800	19156.4	121,144.00	101,987.6	5.32	462.61
Diazol 60 EC	21.08	18.97	3800	19589.1	72,086.00	52496.9	2.68	199.75
Karate 5%EC	33.21	29.89	3800	19636.7	113,582.00	93,945.3	4.78	410.34
Selecron 720 EC	31.78	28.6	3800	19698	108,680.00	88982	4.52	383.87
Profit	14.45	13.01	3800	19340.3	49,438.00	30097.7	1.56	86.50
Control	9.34	8.4	3800	18552	31,920.00	13368	0.72	0.00

Conclusion and Recommendation

The present study showed that insecticides Helerat 5% EC and Karate 5% EC remained the most effective against the pest activity and resulted in the maximum reduction percentage of larval population of pod borer, and the pods damage percentage was also decreased as compared to the use of other insecticides. Similarly the seed yield was also found to be the highest with the use of Helerat 5% EC over the check. Results of yield data revealed that under normal conditions pod borer can cause about 35.36% to 73.62% losses to chick pea yield. The plot sprayed with Helerat 5% EC gave the maximum net return of ETB 101,987.6/ha and also gave the highest benefit cost ratio (5.32). Karate 5% EC sprayed plots provided higher gross return of ETB 113,582.00/hanext to Helerat 5% EC and gave the higher net return of ETB 93,945.3/ha;the benefit cost ratio as a result of using this insecticide was 4.78. The highest marginal rate of return of ETB 462.61 was attained as a result of using insecticide Helerat 5% EC. On the other hand, Karate 5%EC treated plots also gave higher marginal rate of return next to Helerat 5% EC. All of the evaluated fungicides showed promising efficacy as compared to the control plot against the pod borer. However, out of the tested insecticide Helerat 5% EC and Karate 5%EC have shown outstanding controlling potential against the pod borer damage to chickpea. Therefore, these two insecticides are recommended for use against pod borer of chickpea.

References

FAO, 2012. Available online: http://faostat.fao.org/site/567/DesktopDefault.aspx (accessed on 10 January 2012).

Gaur, M. P., Aravind, K. J., and Rajeev, K. V. 2012.A review of impact of Genomic technologies on chickpea breeding strategies.*Agronomy* , 2: 200-203, India.

Geletu, B. and. Anbessa, Y. 1994.Breeding chickpea for resistance to drought.Internationalsymposium on pulse research, April 2-6. New Delhi, India, pp. 145-146.

ICRISAT, 2004.Area, production and productivity of Chickpea (*Cicer arietinum* L.).Patancheru, Hyderabad India pp31-35.

Jagdish, K., Sethi, S.C., Jonansen, C. T., Kelley, M. R. and Rheene, H.A. 1995.Earliness- a cure for most illness of chickpea. P 20-23. In: *Intentional Chickpea and Pigeonpea Newsletter*, ICRISAT, Andhra Pradesh, India

Kanouni, H., Taleei, A. and Okhovat, M. 2011. Aschchyta blight (*Ascochytarabiei* (Pass.) Lab.)of Chickpea (*Cicer arietinum* L.): Breeding strategies for resistance. *International Journal of plant Breeding and Genetics 5:1-22*

Knights, E.J., E.L. Armstrong and E.J. Corbin. 1980. Chickpea – a versatile new grain legume.*Agricultural Gazette of New South Wales*, 91: 40-42.

Passlow, T. 1986. Keynote address. In: *Heliothis*Workshop 1985. *Proceedings Conference andWorkshop Series QC 86004*. (Eds.): M. P. Zalucki& P. H. Twine. Queens land Department ofPrimary Industries, pp. 5-8.

Melese, D. 2005.Morphological and RAPD marker variation analysis in some drought tolerant and susceptible chickpea (*Cicer arietinum* L.) genotypes of Ethiopia.M.Sc Thesis, Addis Ababa University, Ethiopia Pp2-5.

Singh, S.S. and S. K. Yadav. 2006. Evaluation of chickpea varieties for their resistance againstgram pod borer, *Helicoverpaarmigera*. *Indian Journal of Entomology*, 68(4): 321-3 24.

Sequeira, R.V., J.L. McDonald, A.D. Moore, G.A. Wright and L.C. Wright. 2001. Host plantselection by *Helicoverpa*spp. in chickpea-companion cropping systems. *EntomologiaExperimentalisetApplicata*, 101: 1-7.

Tadesse G.1989.Research approach and pest management practices in Ethiopia.pp108-113.In: Proceedings of the 20th Crop Improvement Conference. 28-30, March 1988, IAR, Addis Ababa, Ethiopia.

Tilaye, A., Gelatu, B., and Berhe, A., 1994. Role of cool season food legumes and their production constraints in Ethiopia agriculture.Pp. 3-18.In: *Cool Season Food Legumes of* 67 *Ethiopia*,

White, G.G., D.A.H. Murray and M.P. Walton. 1995. *Heliothis*management in Australia Cooperative Research Centre for Tropical Pest Management, Workshop report: 8-9 November1995. *Bulletin of Entomological Research*, 89: 201-207.

Yadeta, A. and Geletu, B. 2002. Evaluation of Ethiopian chickpea landraces for tolerance to drought.*Genetic Resources and Crop Evolution49:557-564*

Survey of Distribution and Status of Major Diseases of Hot Pepper (*Capsicum annuum* L.) in West Shoa and East Wollega Zones, Ethiopia

Abay Guta[1], Getu Abera[2] and Temesgen Galana[3]
Oromia Agricultural Research Institute
Bako Research Center, P. O. box 3, Bako, West Shoa, Ethiopia
Corresponding author: abbayg12@gmail.com

Abstract

In the current study, disease survey was initiated to determine the relative occurrence, distribution and status of major hot pepper diseases in West Showa and East Wollega Zones. Prevalence, incidence and severity of major hot pepper diseases were assessed and quantified. The survey was conducted in four districts of West showa and East Wollega zones, covering 32 Kebeles and 46 fields. Kebeles were randomly selected from each district based on their representativeness of hot pepper production. The disease assessment was made along the two diagonals (in an "X" pattern) of the field from five points using 1m × 1m (1 m^2) quadrates. The assessment was done for disease prevalence, incidence and severity. The result of the survey indicated that six diseases of hot pepper: Fusarium Wilt, Cercospra Leaf Spot, Bacterial Leaf Spot, Bacteria Soft Rot and Anthracnose diseases prevailed in the study area. The importance of each disease was determined by calculating the prevalance, incidence and severity values. The current study shows that hot pepper production is currently limited by several diseases and indicates the need of research on designing management strategies and options for the major diseases.

Keywords: Incidence, Severity, Distribution, Disease, Hot pepper

Introduction

Hot pepper (*Capsicum annum* L.) is an important crop globally grown as vegetable and spice (Berke, 2002). This crop is native to Latin America and belongs to the family Solanceae (Rodriguez *et al*., 2008). The exact time for the introduction of pepper to Africa in general and Ethiopia in particular is not known. Probably Portuguese had introduced hot pepper to Ethiopia in early 17th century (Huffnagel, 1961). In Ethiopia, the production history and use of pepper is perhaps more ancient than the history of any other vegetable crop except tomato (EEPA, 2003).

Hot pepper is the most important vegetable, which can be found on the daily dish of every Ethiopians (Mohammed, 2005). According to Beyene and David (2007), in Ethiopia hot pepper (*Capsicum annuum*) is an economically and traditionally vital crop, and for most Ethiopians food is tasteless without hot pepper. The fine powdered pungent product is an important flavoring and coloring component in the common traditional sauce "Wot", (stew). In addition to dietary benefits, capsicums are also high value crops in both domestic and export markets. Since it is an industrial Crop, it generates employment to urban and rural workers. The deep red colored cultivars have a very high processing demand in the country (CSA, 2018).

In spite of its dietary and economic benefits, Capsicum productivity in Ethiopia is far below the world average that strongly demands immediate productivity improvement interventions. People consume pepper for intake enhancement as well as to supplement the dietary needs. It is also one of the major income generating crops for most households of the pepper producing areas and plays a vital role in food security in Ethiopia(Roukens, 2005).

Despite the importance of hot pepper in Ethiopia, total crop failure due to diseases has been common and sometimes farmers are forced to abandon their production due to excessive disease pressure in the field (Tameru*et al*., 2003). Among hot pepper diseases, Powdery mildew, Leaf blight, Wilt and Pepper mottle virus (Korobkon et al, 1986; BARC, 2000; Kassahun *et al*., 2016) have been reported in Ethiopia. Recently, wilt causing pathogens are becoming the leading problems reported by causing 86.4% wilt incidence due to *fusarium* wilt in Ethiopia (Asseefa *et al*., 2015). Virus caused 60 to 100% losses of marketable fruit, while up to 100% loss was recorded from pepper anthracnose (Melanie*et al*., 2004). Bacterial spots caused by a seed borne bacterial pathogen (*Xanthomonas campestris* pv. vesicatoria) is also capable of causing severe defoliation of plants, resulting in reduced yield and loss of quality of harvested fruit when severe damage occurs on enlarging fruits (Sun *et al*., 2002)

Even though the study areas have a great potential in terms of physical environment and market opportunities, the production and productivity of pepper is decreasing due to diseases. Therefore, this activity was initiated to determine the relative occurrence, distribution and status of hot pepper disease across study area.

Materials and Methods

Description of the study area

The Field survey was conducted in part of Western Oromia - in West Shoa and East Wollega Zones during 2020 main cropping season. The disease assessment survey was conducted in two districts of West Shoa Zone, Ilu Galan and Bako Tibe; and similary in two districts of East Wollega Zone namely Sibu sire and Bilo Boshe Districts (Table 1). The disease Survey was conducted to assess the prevalence, incidence and severity of major diseases of hot pepper. In most of the areas, the survey was conducted after fruit set to maturity growth stages of the crop. The annual mean minimum and maximum temperatures of the area are 14.5^0C and 29.3^0C, respectively, while the annual rainfall is 1605.7mm. The geographical locations of the surveyed areas were located in a range of latitude and longitude of $08^0$55'10.89"- $09^0$05'04.87"N and $036^0$44'35.44"- $037^0$60'22.73"E, respectively.

Table 1: Characteristic features of surveyed hot pepper fields in West Showa and East Wollega Zones

Zones	Districts	Altitude (m.a.s.l.)	No. fields assessed
West Shoa	Ilu Galan	1705-1793	5
	Bako Tibe	1610-1768	14
	Mean	1610-1793	19
East Wollega	Sibu Sire	1711-2083	18
	Boneya Boshe	1655-1778	8
	Mean	1655-2083	26
	Over all mean	1610-2083	45

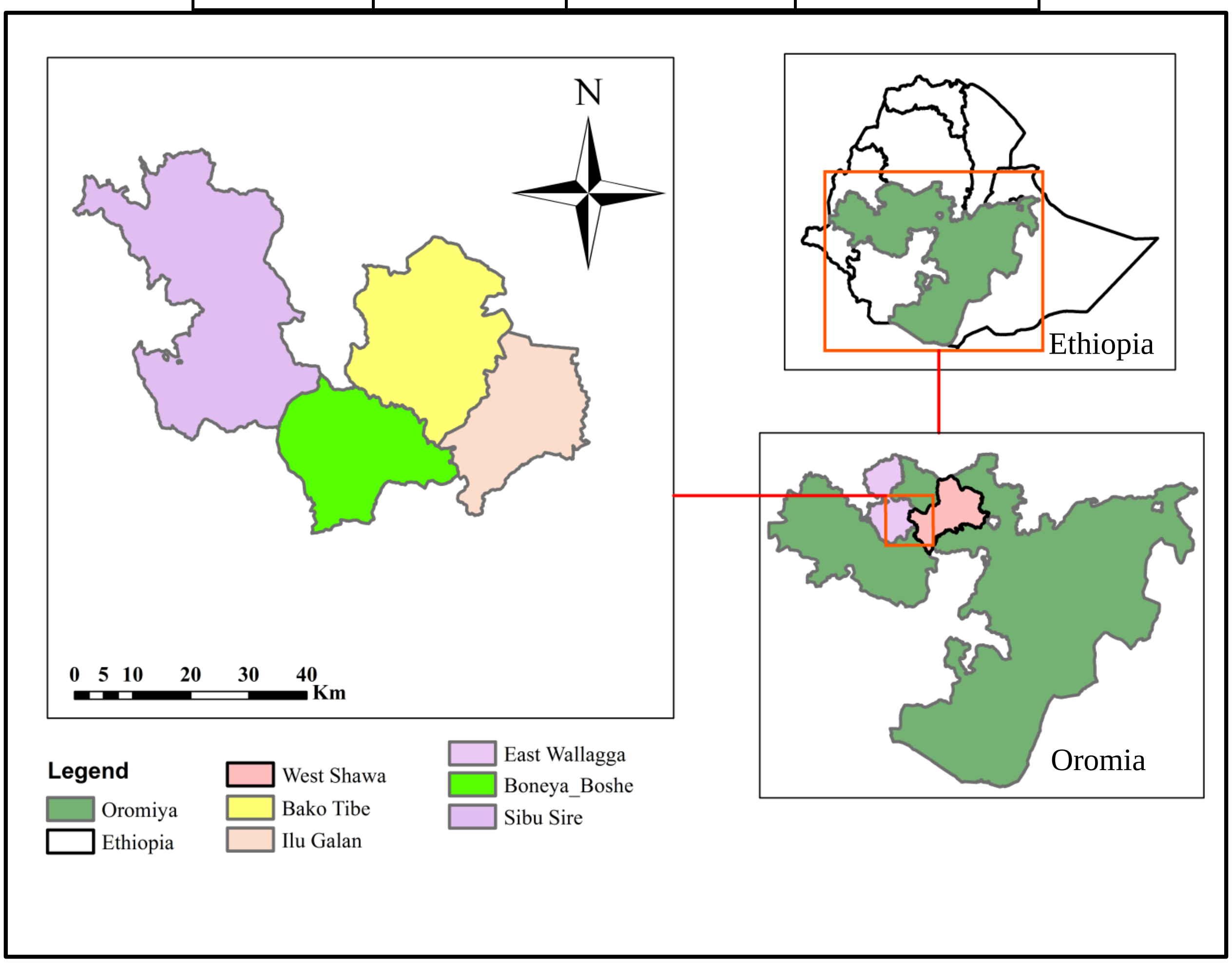


Figure 1. Map of survey site

Table 2: meteorology data during the last ten years (annual temperature and annual rain fall)

Year	Annual Mean Minimum temperature	Annual Mean Maximum Temperature	Annual Mean Rain fall
2011	13.5	27.3	1425.5
2012	13.7	28.7	889.8
2013	12.9	29	1432.6
2014	13.4	28.4	1066.4
2015	12.4	29.9	931.4
2016	14.1	29.7	1330.7
2017	12.7	29.1	1599.5
2018	14	30	1267.1
2019	14.2	29	1342.3
2020	14.5	29.3	1605.7

Source: Bako Meteorology station

Field survey

Hot pepper disease survey was conducted in four districts of two zones during the main season of 2020. The survey was conducted in 32 Kebeles and 46 fields. Random sampling technique was employedfor the survey. Kebeles were randomly selected from each district and based on the representativeness of hot pepper production of the area. The locations were at least 4-7 km apart and the distance of the locations depended on the topography and the relative importance of the crop within each location. The disease assessment was made along the two diagonals (in an “X” pattern) of the field from five points using 1m × 1m (1 m^2) quadrates.

Questionarry was developed to interview farmers on some field-related and other issues. The hot pepper management practices like variety grown- whether local or improved, previous crop (cereals, pulses or vegetables), planting date (sowing) crop density, altitude, weed density per meter square, fertilizer type and rate, soil type, growth stage, disease type observed and fungicide used were collected and recorded. In each field, plants within the quadrates were counted separated into healty and diseased.

Disease scoring

Visual identification of the disease was used on all visited fields. The assessment was done for disease prevalence, incidence and severity on the hot pepper crop in thesurveyed locations.

Disease Prevalence

Disease prevelance, referring to the proportion or percentage of sampling areas in which the disease was presented was computed using the formula:

Disease prevalence (%) = $\frac{\text{Number of locations showing plant disease}}{\text{Total number of location /field}} \times 100$

Disease Incidence

Disease incidence was determined in each field on the basis of visual symptoms and by counting the number of symptomatic or infected plants in a sample of total plants in randomly selected in the fields. An overall disease incidence value was obtained by averaging the incidence among all the fields (including the fields which have no disease). The formula for determination of incidence is:

Disease Incidence (%) = $\frac{\text{number of Diseased plants in the quardate/field}}{\text{Total Number of Plants in quardate/field}} \times 100$

Disease Severity

The proportion of the area of a plant or plant organ affected was calculated using the formula:

Disease Severity (%) = $\frac{\text{Area of plants tisseu affected}}{\text{total number of plants affected}} \times 100$

Table 3: Disease rating scales used in scoring observed diseases in the field

Disease	Scale	Discription	Reference
Fusarium Wilt	0	0% healthy	Ismail *et al*., 2015
	1	1 - 10% one leaf yellowing,	
	2	11-20% more than one leaf yellowing	
	3	21-30% one wilted leaf	
	4	31-50% more than one leaf wilted	
	5	> 50% completely dead/ wilted plants.	
Cercospora Leaf Spot	0	No disease symptom	Gakanihe *et al*., 2004
	1	10% of canopy showing diseased symptoms	
	3	10-20% of canopy showing disease symptoms	
	5	25-50% of the canopy showing disease symptoms	
	7	50-75% of canopy showing disease symptoms	
	9	>75% of canopy showing disease symptoms	
Bactria Leaf Spot	0	0 no symptom	Abbasi *et al*., 2002
	1	symptomless	
	2	A few necrotic spots on a few leaflets	
	3	Afew necrotic spots on many leaflets	
	4	Many spots with coalescence on few leaf	
	5	Many spots with coalescence on many leaflets	
	6	Severe disease, and leaf defoliation and	
	7	A dead plant	

Bactria Soft Rot	0	Healthy fruit on entire plant	Traufield *et al*., 2002
	1	Sunken, light-coloured lesions on exposed fruits lesion can enlarge that may extend to sides	
	2	Dark leathery spot on blossom-end Raised, wart-like brown lesion + Small pale halos- “ghost spots”	
	3	Water-soaked, dull green spots covered with cream mould growth	
	4	Water-soaked sunken lesions that expand Cloudy, yellow blotches directly below skin	
	5	Pods soften and quickly collapse	
Anthracnose	0	Healthy	Siddiqui *et al*., 2008
	1	1-5% of mature leaves with necrotic and chlorotic symptoms	
	2	6-15% of mature leaves with necrotic and chlorotic symptoms	
	3	15-50% of young shoots and stems water soaked lesions and minor die back	
	4	51-95% of water-soaked lesions with abundance mycelia growth and fructification, and extensive shoot dieback	
	5	Dead plan	

Data analysis

The data collected from the survey was analyzed using SPSS statistical software. Analysis was conducted by disaggregating important relevant information by Districts and Zones so that comparison could be made.

Results and Discussion

Status and distribution of hot pepper diseases

Six diseases of hot pepper, Fusarium Wilt (*Fusarium oxysporum*), Cercospra Leaf Spot (*Cercospora capsici*), Bacterial Leaf Spot (*Xanthomonas campestris pv. vesicatoria*), Bacteria Soft Rot (*Erwina cartovora*) and Anthracnose (*Colletotrichum gloeosporioides*) were encountered and assessed in the farms. Prevalence of most leaf diseases varied from field to field depending on environmental conditions, tillage practices, cropping sequence and hybrid susceptibility. Moderate temperatures and moisture in the form of rain and heavy dew usually favor development of foliar diseases and more than one type can be present on individual plants. Disease incidence of hot pepper in the fields was computed for peasant associations’ districts and the entire study areas.

Hot pepper disease prevalence

In this assessment,hot pepper Fusarium Wilt was prevalent in all hot pepper producing districts of West Shoa and East Wollega Zones. The disease prevalence of hot pepper Fuzarium Wilt ranged from 70.59% to 100% (Table 4). This indicatesthat the disease is the most destructive during the growing season. The highest prevalence of Fusarium Wilt (100%) was recorded in Boneya Boshe district followed by Ilu Galan and Bako Tibe that had 83% and 74.62% disease prevalence, respectively, while the lowest prevalence of Fusarium wilt (70.59%) was recorded in Sibu Sire district (Table 4).

Prevalence of hot pepper Cercospra Leaf Spot was 100% in all surveyed districts and the disease was commonly found in all assessed hot pepper fields. Next to Cercospra Leaf Spot, Bacteril Leaf Spotprevelance was found to be 87% in Ilu Galan, 76.47% in Sibu Sire, 75% in Boneya Boshe and 69.23% in Bako Tibe districts (Table 4). The prevalence of Bacteria Soft Rotof hot pepper was found to be 58.82% in Sibu Sire and 23.08% in Bako Tibe Districts. The prevelance of hot pepper Anthracnosewas found to be 30.77%, 26% and 23.53% in Bako Tibe, Boneya Boshe and Sibu Sire districts, respectively.

Incidence of hot pepper diseases

Incidence level of hot pepper Fusarium Wilt varied among districts and zones. Relatively higher mean incidence level (54.8%)of Fusarium Wilt was recored in Bako Tibe district followed by (47%) that of Ilu Galan district (Table 4). Relatively lower levels of mean Fusarium Wilt were observed in Boneya Boshe (43.33%) and Sibu Sire (40.5%) districts. The result of this study was in agreement with the findings of Gebrekiristos *et al.*(2020). In western Ethiopia, Fusarium Wilt incidence of as high as 86.4% was recorded in earlier stufy (Assefa *et al*., 2015). This report indicates that there is variation in the level of infection and accumulation of wilt causing pathogens in the different loacalitiesof Ethiopia.

Cercospora Leaf Spot of hot pepper was observed in all surveyed fields. However, disease incidence was variable from farm to farm. The highest mean Cercospora Leaf Spot incidenceon hot pepper was found to be 90.31% in Bako Tibe district followed by 85% recoreded in Ilu Galan district.Lower level of mean incidence of Cercospora Leaf Spot was 36.33% and 66.53% recorded in Boneya Boshe and Sibu sire Districts, respectively (Table 4).

Bacteria Leaf Spot disease of hot pepper was found in all surveyed fields andand observed to devastat fruit, leaf and steam of the hot pepper. The highest mean incidence of Bacteria Leaf Spot was 76.33% and 73% observed in Bako Tibe and Ilu Galan District, respectively (Table 4). Lower level mean incidence of Bacteria Leaf Spot was recorded in Boneya Boshe (57.33%) and Sibu Sire (56%) districts, respectively (Table 4).Bacteria Soft Rot disease of hot pepper was found in Bako Tibe and Sibu Sire Districts. The disease is often devastating at the fruiting stage when the rainfall is intense and continuous. The maximum mean incidence of 42.4% was recorded in Sibu Sire while the minimum disease mean incidence of27.5% was recorded in Bako Tibe District (Table 4).

Hot pepper Anthracnose disease was observed in Bako Tibe, Sibu Sire and Boneya Boshe Districts with different levels of mean disease incidence. The maximum mean incidence of 39.5% was recorded in Bako Tibe followed by 28% in Boneya Boshe 28% district. On the other hand, the minimum mean incidence of 22.75% for anthracnose was recorded in Sibu Sire District (Table 4).

Table 4:Percentage of Prevalence, Incidence and Severity Index of Hot pepper disease

Zone	Districts	Types of disease	Prevalence %	Incidence %	Severity %
West Shoa	Bako Tibe	Fusarium Wilt	74.62	54.8	54.8
		Cercospra Leaf Spot	100	90.31	43.69
		Bacteril Leaf Spot	69.23	76.33	30.67
		Bacteria Soft Rot	23.08	27.5	23
		Anthracnose	30.77	39.5	24
	Ilu Galan	Fusarium Wilt	83	47	47
		Cercospra Leaf Spot	100	85	26
		Bacterial Leaf Spot	87	73	32
	Sibu Sire	Fusarium Wilt	70.59	40.5	40.5
		Cercospra Leaf Spot	100	66.53	27.94
		Bacterial Leaf Spot	76.47	56	23.22
		Bacteria Soft Rot	58.82	42.4	21.8

East wollega		Anthracnose	23.53	22.75	11
	Boneya Boshe	Fusarium Wilt	100	43.33	43.33
		Cercospra Leaf Spot	100	33.36	36.75
		Bacterial Leaf Spot	75	57.33	24.67
		Anthracnose	26	28	17

Hot pepper disease severity

Survey of farmers' fields in the major hot pepper growing areas of Bako Tibe, Ilu Galan, Sibu Sire and Boneya Boshe Districts revealed that fusarium wilt disease severity varied from one field to another perhaps due to varied environmental conditions prevailing, cropping pattern and inoculum sources. The most infected areas were found in Bako Tibe with 54.8% disease severity followed by Boneya Boshe with mean disease severity of 47%.On the other hand, the minimum disease severity was recorded in Ilu Galan District with mean severity level of 40.5% for fusarium wilt (Table 4). This result shows similar trend with the findings of Shiferaw and Alemayehu (2014) who indicated that the occurrence of fusarium wilt was the highest at Abeshge (55%) followed by Halaba (41%), Hawassa Zuria (36%), Dalocha (32%) and Lanfro (30%) and other Western parts of Ethiopia.

Cercospra Leaf Spot disease severity on hot pepper varied significantly across the studies areas. The highest mean severity of cercospora Leaf Spot of hot pepper was 43.69 % recorded in Bako Tibe District followed by severity level of 36.75% recorded in Boneya Boshe District. On the other hand, the minimum mean disease severity of Cercospora Leaf Spot of hot pepper was 26% recorded in Ilu Galan District (Fig. 2).

In a similar manner to other diseases, severity level of Bacteria Leaf Spot of hot pepper varied significantly across Bako Tibe, Ilu Galan, Sibu Sire and Boneya Boshe Distrcts. The highest mean severity of Bacteria Leaf Spot of hot pepper was 32% recorded in Ilu Galan followed by severity level of 30.67% recorded in Bako Tibe District. The minimum mean severity of Bacteria Leaf Spot was 23.22% and 24.67% assessed in Sibu Sire and Boneya Boshe Districts, respectively (Table 4). The results of the current study show higher level of disease severity than reported earlier byYigrem *et al*. (2019) who found out that Bacterial Leaf Spot occurred with low disease seveity index (7.6 to 18.5%) in all surveyed districts.

Bacteria Soft Rot disease of hot pepper was widely distributed throughout the major hot pepper growing areas of Bako Tibe and Sibu Sire Districts. The mean disease severity of Bacteria Soft Rot was nearly similar in both Bako Tibe and Sibu Sire Districts with mean scoresof 23% and 21.8, respectively (Table 4).

The survey results indicated thatAnthracnose diseasedevastated hot pepper on farmers' field in Bako Tibe, Sibu Sire and Boneya boshe Districts. The highest severity of anthracnose of hot pepper was 24% recorded in Bako Tibe followed by Boneya Boshe 17% severity, but the minimum disease severity was recorded in Sibu Sire Districts (Fig. 2).

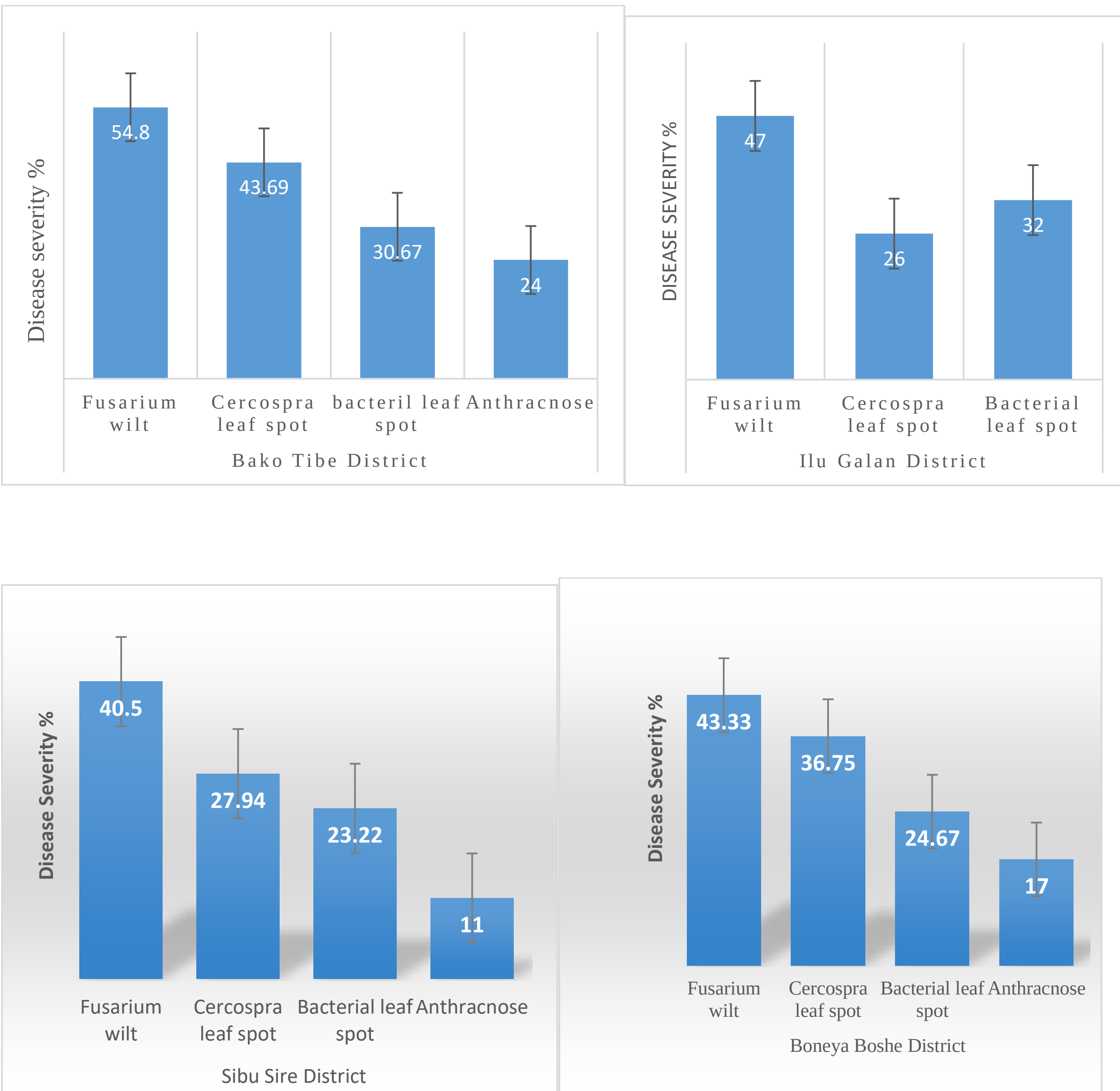


Figure 2: Disease severity of Hot pepper in each District

Conclusion

A survey was conducted to assess the status and distribution of major hot pepeer diseases in the two potential zones –West Showa and East Wollega. Four districts i.e Ilu Galan and Bako Tibe in West Showa; and Sibu Sire and Boneya Boshe in East Wollega were selected for the study. Alltogether, 32 kebeles were covered for diseaseassessment and a total of 45 farms were assessed to score the prevalence, incidence and severity of major hot pepper diseases.

Six diseases of hot pepper, Fusarium Wilt (*Fusarium oxysporum*), Cercospra Leaf Spot (*Cercospora capsici*), Bacterial Leaf Spot (*Xanthomonas campestris pv. vesicatoria*), Bacteria Soft Rot (*Erwina cartovora*) and Anthracnose (*Colletotrichum gloeosporioides*) prevailed in all the surveyd districts with varying level of disese prevalence, incidence and severity. Fusarium wilt of hot pepper appeared to be the most severe (severity level of 40.5 -54.8) accross all the study districts. Highest severity score (54.8%) of this disease was recorded in Bako Tibe district.Cercospra Leaf Spot was the second most severe disease (severity score of 27.94 – 43.69%) of hot pepper in Bako Tibe, Sibu Sire and Boneya Boshe districts. The highest severity was recorded in Bako Tibe and the lowest in Sibu Sire districts. Anthracnose appeared to be the least severe disease in all the districts.

The current survey has identified the major hot pepper diseases that occur in West Showa and East Wallga Zones of Western Oromia with their scores of prevalence, incidence and severity. Apparently, these diseases could be very important in other Zones with similar agro-ecolgoy such as West Wollega, Kellam Wollega and other parts of Ethiopia, particularly the Western and South Western parts in localites where the crop is widely produced. Given the importance of the crop in terms of local consumption as well as both domestic and export markets, the high scores of disease infection scored in the current study suggest that disease management should be an integral component of hot pepper production packages.

References

Berke, T. 2002. The\VB KL Asian Vegetable Research Development Canter Pepper Project.

Rodriguez Y, Depestre T, Gómez O., 2008. Efficiency of selection in pepper lines (Capsicum annuum) from four subpopulations in characters of productive interest. Cienciae Investigación Agraria, 35(1):29-40.

Huffnagel, H.P. 1961. Agriculture in Ethiopia.Food and Agriculture Organization (FAO), Rome, 2428.

EEPA (2003). Spice potential and market study. Addis Ababa. Ethiopia, pp. 103.

Mohammed, Y., 2005. A review of management of major vegetable crop diseases in Ethiopia: in Abukutsa-Onyango et a.l (eds) Proceedings of the Third Horticulture Workshop on Sustainable Horticultural Production in the Tropics, 26th -29th. MSU, Maseno, Kenya.Maseno University.

Beyene T. and David Phillips (2007).Ensuring Small Scale Producers in Ethiopia to Achieve Sustainable and Fair Access to Pepper Market. Uganda Journal of Agriculture, 3 (2): 113-119.

EEPA (Ethiopian Export Promotion Agency), 2014. Export performance of agricultural products. Addis Ababa, Ethiopia: EEPA.

CSA (2018).Agricultural sample survey of 2017/18 year. Report on area and production of major crops (private peasant holdings, meher season), Bulletin 586, vol I, Addis Abeba Ethiopia.

Roukens, O. (2005). Export Potential of Ethiopian Oleoresins. Ethiopian Export Promotion Department, Ethiopia. pp. 7-14.

Tameru, A., Hamacher, J., & Dehne, H. W. (2003). The increase in importance of Ethiopian Pepper Mottle Virus (EPMV) in the rift valley part of Ethiopia: Time to create Awareness among researchers an extension worker. Paper presented at Deutsches Tropentage, October 18-21, 2003, Gottingen, Germany.

Korobkon, A., Tegegn, T., & Dilbo, C. (1986).Chemical control of bacterial leaf spot of hot pepper (Capsicum annuum L.) Caused by Xanthomonas campestris pv. vesicatoria. Scientific Phytopathological Laboratory (SPL) Progress Report for the Period 1985/86 (pp. 92-199).

BARC (Bako Agricultural Research Center). (2000). Progress Report 1999/2000.Bako Agricultural Research Center, Crop Protection Research Division.

Kassahun, S., Tariku, H., & Mekonnen, A. (2016).Characterization and Evaluation of Hot Pepper (Capsicum annuum L.)Cultivars against Bacterial Wilt Disease (Ralstonia solanacearum). Pyrex Journal of Microbiology and Biotechnology Research, 2 (3), 22-29.

Assefa, W., Dawit, W., Lencho, A., & Hunduma, T. (2015).Assessment of wilt intensity and identification of causal fungal and bacterial pathogens on hot pepper (capsicum annuum L.) in Bako Tibbe and Nonno districts of West Shewa Zone, Ethiopia. Intl. J. Phytol., 4 (1), 21-28. https://doi.org/10.33687/phytopath. 004.01.0972

Melanie L. L. I. and Sally A. M. (2004). Anthracnose Fruit Rot of Pepper [Internet]. Extension Fact sheet, Ohio State University [Online]. Available from: http://ohioline.osu.edu (Accessed: 8/12/2010)

Sun, X., Nielsen, M. C. and Miller, J. W. (2002).Bacterial Spot of Tomato and Pepper.Plant Pathology Circular No. 129. (Revised) April/ May; Fl. Dept. Agriculture and Cons. Svcs. Division of Plant Industry.

Wheeler, B. E. J. 1969. An Introduction to plant diseases.Wiley and Sons, London.374 pp.

M. A. Ismail, S. I. I. Abdel-Hafez, N. A. Hussein, and N. A. Abdel-Hameed, (2015). Contributions to the Genus Fusarium in Egypt with Dichotomous Keys for Identification of Species, TMKARPINSKI Publisher, Suchy Las, Poland, 1st edition.

Galanihe LD, Priyantha MGDL, Yapa DR., Bandara HMS, Ranasinghe JADAR (2004). Insect pest and diseases incidences of exotic hybrid Chilli pepper varieties grown in the low Country dry zone of Sri Lanka.Annals of Sri Lanka. 6: 99-106.

Abbasi, P. A., Soltani, N., Cuppels, D. A., and Lazarovits, G. (2002).Reduction of bacterial spot disease severity on tomato and pepper plants with foliar applications of ammonium lignosulfonate and potassium phosphate.*Plant Dis.* 86, 1232–1236. doi: 10.1094/pdis.2002.86.11.1232

Traunfeld JH, Malinoski MK. (2002). Some common diseases of chilies.Home and Garden Information Center, Maryland.Cooperative Extension, University of Maryland, College Park.

Siddiqui Y, Meon S, Ismail R, Rahmani M, Ali A. (2008). Bio-efficiency of compost extract on the wet rot incidence, morphological and physiological growth of okra (Abelmoschus esculentus [(L.) Moench]. Scientia Horticulturae. 117: 9-14.

Gabrekiristos, E., Teshome, D., & Ayana, G. (2020).Distribution and Relative Importance of Hot Pepper Fusarium Wilt (Fusarium oxysporium f.sp. capsici) and Associated Agronomic Factors in the Central Rift Valley of Ethiopia.Adv Crop Sci Tech, 8, 437.

Shiferaw Mekonen and Alemayehu Chala (2014) Assessment of Hot Pepper (Capsicum species) Diseases in Southern Ethiopia International Journal of Science and Research (IJSR). Vol. 3:3

Yigrem M., Daniel T. and Abebe B. (2019).Assessment of Prevalence, Incidence and Severity of Red Pepper Disease in Capsicum frutescens L. at Central Gondar, Ethiopia.Journal of Academia and Industrial Research (JAIR). 8 (3), 2278-521.

Evaluation of Fungicides for Management of Garlic Rust (*Puccinia allii*)

On the Highlands of Bale

Mohammedamin Abdurezake*and Dagne Kora

Sinana Agricultural Research Center, P.O.Box-208, Bale-Robe, Ethiopia

***Corresponding author: mohammed12abdu@gmail.com**

Abstract

A field experiment was conducted for two years (2019/2020 GC) at Goba and Sinana districts of Bale with the objective of identifying effective fungicides for the management of garlic rust, Puccinia allii. The highest garlic rust disease severity of 83.46 % and the lowest (11.16 %) were recorded from unsprayed control and Natura 250 EW treated plots, respectively. Similarly, the highest AUDPC (834.58 %-days) and the lowest AUDPC (111.58 %-days) and r (-0.004976units-1) were calculated from unsprayed control and Natura 250 EW sprayed plots, respectively. Regarding yield and yield-related traits, ANOVA showed significant variations (P<0.05) among treatments for bulb weight (BW) and tuber yield. The highest number of BW (29.16 g) and bulb yield (10.77 tone/ha) were recorded from a plot sprayed with Diprocon and Natura 250 EW treated plots, respectively while the lowest number of BW (13.6 g) and bulb yield (4.56 tone/ha) was recorded from unsprayed control plots. The highest (ETB 950 and 480) marginal rate of return was obtained from Tilt 250EC and Natura 250 EW treated plots, respectively. Therefore, based on the result of this study, fungicide Tilt 250 EC and Natura 250 EW are recommended for the management of Garlic rust for both small-scale and large-scale production systems.

Keywords: Garlic, fungicides, AUDPC, bulb yield, the net return, MRR%

Introduction

Garlic (*Allium sativum* L.) is one of the main *Allium* vegetable crops known worldwide in terms of its production and economic value. It belongs to the family *Alliaceae* and is the second most widely used Allium next to onion (Worku and Azene, 2015). In Ethiopia, the Alliums group (onion, garlic, and shallot) are important bulb crops produced for home consumption, spices, medicinal plant and as asource of income to many peasant farmers in most parts of the country. Garlic contains different essential minerals, vitamins and many other substances used for the health of human beings. More than 3000 publications in the past years have confirmed the efficacy of garlic for the prevention and treatment of a variety of diseases, acknowledging and validating its traditional uses.

It may impudence the risk of heart disease and is also used for the treatment of fatigue, although the mechanism involved remains unclear. The anti-fatigue function of garlic may be closely related to its many favorable biological and pharmacological effects (Morihara*et al*, 2007).Garlic has historically been used to treat aches and pains, leprosy, deafness, diarrhea, constipation and parasitic infection.

The area under garlic cultivation in Ethiopia was 11,845.53 ha of land with a production of about 107743.5 tonnes (CSA, 2016). In the highlands of Bale and the southeastern Ethiopia at large, farmers produce garlic under rain-fed conditions during both '*Bona*' (August - December) and '*Gena*' (March - July) cropping seasons for commercial purposes.

Garlic production is constrained by multiple biotic and abiotic factors. Among the biotic factors, Garlic rust is the major bottleneck in almost all garlic-producing regions of Ethiopia (Tilahun and Hasen, 2018).The disease is caused by an air-borne obligate pathogen called *Puccinia allii* (Rudolphi) and extremely reduces the productivity of Alliaceae, especially garlic. It is the most common, probably the only disease of the crop in the highlands of Bale. High severity level of 83.7 % was reported which caused around 58% of the crop losses in the region (Yonas, 2012). The use of resistant varieties is the least expensive, easiest, safest, and one of the most effective means of controlling plant diseases in crops (Agrios, 2004). But, in the absence of resistant varietymost common means of controlling plant diseases in the field is through the use of chemicals that are toxic to the pathogens. For the control of the disease, using fungicides is common by the farmers in the area. Even though the fungicides can control the disease, they differ in efficacy, price and availalblity.In order to identify the most effective and economically feasible fungicides, screening for the efficacyof a variety of commercially available fungicides is quite important. In line with this, the objective of this study was to evaluate the efficacy of different fungicides against garlic rust and identify or recommend the most effective and economically viable ones.

Materials and Methods

A local variety of garlic was planted in a sized plot of 1.5 × 2m with the space between plot and replications being1m and 0.5m respectively. The experimental design was Randomized Complete Block (RCBD) with a factorial arrangement with the distance of 0.1m and 0.3m between plant and rows respectively. During the application of each of the fungicides, a plastic sheet was used to prevent drift spray to adjacent plots. Treatments are described in Table 1.

Table 1. Description of Experimental Treatments

Treatment (chemical)	Rate	Volume of spraying water/ha	Spray interval (days)
Rex®duo	0.5 l/ha	250	10
Diprocon 30 EC	0.45 l/ha	250	10
Omaxim	2.5 kg/ha	200	10
Natura 250 EW	0.5 l/ha	250	10
Ridomil Gold	2.5 kg/ha	250	10
Tilt (Propiconazole)	0.5	250	10
Unsprayed (control)	-	-	-

Data collected

Disease incidence: was assessed by dividing the rust infected plant in the central rows by the total sampled plant in the central rows from the onset of the symptom appearance and on aweekly basis thereof.

Disease severity: was rated in the percentage of the leaf surface covered with lesions from pre-tagged plants from central rows using the standard disease scale of rust severity 1-5 (Koike *et al*., 2001) from the onset of the disease on weekly basis.

Days to maturity: number of days required from emergence to 75% leaf fall.

Plant height (cm): the average height of 10 plants of each plot measured from ground level to the tip of the pseudo stem at maturity.

Total yield (t/ha): yield estimated from the middle three rows of each plot after curing and transformed to tons per hectare.

Bulb weight (gm): average weight of 10 bulbs taken from each plot after curing.

Bulb diameter (mm): average diameter of 10 bulbs from each plot after curing using a digital caliper.

Number of cloves per bulb: average number of cloves of 10 bulbs from each plot.

Cloves weight (gm): weight of the bulb divided by several cloves per bulb.

Statistical analyses

All data such as disease incidence, disease severity, AUDPC, yield and yield components on the field were subjected to Analysis of Variance using Gen-Stat 15th edition computer software. Means that were significantly different were compared using List Significant Difference (LSD) at 5% probability of significance. Correlation analysis was employed to assess the association of diseases severity with yield and yield-related parameters. The disease severity scores were converted into Percentage severity index (PSI) for analysis using the following formula.

$$\mathrm{PSI} = \frac{\mathrm{Snr}}{\mathrm{Nps} \times \mathrm{Msc}} \times 100$$

Where:

Snr = sum of numerical ratings

Nps = number plants scored

Msc = maximum score on the scale

The Area under Disease Progress Curve (AUDPC) values were calculated for each plot using the following formula (Campbell and Madden 1990):

$$\mathrm{AUDPC} = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i)$$

Where, X_i= the PSI of disease at the i^{th} assessment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

Economic Analysis

Fungicide costs, fungicide application cost (labour used for spraying of fungicides, equipment like knapsack sprayer) and garlic price were considered to estimate the Profitability of the fungicides. Net return from fungicide application was calculated using the following formula (Wegulo, 2010).

Rn = YiP – (Fc + Ac) (Wegulo, 2010)

Where Rn = the net return from fungicide application (birr/ha);

Yi = is yield increase from fungicide application (kg /ha), obtained by subtracting the yield in the control treatment from the yield in the fungicide treatment.

P = is the garlic prices (birr /kg).

Fc = is the fungicide cost (birr /ha).

Ac = the fungicide application cost (birr/ ha).

Results and Discussion

Disease severity

The combined Analysis of Variance over years and locations did not show statistically significant variations but showed statistically significant variations across treatments for disease parameters such as disease severity (%) and Area under Disease Progress Curve (AUDPC) (%-days).

Statistically significant difference ($P<0.05$) was observed among treatments for disease severity. The highest garlic rust severity (83.46 %) was recorded from theplot without fungicide treatment (untreated control), while the lowest disease severity of 11.16 % was recorded from theplot sprayed with Natura fungicide (Table 2). This result is in line with the work of (Worku, 2017) who found out that Garlic rust (*Puccinia allii*) severity level on garlic plots sprayed with the three different NativoSC300 (Trifloxystrobin 100g/l +Tebuconazole 200g/l) spray frequencies (five times in every 7-days, three times in every 14-days and two times in every 21-days) was lower as compared to the unsprayed plots.

Area under Disease Progress Curve (AUDPC)

In the same way, statistically significant differences ($P < 0.05$) were observed for AUDPC. The highest AUDPC of (834.58 %-days and the lowest 111.58 %-days) were calculated from a non-treated plot and a plot sprayed with Natura fungicide, respectively (Table 2).This is in agreement with the work of Zemenu *et al., 2020)* who reported that the highest AUDPC value was recorded from untreated plots of all treatments.

Table 2: Effect of Fungicide application on Garlic rust Severity (%) and AUDPC (% days) in 2019/2020

Treatment	*Severity (%)*	*AUDPC*
Control	83.46	834.58
Ridomil	33.472	334.72
Omaxim	30.575	305.75

Rexduo	12.883	128.83
Diprocon	23.817	238.17
Tilt	13.933	139.33
Natura	11.158	111.58
MEAN	*29.90*	*298.99*
CV (%)	*27.71*	*27.71*
LSD (5%)	*5.73*	*57.33*

Agronomic, yield and yield-related parameters

The combined analysis on plant height, maturity date, bulb diameter and marketable bulb yield revealed significant differences among the tested fungicides (Table 3). Concerning yield and yield-related parameters, higher bulb weight of 29.16 and 28.64 were recorded from Diprocon and Tilt sprayed plots, respectively while the smallest bulb weight (13.60) was recorded from unsprayed plots (Table 3). Likewise, the highest tuber yield of 10.77ton/ha and 10.51 ton/ha was recorded from a plot treated with fungicides - Natura and Tilt, respectively, while the lowest tuber yield of 4.56 ton/ha was recorded from a plot with no fungicide treatment (unsprayed control) (Table 3).

Table 3: Yield and yield components of Garlic influenced by the fungicide application against Garlic Rust

Treatment	DM(days)	PH(cm)	BW(g)	TYLD(ton/ha)
Control	107.350	31.1	13.60	4.56[c]
RidomilGold MZ 68 WP	120.52	46.04	24.03	8.67[b]
Omaxim	119.317	49.93	27.33	7.76[b]
Rexduo	120.975	56.460	28.07	8.64[b]
Diprocon	125.417	59.642	29.16	8.83[b]
Tilt	126.000	58.67	28.644	10.51[a]
Natura	130.750	59.88	24.957	10.77[a]
MEAN	121.47	51.68	25.11	8.53
CV (%)	4.83	18.73	24.87	19.50

LSD (5%)	3.05	4.91	3.12	1.2396

Cost-benefit Analysis

The result showed that Natura 250 EW sprayed plot provided the highest gross returns (ETB 323100.00/ha) followed by Tilt 250EC which provided higher gross returns (ETB 315300.00/ha) and the lowest gross return ETB 136800.00/ha was computed from the untreated check. The plot sprayed with Tilt 250EC gave the maximum net return (ETB 294950.00/ha) and also gave the highest benefit-cost ratio (14.5). Natura 250 EW also gave higher net return (ETB 284,669.00/ha) and also gave higher benefit-cost ratio (7.4). The highest (ETB 950) marginal rate of return was obtained from Tilt 250EC followed by Natura 250 EW (ETB 480) treated plots. In other words, for every ETB 1.00 investment in Tilt 250 EC and Natura 250 EW cost andspraying, there was a gain of ETB 9.50 and4.80, respectively (Table 4). Therefore the most economic benefit for garlic rust management was obtained from Tilt 250EC and Natura 250 EW sprayed plots.

Table 4: Return and Benefit-Cost Ratio of Treatment for the Control of Garlic Rust during 2019/20 GC Season

Treatment	Yield (qt/ha)	Sale price (ETB/qt)	Total Variable Cost (ETB/ha)	Gross Return (Price x Qt)	Net Return (GR-TVC)	Benefit-cost ratio (GMP/TVC)	MRR %
Control	45.6	3000	35068	136800	101732	2.9	0
RidomilGold MZ 68 WP	86.7	3000	39451	260100	220649	5.6	301
Omaxim	77.6	3000	39178	232800	193622	4.9	234
Rexduo	86.4	3000	37792	259200	221408	5.9	320
Diprocon	88.3	3000	37834	264900	227066	6	331
Tilt 250 EC	105.1	3000	20350	315300	294950	14.5	950
Natura 250 EW	107.7	3000	38431	323100	284669	7.4	480

Conclusion and Recommendation

Garlic (*Allium sativum* L.) is one of the main allium vegetable crops known worldwide interms of production and economic value. It belongs to the family *Alliaceae* and is the second most widely used Allium next to onion (Worku and Azene, 2015).Garlic production is constrained by multiple biotic and abiotic factors. Among the biotic factors, garlic rust is the most important disease in almost all garlic-producing regions of Ethiopia (Tesfaye *et al.*, 1988).

The disease is caused by an air-borne obligate pathogen called *Pucciniaallii (*Rudolphi*)* and highly reduces the productivity of *Alliaceae*, especially garlic to the extent of total crop failure. It is the most common, and is probably the single most important disease of the crop in the highlands of Bale. High severity level of 83.7 % was reported which causes around 58% of the crop losses in the region (Yonas, 2012).Farmers are highlychallenged by the huge productivity loss due to the disease. To tackle this problem, different fungicides supposed to control/reduce the diseases were evaluated in Goba and Sinana district of Bale zone. All of the evaluated fungicides have shown a comparative efficacy as compared to the unteated plot against the disease. The plot sprayed with Tilt 250EC gave the maximum net return ETB 294950.00/ha and also gave the highest benefit-cost ratio (14.5). Natura 250 EW also gave higher net return ETB 284,669.00/ha and also resulted in higher benefit-cost ratio (7.4). The highest (ETB 950 and 480) marginal rate of return was obtained from Tilt 250EC and Natura 250 EW treated plots, respectively. However, out of the tested fungicides Tilt 250 EC and Natura 250 EW had shown better controlling potential against the disease. Therefore, Tilt250EC and Natura250 EW were recommended for use against garlic rust.

References

Agrios, G.N (2004) Plant Pathology. Elsevier academic press, San Diego.

Campbell & Madden, L.V. 1990. Monitoring epidemics In Environment.Introduction to Plant Disease Epidemiolog. London: Wiley. pp. 43-73.

Morihara N, Nishihama T, Ushijima M, et al. (2007) Garlic asan anti-fatigue agent. MolNutr Food Res 51, 1329–1334.

Tilahun.N and Hasen,S.(2018). Management of Garlic Rust (Puccinia allii) Through Fungicide at Bale Highlands, South Eastern Ethiopia.Journal of food science and quality assessment,Vol,81:82-84

Wegulo, S. (2010).Foliar diseases of winter wheat management with fungicides.University of Nebraska-Lincoln Neb Guide, 696- 702.

Worku, Y. (2017). Determination of optimum nativo SC 300 (Trifloxystrobin 100g/l + Tebuconazole 200g/l) sprays frequency for control of rust (PucciniaalliiRudolphi) on garlic in Bale highlands, South Eastern Ethiopia. American Journal of Agriculture and Forestry 5:16-19.

Worku, M and Azene.T (2015b) Effect of Spacing in Incidence and Severity of Garlic Rust (*PucciniaAllii* (Rudolphi.) and Bulb Yield and Related Traits of Garlic at Eastern Ethiopia. J Plant PatholMicrobiol 6: 314. doi:10.4172/2157-7471.1000314

Yonas W and Mashilla D (2012) Effects of Garlic Rust (*Pucciniaallii*) on Yield and Yield Components of Garlic in Bale Highlands, South Eastern Ethiopia. Journal of Plant Pathology and Microbiology 2012, 3:2

Yonas W and Mashilla.D (2012) Effects of Garlic Rust (*Pucciniaallii*) on Yield and (Placeholder1) (Azene, 2015)Yield Components of Garlic in Bale Highlands, South Eastern Ethiopia. J Plant PatholMicrobiol 3:118. doi:10.4172/2157-7471.1000118

Zemenu et al.2020. Management of Rust (Pucciniaallii R.) through Host Resistance and Alternate Application of Fungicides on Garlic (Allium sativum L.) in North Wollo, Ethiopia.East African Journal of Sciences (2020). Volume 14 (1) 65-82

Survey of Distribution and Status of Major Cereal Crop Disease in West Shoa, Horro Guduru Wollega and East Wollega Zones, Ethiopia

Abay Guta*, Getu Abera and Abreham Negera

Bako Research center, P. O. box 3, Bako, Shoa, Ethiopia

***Corresponding author: abbayg12@gmail.com**

Abstract

*A field survey was conducted to assess diseases of five important cereal crops i.e Maize, wheat, sorghum, barley and rice in parts of Western Oromia: West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedele Zones during 2019 and 2020 main cropping season, covering 121 farms altogether. Prevalence, incidence and severity of each disese were scored. Diseases recorded on maize include Anthracnose (*Colletotrichum sublineolum*), Leaf Blight (*Helminthosporium turcicum *Pass), Zonate Spot (*Gloeocercospora sorghi*) and Loos Smut (*Sporisorium sorghi*). Major diseases recorded on sorghum include Anthracnose (*Colletotrichum sublineolum*), Leaf Blight (*Helminthosporium turcicum *Pass), Zonate Spot (*Gloeocercospora sorghi*) and Loos Smut (*Sporisorium sorghi*). Though many common diseases were scored on wheat, two of them - Septoria Leaf Blotches (*Septoria tritici *spps) and Fusarium Head Blight (*Fusarium graminearum *spps) appeared to be economically the most important ones. Three diseases i.e Brown spot* Brown spot (**Cochlidolus miyabeanus**), Blast (Magnaporthe oryzae) and Bacterial Blight (Xanthomonas oryzae *pv. oryzae*) *were recorded on rice in Chawaka district where as only net blotch appeared to be economically important for barley*.

Keyword: Distribution, status, major Cereal disease, Prevalence, Severity

Introduction

Agriculture is vital in supporting sustainable rural livelihoods and economic growth for most of Africa's growing population. Between 20 - 30% of GDP and 55% of the total value of African exports comes from the agricultural sector (World Bank, 2008). However, there has been a decreased trend in per capita food production in Africa over the years. Between 1970 and 2007, there was a reduction of 30% in per capita food production in Eastern Africa, 20% in Southern Africa, 2% in Western Africa, and 40% in Central Africa (USDA, 2010). In comparison, per capital, food production has increased increased by 35% in South Asia (Lal, 2015).

Agriculture is the fundamental driver for Ethiopia's economy and long-term food security as it offers about 80-85% of employment, more than 61% of the total export and 38.5% of gross domestic product of the country (Degaga and Angasu, 2017). Ethiopia has diverse agro-ecology that permits different agricultural systems and production of different crops. The existence of this diverse agro-ecology together with diverse farming systems, socio-economic, cultures and climate zones provided Ethiopia with various biological wealth of plants, animals, and microbial species, especially crop diversity (Atnaf *et al*., 2015).

Cereal crops are plants belonging to the grass family Poaceae that are grown and harvested primarily for their edible grain (McKevith *et al*., 2004). The economic and social importance of cereal crops cannot be understated, as they provide fundamental nutrition for the vast majority of the world's population. Most cereal crops are grown primarily for their grain, which contains a nutritional starchy endosperm, and forms a staple part of the human diet. However, many cereals can also be used to feed livestock and their utility is further enhanced by their capacity for long term storage (McKevith *et al*., 2004).Food and Agriculture Organization of the United Nations estimates that2609 million tonnes of cereal crops were produced in 2018 (FAO, 2019).

The productivity of major crops in Ethiopia has been consistently below the global average. In Ethiopia, the national productivity of major crops for 2018 is 2.257 t/ha. Southern Ethiopia has a 1.882 t/ha productivity growth record for the same year, which is by far below the national average (CSA, 2016; MoFED, 2018). Moreover, the average national productivity of cereals such as maize, wheat, teff, barley, and sorghum in 2018 were 2.11, 1.66, 5.8, 2.3, and 1.85 t/ha, respectively. Pests (weeds, diseases, and insect and other pests) are major constraints that play great role in reducing cereal production and productivity in different parts of Ethiopia. The impact of these biotic factors on the general crop performance, yield and grain quality varies depending upon the genetic, environmental, management conditions and the interactions of these factors.

Many different types of organisms can infect cereal crops, including a range of bacteria, oomycetes, fungi, viruses and nematodes (Dean *et al.,* 2012). Fungal diseases are considered to be one of the most dominant groups of cereal crop pathogens, with agents causing disease at every level of plant physiology (Dean *et al.*, 2012; Doehlemann *et al*., 2017). Different fungal infections can thus cause a wide range of symptoms that can all contribute to yield losses.Thus it is very crucial to assess and record major diseases of cereal crops. The identification of major crop diseases in a given area is fundamentally important for developing management options. More over as there is often dynamism in pests- where climate change, farm activities and other human interventions tend to alter statuses of crop pests, it is quite necessary to periodically record their status and distribution.

In line with this,the studywas initiated to determine relative occurrence, distribution and status of major cereals' diseases in parts of western Oromia.

Materials and Methods

Description of the study area

The field survey was conducted in West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedele Zones during 2019 and 2020 main cropping season. Disease assessment survey was conducted in two districts of West Shoa Zone Chalia and Ilu galan Districts; two districts of Horro Guduru Wollega Zone: Guduru and Horro Districts; in five districts of East Wollega Zone namely Gida Ayaana, Guto Gida, Sibu Sore, Jima Arjo and Diga Districts; and Chewaka District of Buno Bedelle Zone (Table 1).

The disease survey was conducted to assess the prevalence, incidence and severity of major cereal crops: maize, wheat, barley, Sorghum and rice. In most of the areas, the survey was conducted during dough crop growth stage.The survey was conducted from 20th to 27th September for low land; from 16th to 23rd October for mid land; and from 5th to 12th November for highland areas. The annual mean minimum and maximum temperature of the area is 120C and 27.40C, respectively, while the annual rainfall is 1415.2 mm. The geographical locations of the surveyed areas were in the range of latitude and longitude of 08^{0}34.70'- 09^{0}40.41'N and 036^{0}06.47'- 037^{0}29.30'E, respectively.

Field survey

The survey was conducted in 54 Kebeles and 121 fields in the ten districts of the four zones. Purposive sampling technique was applied in the survey. Kebeles were randomly selected from each district and based on their representativeness of cereal production of the area. The number of fields assessed fro each crop was:Maize 55 samples, Sorghum 14 samples, Wheat 23 samples, Barley 19 samples and Rice 10 samples (Table 1). The locations between successivesamples of same crop (between maize and maize, between wheat and wheat) were at least 4-6 km apart depending on the topography and the relative importance of the crop within each location. The disease assessment was made along the two diagonals (in an "X" pattern) of the field from five points using 1m × 1m (1 m^2) quadrates from small cereals and 2m × 2m (4 m^2) quadrates for maize and sorghum.

Questionarry was prepared to interview farmers on issues like variety grown, preceeding crop, planting date,seed rate, weed management practicess, fertilizers used and rate, diseases observed, fungicides used and others. In each field, plants within the quadrates were counted and categorized into healty and diseased ones.

Table 1: Characteristic features of surveyed Cereal fields in four Zones in Western Oromia

Zone	Districts	Crops	Altitude (m.a.s.l)*	No. field assessed
West Shoa	Ilu Galan	Maize	1711-1874	9
	Calia	Wheat	2485-2630	7
		Barley	2435-2632	6
		Mean	1711-2632	22
H/G/Wollega	Guduru	Maize	2286-2396	9
		Wheat	2315-2446	8
		Barley	2292-2349	7
	Horro	Wheat	2451-2757	8
		Barley	2350-2751	6
		Mean	2286-2757	38
East Wollega	Gida Ayyana	Maize	1290-2469	9
	Guto Gida	Maize	1333-1379	7
	Sibu Sire	Maize	1744-1841	7
	Jima Arjo	Maize	2170-2345	6
	Diga	Sorghum	2113-2286	6
		Mean	1290-2469	35
Buno Bedelle	Chawaka	Maize	1231-1291	8
		Sorghum	1204-1256	8
		Rice	1202-1265	10
		Mean	1202-1265	26
		Over all of mean	1202-2757	121

*m.a.s.l= meters above sea level

Disease scoring

Visual identification of the disease was used on all visited fields. The assessment was done for disease prevalence, incidence and severity for each crop in the reported locations.

Disease prevalence

Disease prevalence was calculated using the formula:

$$\text{Disease prevalence (\%)} = \frac{\text{Number of locations showing plant disease}}{\text{Total number of location or fields}} \times 100$$

Disease Incidence

Disease incidence was determined in each field on the basis of visual symptoms and by counting the number of symptomatic or infected plants in a sample of total plants in randomly selected samples. The formula for determination of incidence is:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of Diseased plants in the sample}}{\text{Total number of plant in the quardate}} \times 100$$

Disease Severity

The level of disease severity for each field was determined by using visual disease rating scale as given by Jan and Wiese (1991):

$$\text{Disease Severity (\%)} = \frac{\text{Area of plants tisseu affected}}{\text{Total number of plants affected}} \times 100$$

Data analysis

Data was analyzed using SPSS software. Analysis was conducted by disaggregating important relevant information by district and region so that comparison could be made

Result and Discussion

Status and distribution of cereal diseases

Prevalence of most foliar diseases varied from field to fiel depending on environmental conditions, tillage practices, cropping sequence, and cultivar susceptibility. Moderate temperatures and moisture in the form of rain and heavy dew usually favor development of foliar diseases and more than one type can be present on individual plants.

Maize diseases

Prevalence

Results ofthe survey indicated that the major maize diseses that prevailed in the study area include Turcicum Leaf Blight (*Exserohilum turcicum*), Eyespot (*Kabatiella zeae*), Phaeosphaeria Leaf Spot (*Phaeosphaeria maydis*), Gray Leaf Spot (*Cercospora zeae-maydis*), Culvularia Leaf Spot (*Curvularia pallescens*), Brown Sport (*Physoderma maydis*), Maize Streak Virus and Common Smut (*Ustilago maydis*).These diseases were highly prevalent with high level of incidence and severity particularly in the six districts of the four zones. Maize Streak Virus and Maize Common Smut were observed to be apparently less important (minor) in most districts.The prevalence of major maize diseases in the study area is indicated in Table 2.

Prevalence of maize Turcicum Leaf Blight was 100% in all the surveyed districts.Likewise, Gray Leaf Spot was 100% prevalent in Ilu Galan, Guduru and Jima Arjo districts but in Gida Ayyana its prevalence was 83.33%. In Guto Gida and Chewaka districts, Gray Leaf spot was 80% prevalent. The prevalence of Phaeosphaeria Leaf Spot was found to be 100% in Ilu Galan, Sibu Sire and Jima Arjo Districts. Maize Culvularia Leaf Spot prevalence in Guto Gida was 100%; it was 83.3% prevalent in Gida Ayyana and Chewaka while the prevalence was 80% in Jima Arjo district. Maize Eyespot disease was 100% prevalent in Guto Gida and Sibu Sire districts while it was 80% prevalent in Chewaka district. Maize Brown Spot disease was 100% prevalent in Jima Arjo while it was 80% prevalent in Gida Ayyana District.

Incidence

Incidence of Turcicum Leaf Blight generally ranged from 81.25% - 100%. The maximum Turcicum Leaf Blight incidence of 100 % was recorded in Jima Arjo district followed by Guduru and Guto Gida where the disease prevailed 94% and 91%, respectively (Table 2). Therefore, all the surveyed areas in this studycould be categorized under high Turcicum Leaf Blight incidence. Incidence of Maize Gray Leaf Spot and Phaeosphaeria Leaf Spot rangedbetween 51.5% - 100% and 26.5%-100%, respectively (Table 2).

The maximum Gray Leaf Spot and Phaeosphaeria Leaf Spot incidence was recorded in Jima Arjo district while the minimum incidences of the two diseaseswere recorded in Gida Ayyana district. Maize Culvularia Leaf Spot had its highest incidence of 100% in Guto Gida followed by Chewaka, Sibu Sira and Jimma Arjo with incidence of 94%, 90% and 85%, respectively where as its lowest incidence of 30% was recorded in Ilu Galan; other districts have incidence values that lie in between.The highest Brown Spot incidence of 80% was recorded in Gida Ayyana followed by 66% and 62% in Jimma Arjo and Guto Gida, respectively; it was not incident, however, in Ilu Galan, Guduru and Sibu Sire districts.

Severity

In terms of Turcicum Leaf Blight severity, the most affected fields were found in Sibu Sire with 55.5% disease severity, followed by Guto Gida and Jima Arjo districts with 45.8% and 41.5% severity levels, respectively. On the other hand the minimum severity of 34.5% was noticed in Guduru district. The survey result revealed that Turcicum Leaf Blight of maize was prevalent in major maize growing districts with the severity level ranging from 34.5 to 55.55% (Table 2).

The maximum Phaeosphaeria Leaf Spot severity of 38% was observed in Sibu Sire followed by 31.33% in Guduru district and the minimum severity was 8.67% noticed in Guto Gida district. The survey result revealed that Gray Leaf Spot of maize was prevalent in all the maize growing surveyed districts in low to severe form with severity ranging from 11.4% in Guduru to 37.4%Chawaka district. Culvularia Leaf Spot of maize was prevalent in all the surveyed districts with severity level ranging from 11% in Ilu Galan to 25% in Jimma Arjo district.

The severity ofBrown Spot ranged from 13.5 -30% in Guto Gidda, Gidda Ayyana, Chawaka and Jimma Arjo districts where as its severity was virtually zero in Ilu Galan, Guduru and Sibu Sire districts. The severity of Eyespot ranged from 11.5% in Guto Gida to 21% in Guduru district; in Jimma Arjo Eyespot severity was virtually zero. From the surveyed districts, Maize Streak Virus disease severity of 15%, 14.33% and 10.83% was recoreded in Gida Ayyana, Guto Gida and Chawaka districts, respectively.Similary, Maize Common Smut severity of 15% was recorded in Guto Gida District (Table 2).

Table 2: Percentage of Prevalence, Incidence and Severity Index of Maize disease surveyed fields.

Zones	Districts	Types Of Disease	Prevalence %	Incidence %	Severity %
West Shoa	Ilu Galan	Turcicum Leaf Blight	100	86.6	36.6
		Eyespot	60	30	18.33
		Phaeosphaeria Leaf Spot	100	56.6	10.64
		Gray Leaf Spot	100	55.2	14
		Brown Sport	0	0	0
		Culvularia Leaf Spot	40	30	11
H/G/Wollega	Guduru	Turcicum Leaf Blight	100	94	34.8
		Eyespot	57	72	21
		Phaeosphaeria Leaf Spot	60	90	31.33
		Brown Spot	0	0	0
		Gray Leaf Spot	100	85	11.4
		Culvularia Leaf Spot	47	66	19
East Wollega	Gida Ayyana	Turcicum Leaf Blight	100	84.5	37.5
		Eyespot	33.33	100	16
		Phaeosphaeria Leaf Spot	66.67	26.5	27.5
		Gray Leaf Spot	83.33	51.8	22.5
		Culvularia Leaf Spot	83.33	76.25	15.75
		Brown Spot	83.33	80	23.4
		Maize Streak Virus	16.67	15	15
	Guto Gida	Turcicum Leaf Blight	100	91	45.8
		Eyespot	100	26.25	11.5
		Phaeosphaerialeaf Spot	60	59.33	8.67
		Gray Leaf Spot	80	80.75	12.25
		Culvularia Leafspot	100	100	15.4
		Brown Spot	40	62	13.5
		Maize Streak Virus	60	30.67	14.33
		Maize Head Smut	40	20	15
	Sibu Sire	Turcicum Leaf Blight	100	81.25	55.5
		Eyespot	100	49	19.75
		Phaeosphaeria Leaf Spot	100	72.75	38
		Gray Leaf Spot	75	76.67	17.33
		Culvularia Leaf Spot	75	90	24
		Brown Spot	0	0	0
	Jimma Arjo	Turcicum Leaf Blight	100	100	41.5
		Phaeosphaeria Leaf Spot	100	100	27
		Eyespot	0	0	0
		Gray Leaf Spot	100	100	29
		Culvularia Leaf Spot	80	85	25
		Brown Spot	100	66	30
Buno Bedelle	Chawaka	Turcicum Leaf Blight	100	82.5	41
		Culvularia Leaf Spot	83.33	94	22.6
		Gray Leaf Spot	80	58.67	37.4
		Brown Spot	50	40.33	24.75
		Phaeosphaeria Leaf Spot	66.67	42.75	18.5
		Eyespot	80	41.6	10.2
		Maize Streak Virus	100	18.33	10.83

Sorghum diseases

Prevalence

The survey results indicated that Anthracnose (*Colletotrichum sublineolum*),Leaf Blight (*Helminthosporium turcicum* Pass), Zonate Spot (*Gloeocercospora sorghi*) and Loos Smut (*Sporisorium sorghi*) were the major diseases of high prevalence in two districts of the study area with high incidence and severity level (Table 3). The prevalence of sorghum Anthracnose (*Colletotrichum sublineolum*) and Leaf Blight*(Helminthosporium turcicum)* were 100% in both surveyed districts(Table 3). Sorghum Zonate spot disease prevalence was assessed in Chawaka and Diga where prevalence of 80% and 76%, respectively were recorded. Sorghum loose smut prevalence was recorded to be 66.67% in Diga Disrict and 20% in Chawaka District (Table 3).

Incidence

Sorghum Anthracnose *(Colletotrichum sublineolum)*disease incidence was found to be100% in all surveyed fields. The surveyed areas were categorized under high Anthracnose disease incidence (Table 3). Disease incidence of Zonate Leaf Spot was recorded to be 70% and 42%inDigaand Chewaka Districts, respectively. Incidence of Sorghum Leaf Blight was 66% and 90.67% in Chawaka and Diga districts, respectively (Table 3). Also sorghum Loose smut incidence was recorded in both Districts; 34.5% in Diga and10 % in Chawaka (Table 3).

Severity

In Diga district disease severity was 48%, 19.94%, 26% and 28% for Anthracnose, Leaf Blight, Zonate Spot and Loos Smut, respectively where as in Chawaka district, the severity level of the diseases was 54.5%, 34.5%, 26% and 18% in that order (Table 3).

Table 3: Percentage of Prevalence, Incidence and Severity of Sorghum diseases in surveyed fields.

Zones	Districts	Types of disease	Disease Prevalence %	Disease Incidence %	Disease Severity %
East Wollega	Diga	Anthracnose	100	100	48
		Leaf blight	100	90.67	19.94
		Zonate spot	76	70	26
		Loos smut	66.67	34.5	28
Buno Bedelle	Chawaka	Anthracnose	100	100	54.5
		Leaf blight	100	66	34.5
		Zonate spot	80	42	26
		Loos smut	20	10	18

Wheat, Barley and Rice diseases

Several wheat diseases such as yellow rust (*Puccina stiriiformis*), stem rust (*Puccina graminis*), Septoria Leaf Blotches (*Septoria tritici spps)*, Fusarium Head Blight *(Fusarium graminearumspps)* and loose smut *(Ustilago tritici)* were recorded in all wheat growing areas covered by this survey (Table 4). According to the results of this survey, however, most of the wheat diseases except Fusarium Head Blight and Septoria Leaf Blotch appeared *to be of* minor importance from disease severity point of view.Septoria Leaf Blotches of wheat occurred in Guduru, Chalia and Horro districts with mean severity level of 53%, 49% and 34%, respectively. Similarly Fusarium Head Blight had mean severity level in the range of 19.8%-26.7% and occurred in all the three districts surveyed for wheat (Table 4).

Diseases recorded for barley in Chalia, Guduru and Horo districts include yellow rust (*Puccina stiriiformis*), stem rust (*Puccina graminis*) and Net Blotch (*Pyrenophora teres* or *Helminthosporium teres*). Net blotch appeared to be the most important of all the diseases recorded on barley with severity level ranging from 26.2% to 34%; yellow and stem rusts appeared to be of minor importance. Rice diseases were assessed in Chawaka district andthree diseases namely Brown spot (***Cochlidolus miyabeanus***), Blast (*Magnaporthe oryzae*) and Bacterial Blight (*Xanthomonas oryzae pv. oryzae*) were recorded with mean severity level of 26.89%, 34.6% and 27.6%, respectively.

Table 4: percentage of prevalence, incidence and severity index of Wheat, Barley and Rice crops disease

Zones	Districts	Types of crops assessed	Types Of Disease	No. of field assessed	Prevalence %	Incidence rage	Incidence mean %	severity range	Severity mean %
West Shoa	Chalia	Wheat	Fusarium Head Blight	7	92	0-54	37.6	0-34	26.7
			Septoral Blotch	7	100	45-67	56	34-54	49
			Yellow Rust	7	50	0-39	34	0-26MS	11
			Stem Rust	7	46	0-41	31	0-27MS	19
			Loos Smut	7	25	0-19	13	0-16	11
			Net Blotch	6	100	60-100	84.66	32-49	42.6
Horro Guduru Wollega	Guduru	Wheat	Fusarium Head Blight	8	63	0-39	30	0-37	22.5
			Septoral Blotch	8	100	65-89	76	46-58	53
			Yellow Rust	8	33.34	0-30	21	0-18MR	12
			Stem Rust	8	33.34	0-27	22	0-17MR	12
	Horro	Wheat	Fusarium Head Blight	8	66.67	0-51	43	0-30	19.8
			Septoral Blotch	8	100	59-99	88	24-44	34
			Yellow Rust	8	42	0-49	33	0-29MS	24
			Stem Rust	8	61	0-45	38	0-16MS	9
West Shoa	Chalia	Barley	Stem Rust	6	57	0-44	38	0-28MS	21
			Yellow Rust	6	43	0-39	35	0-19MS	13
Horro Guduru Wollega	Guduru	Barley	Net Blotch	7	66.67	0-86	54	0-38	30
			Stem Rust	7	55	0-39	32	0-25MR	13
			Yellow Rust	7	33.34	0-17	14	0-16MR	9
	Horro	Barley	Net Blotch	6	100	45-78	62	18-34	26.2

			Stem Rust	6	80	0-37	29	0-19MR	14
			Yellow Rust	6	20	0-27	20	0-18MR	12
Bono Bedelle	Chawaka	Rice	Brown Spot	10	100		92.67		26.89
			Blast	10	100		61.67		34.6
			Bacterial Blight	10	33.33		43.33		27.67

Conclusion

Generally the results of survey conducted in four Zones and 10 districts of the Western part of Oromia in 2019 and 2020 has enabled to document various diseases that occur on the five major cereal crops: maize, wheat, sorghum, barley and rice. Some of the diseases are quite economically very important from view point of key parameters such as severity while others, though have wide prevalence and incidence, are less important from disease severity point of view. Research should focus on the major diseases showing high level of severity to avail various alternatives of management, towards developing Integrated Pest Management.

Major maize diseses that prevailed in the study area include Turcicum Leaf Blight (*E. turcicum*), Eyespot (*Kabatiella zeae*), Phaeosphaeria Leaf Spot (*Phaeosphaeria maydis*), Gray Leaf Spot (*Cercospora zeae-maydis*), Culvularia Leaf Spot (*Curvularia pallescens*), Brown Sport (*Physoderma maydis*), Maize Streak Virus and Maize Common Smut (*Ustilago maydis*). Major diseases of sorghum were Anthracnose (*Colletotrichum sublineolum*),Leaf Blight (*Helminthosporium turcicum* Pass), Zonate Spot (*Gloeocercospora sorghi*) and Loose Smut (*Sporisorium sorghi*) which could be considered as quite important because of high severity level. Although many common diseases were recorded in the surveyd districts, the results of severity level show that only two of the diseases – Spetoria Leaf Blotch and Fusarium Head Blight appeared to be economically important. Similarly Net Blotch appeared to be the most important disease for balry. Three disease of rice i.e Brown spot, blast and bacterial blight were recorded for rice in Chawaka district.

In addition to the survey results, yield loss assessments may be required for some crop-diseases combinations in order to determine whether they are economically important or not. Loss assessments could be of quantity or quality based on the purpose of production of the particular crop. More over, areas that have not be covered by the current survey, but yet offer high potential for the production of these crops, need to be surveyd to get broader understanding of specific crop-disease combinations and their economic importance.

Reference

CSA, 2018. Annual Agriculture Sample Survey of Impact of Agricultural Production at National Level Report; CSA: Addis Ababa, Ethiopia; pp. 10–36.

Dean, R., Van Kan, J., Pretorius, Z., Hammond-Kosack K., Di Pietro. A., Spanu, P., Rudd, J., Dickman M., Kahmann R., Ellis, J. (2012). The Top 10 fungal pathogens in molecular plant pathology.Mol. Plant Pathol. 13, 414–430. [CrossRef]

Doehlemann, G., Okmen, B., Zhu, W., Sharon, A.PlantPathogenicFungi. Microbiol.Spectr. 2017,5. [CrossRef]

Food and Agriculture Organization. Crop Prospects and Food Situation, March 2019; FAO: Rome, Italy, 2019.

Lal, R., 2015. Sustainable intensification for adaptation and mitigation of climate change and advancement of food security in Africa.In sustainable intensification to advance food security and enhance climate resilience in Africa (pp. 3-17).Springer, Cham.

McKevith, B. (2004) Nutritional aspects of cereals.Nutr. Bull., 29, 111–142. [CrossRef]

MoFED (2018). Annual Progress Report of the GTP II; Ministry of Finance and Economic Development: Addis Ababa, Ethiopia, 2018; pp. 1–33.

Wassie, S.B. Technical efficiency of major crops in Ethiopia: Stochastic frontier model. Acad. J. Agric. Res. 2014, 2, 147–153. 9. OECD/FAO. Agriculture in SSA: Prospects and challenges for the next decade. In OECD-FAO Agricultural Outlook 2016–2025; OECD Publishing: Paris, France, 2019; pp. 59–96.

USDA, 2010.United States department of agriculture –.Food security assessment, 2010 – 20. Indicators in 2010 for many lower-income countries due in part to economic recovery. Accessed 20 June 2019.Available:https://www.ers.usda.gov/webdoc s/publications /37229/13462_gfa21_1_.pdf? v=0

World Bank, 2008. World development report 2008: Agriculture for development. Washington,

DC. © World Bank. 2007. https://openknowledge.worldbank.org/handle/109 86/5990 License: CC BY 3.0 IGO.

Field Evaluation of Insecticides for Management of Russian Wheat Aphid (*Diuraphis noxia M.*) on Durum Wheat in South-Eastern of Ethiopia

Megersa Abdisa* and Addisu Alemu
Sinana Research Center, Bale-Robe, Ethiopia
***Corresponding Author: megersaabdisa.58@gmail.com**

Abstract

Russian Wheat Aphids (RWA) (Diuraphis noxia M.) is responsible for significant yield loss of wheat and is mainly controlled by using insecticides. In this study, the efficacy of five insecticides was evaluated against Russian Wheat Aphids on wheat using a Randomized Complete Block Design in three replications. The study was conducted during 2019 and 2020 at three locations – one on research station and two on-farm locations viz. Sinana on-station, Selka area, and Robe Area. The efficacy percent of Dimeto 40% EC, Odimeto 40 % EC, Lefotheate 40 % EC, Profit 72 EC, and Malamar 50% EC were 86.7%, 84.35%, 80.86%, 77% and 61.85%, respectively. The lowest RWA infestation was observed in plots treated with Dimeto 40% EC and Odimeto 40 % EC and the same treatments also resulted in the highest yield of all other tested insecticides. Malamar 50 % EC showed the poorest efficacy against RWA as compared to the other treatments. The performances of Lefothoate 40% EC and Profit 72% EC were found to be intermediate in controlling RWA on wheat. Therefore, insecticides Dimeto 40% EC and Odimeto 40 EC were found to be most effective to control RWA on wheat.

Keywords: Russian wheat aphids, *Diuraphis noxia*, wheat, *Triticum aestivum*, Effective insecticide(s)

Introduction

Wheat (*Triticum sp*.) is one of the most important cereals cultivated in the world (Adugna and Tesema, 1987). Ethiopia is the second largest producer of wheat in Africa next to South Africa (Bayeh and Tadesse, 1994). In Ethiopia, wheat stands fourth in area coverage; eighty-one percent of the total land cultivated to grain crops is covered by cereals out of which wheat accounts for 13.14% of the area (Du Toit and Walters, 1984). Wheat is one of the major cereal crops produced on the highlands of Ethiopia at altitude range of 1500 to 2800m.a.s.l (Girma *et al*., 1993)

At national level, during the 2015/16 cropping season about 1.7 million hectares of land was covered by bread and durum wheat from which about 42.1 million quintals of yield was harvested (Kindler and Springer, 1989). In Ethiopia, wheat has been produced solely by rain -fed practice but in the most recent couple of years, the production of irrigated wheat has been put in place in many parts of the country in an effort to substitute imported wheat. Of the current total wheat production area, 75% is located in Arsi, Bale and Shewa areas. The remaining amount is produced in the rest of the north and Southern regions (Mornhinweg *et al*., 2006). Durum wheat (*Triticum turgidum L*.) is the second most cultivated wheat in the world next to bread wheat (Walters *et al*, 1980). Durum wheat is an indigenous to Ethiopia and it has been under cultivation since ancient times. Ethiopia is considered to be the center of genetic diversity of this crop. It is traditionally grown on heavy black clay soils (vertisols) of the central and northern highlands of Ethiopia between 1800-2800 meters above sea level.

However, the productivity of durum wheat in the country is very low compared to world average. This is due to several biotic and abiotic factors. The biotic stresses include insect pests such as aphids and barley shoot fly, which can cause yield losses of 79% and 56%, respectively;also fungal diseases such as yellow rust, stem rust, leaf rust, septoria leaf blotches and fusarium head blight are significantly threatening wheat production in most of wheat producing agro ecologies(Bekele, 2003).

RWA was reported in the Wukro (Atsbi) and Adigrat regions of northern Ethiopia in 1972/73 and western Welo region of Northwestern Ethiopia in 1974 (Adugna and Tesema, 1987). Crops damaged by RWA include wheat, barley, oat, rye and triticale,) (Walters *et al*., 1980); but barley and wheat are the most affected by RWA. Yield losses due to RWA are severe with individual plant losses as high as 90% (Du Toit and Walters, 1984). Robinson (1992) recorded crop losses of 68% in Ethiopia and 35- 60% in South Africa for wheat. This insect generally causes yield losses of 41-79 % in barley and up to 86% in wheat in Ethiopia (Miller and Adugna, 1988).

The major management methods of RWA on wheat are the use of resistant varieties, cultural methods, biological methods and using effective insecticides. Therefore, the objective of the the present study wasto evaluate different insecticides for their efficacy against RWA on durum wheat to recommend the most effective one.

Materials and Methods

Description of the study area

The study was conducted at Sinana Agricultural Research Center (SARC) on-station and two on-farm sites.The Center is located at $07^0$07’ N latitude and $40^0$10’E, with elevation of 2400 meters above sea level and characterized by bimodal rainfall. Accordingly there are two distinct seasons favorable for crop production. The two seasons are locally named after the time of crop harvest. The first season that extends from March to July is “Ganna” while the other season extending from July to December is”Bona”. The total annual rainfall ranges from 750-1000 mm (average 860 mm). The average annual maximum temperature is 21^0C while that of minimum temperature is 9^0C.Some preliminary analysis of soils in the center indicated that the soils are clay in texture (dark brown vertisol), slightly acidic in reaction (PH 6.2), and having 3.9% of organic matter, 0.243% total N, 30ppm available phosphorous and 240mg/kg K and CEC 64meq/kg soil.

Treatments and experimental design

The performance of different insecticides against RWA was evaluated for two years, in 2019 and 2020 during ‘bona’ (main cropping season) at three locations *viz*. Sinana on-station, Selka area, and Robe Area. Five insecticides and un-treated check were evaluated. The test insecticides included Dimeto 40% EC, Lefothoate 40% EC, Profit 72% EC, Odimeto 40% EC, and Malamar 50% EC (Table 1).The insecticides have been registered for wheat growers in the South Eastern highlands of Ethiopia. The treatments were arranged in RCBD with three replications. The plot size was 2 m by 3 m or $6m^2$.The spacing between plant rows, plots and blocks were 20 cm, 1 m and 1.5m, respectively. Recommended fertilizer, seed rates, weeding and cultivation practices were employed. The spraying of insecticides was done three times: first at tillering stage, second at booting stage and the third at the milky stage of wheat. Spray was made using manually operated knapsack spayer.

Table1.List of insecticides tested and their application rate against RWA on wheat at Sinana, South Eastern Ethiopia,

Trade	Common	Rates of Insecticides/ ha	Rate of water/ ha
Name	Name	(Li)	(Li)
Dimeto 40% EC	Dimethoate	1	300
Lefothoate 40% EC	Dimethoat	0.5	150
Profit 72% EC	Profenofos	0.75	250
Odimeto 40 EC	Dimethoate	1	250
Malamar 50%EC	Malathion	2	180
Unsprayed Check	-	-	-

Data Collection

Data collected include plant damage parameters (leaf rolling, leaf chlorosis and Russian wheat aphid population per plant); yield and yield component parameters (number of tillers per plant, plant height,spike length, seed per spike and grain yield).Leaf rolling was recorded visually from the leaf of tillers after seedling emergence to flowering stage with 14 days intervals on a rating scale of 1-3 (Webster *et al*., 1987) where 1= no leaf rolling; 2 =one or more leaves completely folded and 3 =one or more leaves completelyfolded.Leaf chlorosiswas recorded visually from the leaf of tillers after seedling emergence to flowering stage with 14 days intervals using 0-9 scoring scale (Webster *et al*., 1987) where 0 =immune; 1= plants appear healthy, may have small isolated chlorotic spots; 2= isolated chlorotic spots prominent; 3= chlorosis ≤ 15% of the total leaf area, chlorotic spots coalesced; 4: chlorosis > 15% but ≤ 25% of the total leaf area chlorotic lesions coalesced, streaky appearance; 5= chlorosis > 25% but ≤ 40% of the total leaf area, well defined streak, 6 = chlorosis > 40% but ≤ 55% of the total leaf area;7= chlorosis > 55% but ≤ 70% of the total leaf area; 8= chlorosis > 70% but < 85% of the total leaf area and 9 = plant death or beyond recovery.

RWA population count per tiller was taken from the whole parts of the tillers by dusting the aphids over paper using soft brush and then counting them individually at every two weeks interval after infestation.Number of tillers per plant was recorded at the average number of total tillers per plant without panicle excluding the main shoot.Plant height (cm) was recorded as the length of the plant from the base of the main stem to the tip of the panicle excluding the awns at late flowering stage.Spike length (cm) was recorded as the length of the spike in cm from the base of the spike to the tip of the spike excluding the awns at harvesting stage. Number of seeds per spike was recorded asan average number of total seeds per spike.

Data Analyses

Data were analyzed using the SAS software, version 9.0(SAS 2003) at 5% level of significance. Significant treatment means (P <0.05) were separated using LSD tests. The count data were subjected to square root transformation. Efficacy percentages were calculated by using the following formula:

$$\text{Efficacy (\%)} = \frac{BAI - AAI}{BAI} * 100$$

Where: BAI= aphid count before application of insecticides and;

AAI= aphid count after application of insecticides

Results and Discussion

The combined analysis of variance (ANOVA) for grain yield of durum wheat is given in Table 2 ANOVA showed significant statistical difference (P ≤ 0.001) among treatments for the main effects.

Number of aphids per tiller:the number of aphids per tiller was increased as the crop growth stages increased;RWA population peaked at the milky stage of crop growth (Table 3). The efficacy percent of Dimeto 40% EC, Odimeto 40 EC, Lefotheate 40 EC, Profit 72 EC, and Malamar 50% EC were 86.7%, 84.35%, 80.86% ,77% and 61.85%,respectively(Table 3). The untreated check had the highest mean number of aphids per tiller.

Table 2.Combined Analysis of Variance (ANOVA)

Source of Variation	Df	Sum Square	Mean Square	F value	Pr (>F)
Trt	5	5288440.074	1057688.015	397.72	< 0.0001
Rep	2	7263.871	3631.936	1.37	0.2990
Error	10	26593.632	2659.363	-	-
Total	17	5322297.577	-	-	-

Table 3. Effect of insecticides on RWA population at different growth stages of wheat

Treatments	Crop growth stage							
	Tillering stage		Booting stage		Milky stage		Total	
	BAI	AAI	BAI	AAI	BAI	AAI	BAI	AAI
Dimeto 40% EC	0.25	0.00	3.85	0.65	5.35	0.60	3.15	0.42
Lefotheate 40 EC	0.26	0.03	4.45	0.97	5.77	1.00	3.5	0.67
Profit 72 EC	0.25	0.00	4.83	1.25	5.74	1.25	3.61	0.83
Odimeto 40 EC	0.25	0.00	3.87	0.85	5.27	0.62	3.13	0.49
Malamar 50% EC	0.26	0.10	5.25	1.85	5.50	2.15	3.67	1.4
Un-treated	0.25	0.62	10.20	12.50	16.16	18.12	8.87	10.41
Mean	0.253	0.125	5.41	3.01	7.3	3.96	4.32	2.37

BAI = aphid count before insecticide application; AAI = aphid count after insecticide application

Effect of different insecticides on leaf rolling, leaf chlorosis and number of aphids per tiller

Applications of Dimeto 40% EC and Odimeto 40% EC resulted in significantly lower number of leaf rolling score of 1.10 and 1.26,respectively than the rest of the treatments (Table 4).The leaf rolling score was significantly higher in plots treated with Malamar 50% EC, Profit 72% EC and Lefotheate 40 % EC insecticides: 1.80, 1.62 and 1.50 leaf rolling per plot, respectively over the rest of the treatments except untreated check (Table 4).Performance of Lefotheate 40% EC and Profit

72% EC was intermediate between the best performing treatments(Dimeto 40% EC and Odimeto 40% EC) and the rest of the treatments on a rating scale of 1- 3.

There was significant difference ($p<0.05$) among treatments in affecting chlorophyll (Table 4). Significant differences in leaf chlorosis ($p<0.05$) were observed among the different insecticides as compared with untreated check. Larger chlorotic streaks and higher chlorotic scores (3.20) were observed on the untreated check. The result showed that from the five insecticides evaluated, the least chlorotic scoreswererecorded on Dimeto 40% EC (1.60) andOdimeto 40 EC (1.67).

As discussed earlier also, relatively lower number of mean RWA per tiller was recorded for insecticides Dimeto 40% EC andOdimeto 40 EC i.e 0.42 and 0.49, respectively. On the other hand, relatively higher mean number of RWA per tiller was recorded on Malamar 50% EC,Profit 72 EC treated plots i.e 1.4 and 0.83, respectively. The highest mean number of RWA per tiller (10.41) was recorded for untreated check (Table 4).

Table 4. Effect of insecticides on plant damage parameters (RWA population, leaf chlorosis and leaf rolling) under field conditions

Treatments	**Plant damage parameters**		
(Insecticides)	Leaf Rolling	Leaf Chlorosis	RWA population per tiller
Dimeto 40% EC	1.10[d]	1.60[e]	0.42[d]
Lefotheate 40 EC	1.50[c]	2.00[d]	0.67[cd]
Profit 72 EC	1.62[c]	1.87[cd]	0.83[c]
Odimeto 40 EC	1.26[d]	1.63[e]	0.49[d]
Malamar 50% EC	1.80[b]	2.40[b]	1.4[b]
Control	2.47[a]	3.20[a]	10.41[a]
Mean	1.63	2.12	2.37
LSD	0.1546	0.2635	0.29
CV (%)	5.35	7.00	6.8

Means in columns followed by the same letter(s) are not significantly different at $p<0.05$

Effect of insecticides on yield and yield parameters

Number of tillers per plant

The application of insecticide Dimeto 40% EC resulted in the highest (4.37) mean number of tillers per plant, which however, was not significantly different from Lefothoate 40% and Odimeto 40%

EC treatments that resulted in mean tiller number of 4.00 and 4.04, respectively. The lowest mean number of tillers per plant was recorded from the unsprayed check (Table 5).

Plant height

The application of Dimeto 40% EC resulted in the highest mean plant height (78.24 cm) followed by Lefothoate 40 EC that resulted in mean plant height of 77.43 cm. However, there was no significant variation among insecticide treatments for plant height. Untreated check resulted in the shortest mean plant height of 71.85 cm that was significantly lower from the other i.e insecticide treatments.

Spike Length

The highest mean spike length (4.96 cm) was recorded from Dimeto 40 EC treatment which however was not significantly different from Lefothoate 40 EC and Odimeto 40 EC that resulted in mean spike lengths of 4.85 cm and 4.82 cm, respectively. The lowest mean spike length was recorded from untreated check which was statisticacally at par with two of insecticide treatments i.e Profit 72 EC and Malamar 50 EC that resulted in mean spike lengths of 4.57 cm and 4.47 cm, respectively (Table 5).

Number of seeds per spike

The highest number of mean seeds per spike (45.89) was recorded from Dimeto 40 EC treatment which however was not significantly different from Odimeto 40 EC, Lefothoate 40 EC and Profit 72 EC which resulted in mean seed per spike of 45.62, 43.68 and 42.52, respectively. The least mean number of seeds spike was recorded from untreated check which was statistically at par with Malamar 50 EC insecticide treatment (Table 5).

Grain Yield

Dimeto 40 EC and Odimeto 40 EC insecticide treatments resulted in higher durum wheat grain yield, 5021.2 and 4943.5 kg/ha, respectively. The two treatments were statisticacally at par with each other but significantly varied from all other treatments. The other insecticide treatments – Lefothoate 40 EC, Profit 72 EC and Malamar 50 EC gave grain yield of 4710, 4148 and 4024 kg/ha, respectively. The least grain yield (3516.07 kg/ha) was attained from untreated check (Table 5).

Table 5.Effect of insecticides on yield and yied components (number of tillers per plant, plant height, spike length, and seed per spike) of wheatin relation to RWA infestation.

Yield component parameters

TreatmentsTillers/plant PH (cm) SL (cm) SPS GY (Kg/ha)

Dimeto 40% EC	4.37^{a}	78.24^{a}	4.96^{a}	45.89^{a}	5021.2^{a}
Lefothoate 40 EC	4.00^{ab}	77.43^{a}	4.82^{ab}	43.68^{a}	4710^{b}
Profit 72 EC	3.84^{b}	76.97^{a}	4.57^{bc}	42.52^{ab}	4148^{c}
Odimeto 40 EC	4.04^{ab}	76.62^{a}	4.85^{ab}	45.62^{a}	4943.5^{a}
Malamar 50% EC	3.72^{b}	76.88^{a}	4.47^{c}	39.64^{bc}	4024^{d}
Control	3.32^{c}	71.85^{b}	4.33^{c}	38.12^{c}	3516.07^{e}
Mean	3.88	76.33	4.67	42.58	4393.79
LSD	0.375	4.0299	0.3205	3.9446	91.18
CV (%)	14.61	7.99	10.39	14.01	1.17

Tillers/plant = no of tillers per plant; PH = plant height; SL = spike length; SPS = no of seed per spike; GY = grain yield

Means in columns followed by the same letter(s) are not significantly different at $p<0.05$

Conclusion and Recommendation

Russian wheat aphid has since long been on record as a major insect pest of wheatin south Eastern highlands of Ethiopia. In the current study, the ANOVA of grain yield showed significant variation among treatments or insecticides evaluated. Among insecticide treatments, the highest grain yield (5021.2 kg/ha) was attained from the application of Dimetho 40 % EC while the lowest (4024 kg/ha) was from Malamar 50% EC. Untreated check resulted in the least grain yield (3516.07) of durum wheat of all the treatments evaluated. The aphid's population per plant was increased with the crop growth stage from tillering to milky stage.

The efficacy percent of insecticides Dimeto 40% EC, Odimeto 40%EC, Lefotheate 40% EC, Profit72% EC, and Malamar 50% EC were found to be 86.7%, 84.35%, 80.86% ,77% and 61.85%,respectively.From the result, Dimeto 40% EC and Odimeto 40 EC were found to bemore effective insecticides to manage RWA on wheat as compared to other insecticides and increased the wheat yield; whereas insecticides Lefothoate 40 EC and Profit 72 EC were found to be of medium performance to control RWA on wheat. On the other hand, Malamar 50% EC insecticide was found to beleast effective than the other tested insecticides and its application did not result in appreciable wheat grain yield.

According to the results of this study, the most effective insecticides reduced plant damage and resulted in increased yield and yield components. This indicates that when other alternatives of management are not feasible for technical or economic reasons, the use of effective insecticides can safe wheat yield losses due to high RWA infestations. This study also demonstrated that population abundance of RWA on durum wheat crop was appreciably reduced by using effective insecticides, and the infestation level thereof was also reduced. Therefore, whenever farmers encounter high infestations of RWA that can significantly reduce yield, the use of the two insecticides, Dimeto 40% EC and Odimeto 40% EC is preferably recommended though other insecticides can also be used based on availability and price on local market.

References

Adugna Haile and Tesema Megenasa. 1987. Survey of aphids on barley in parts of Shewa, Wello, and Tigray, Ethiopia. Ethiop. J. Agric. sci. IX: 39-40.

Bayeh Mulatu and Tadesse Gebremedhin. 1994. Russian Wheat Aphid a major pest of barley in Ethiopia. PP. 169-174. In: Frank, B.P., and M.K. C.L. Kroening,. Simmons (eds.) Proceeding of the sixth Russian Wheat Aphid workshop, January 23-25, 1994, Colorado State University, Colorado.

Bekele Hundie, 2003. Short report on strip rust and stem rust. pp: 67-78.

Du Toit, F. and Walters M. C., (1984). Damage assessment and economic threshold values for chemical control of the Russian wheat aphid, Diuraphis noxia (Mordvilko) on winter wheat,; Pp 58-62. In: M C walters (ed). Progress in Russian wheat aphid (Diuraphis noxia) research in the Republic of South Africa

Girma, M., G.E. Wilde and Harvey T.L., 1993. Russian Wheat Aphid (Homoptera: k2Aphididae) affects yield and quality of wheat. J. Econ. Entomol. 86: 594-601.

Kindler, S.D. and Springer T.L., 1989. Alternate hosts of Russian Wheat Aphid (Homoptera: Aphididae). J. Econ. Entomol. 82: 1358-1362.

Kiplagat, O. K., 2005. The Russian wheat aphid (Diuraphis noxia Mord.): Damage on Kenyan wheat (Triticum aestivum L.) varieties and possible control through resistance breeding . Thesis, Wageningen University, The Netherlands. ISBN 90-8504-175-9

Miller, R.H. and Adugna Haile. 1988. Russian Wheat Aphid on barley in Ethiopia, Rachis. 7: 51-52.

Mornhinweg D.W, Brewer MJ, Porter D.R., 2006. Effect of Russian wheat aphid on yield and yield components of field grown susceptible and resistant spring barley.Crop. Sci. 46(1): 36-42.

Robinson, J., 1992b. Predators and parasitods of Russian Wheat Aphid in central Mexico.Southwest.Entomol. 17: 185-186.

Walters, M.C, F. Penn, T.C. Botha, K. Aalbersberg, P.H. Hewitt and Broodry S.W. k., 1980. The Russian Wheat Aphid. Farming in South Africa Leaflet series wheat C3:1-6.

Webster, J.A., K.J. Starks and Burton R.L., 1987. Plant resitance studies with Diuraphis noxia (Homoptera: Aphididae), a new United State wheat pest. J. Econ. Entomol. 80: 944-949.

Survey of Distribution and Status of Major Pulse and Oil Crops Diseases in West Shoa, Horro Guduru Wollega and East Wollega Zones, Ethiopia

Abay Guta*, Getu Abera and Abreham Negera
Bako Research center, P. O. box 3,Bako, Shoa, Ethiopia
***Corresponding author: abbayg12@gmail.com**

Abstract

*Field survey was conducted in part of Western Oromia in West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedele Zones covering 90 fields to assess diseases of faba bean, field pea, soybean, ground nut and sesame. Major diseases of faba bean recorded in Horro, Jimma Arjo and Chalia districts include Chocolate spot (*Botrytis fabae *S.), Ascochyta blight (*Ascochyta fabae*), Rust (*Uromyces fabae*) and faba bean Gall (Olpidium species). Similary, Powdery mildew (*Erysiphe pisi *var.), down mildew (Peronospora viciae), Septoria blotch (Septoria pisi) and Ascochyta blight () were the major diseases recorded on field pea in Chalia and Horro districts. Diseases recorded on soybean in Ilu Galan, Gida Ayana and chawaka districts include forage leaf spot (Cercospora sojina), Bacterial pustule (Xanthomonas axonopodis pv. glycines), Brown spot (*Septoria glycines*) and Cecospora leaf blight (*Cercospora kikuchii.*). Four major diseases were recorded on ground nut in Gida Ayana district and two diseases were recorded on sesame in Chawaka district. For all diseases, key parameters: prevalence, incidence and severity were described.*

Keywords: Distribution, status, major pulse and oil seeds disease, Prevalence, Severity

Introduction

Agriculture is the fundamental driver for Ethiopia's economy and long-term food security as it offers about 80-85% of employment, more than 61% of the total export and 38.5% of gross domestic product of the country (Degaga & Angasu, 2017). Ethiopia has diverse agro-ecology that permits different agricultural systems and production of different crops. The existence of this diverse agro-ecology, together with diverse farming systems, socio-economic, cultures and climate zones provid Ethiopia with various biological wealth of plants, animals, and microbial species, especially crop diversity (Atnaf *et al*., 2015).

Pulses are rich in proteins and serve as an economical source of nutrition: pulses can play a significant role in improving smallholders' food security as an affordable source of protein – in fact, pulses make up around 15% of the average Ethiopia diet (IFPRI, 2010). Pulses complement cereals as a source of protein and minerals as they provide 15-40% of protein (Monti and Grillo, 1983) compared to 6 to 10% for cereals and contain essential amino acid lysine, which is missing in cereals. As a protein source, pulses are more affordable for smallholders compared to meat, fish, and dairy products. Pulses also provide complex carbohydrates, fiber, and several vitamins and minerals (iron, magnesium, phosphorus, zinc and other minerals), which play a variety of roles in maintaining good health.

Like other plant-based foods, they contain no cholesterol and little fat or sodium. The World Health Organization (WHO, 2008) estimates that up to 80% of heart disease, stroke, and type 2 diabetes and over a third of cancers could be prevented by eliminating risk factors, such as unhealthy diets and promoting better eating habits, of which pulses are essential component. Pulses can help lower blood cholesterol and attenuate blood glucose, which is a key factor against diabetes and cardiovascular disease. Eating pulses as a replacement to some animal protein also helps limit the intake of saturated fats and increases the intake of fibers.

The diverse and important roles played by pulses in farming systems and in the diets of people make them ideal crops for achieving the Sustainable Developmental Goals of reducing poverty and hunger, improving human health and nutrition, and enhancing ecosystem resilience. Moreover, many pulses can enhance soil fertility and improve productivity (Campbell, *et al*., 1992 and Schwenke, *et al*., 1998).

The legume crops are severely damaged by a number of fungal, bacterial and viral diseases. Cool climate pulses are immensely damaged by Ascochyta blight as it is the most severe disease that attacks on leaves mainly attacking chickpea, faba bean and field pea and it may lead to total crop failure. The strains of these fungi are spread worldwide and host specific (Davidson *et al*., 2007) The pathogenic fungus starts sexual reproduction on the damaged residue that provides the space for accommodation of ascospores that are airborne and have potential to spread to longer distances. Then these fungi spread themselves within short range through splash borne asexual conidia. This disease damages all the aerial parts of the plant and symbolized by necrotic lesions and drops the yield to drastic limits. The quality of seed is damaged or it may poorly develop affecting seed viability (Davidson *et al*., 2007).

As diseases are key biotic constraints to the production of pulses, significantly limiting yield, it is quite important to conduct disease assessments. Although major diseases of some pulse crops have been on record, periodical surveys and quantification are very important as there is pathogen dynamism due to climate change, farm activities and other fomrs of human interventions in the ecosystems. Thus the main objective of this study was to make assessments and quantification of pulse diseses in different Zones and districts of Western Oromia.

Materials and Methods

Description of the study area

The Field survey was conducted in parts of Western Oromia i.e West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedele Zones during 2019 and 2020 main cropping season. The disease assessment survey was conducted in two districts of West Shoa Zone Chalia and Ilu Galan Districts; in one district of Horro Guduru Wollega Zone-Horro District; in two districts of East Wollega Zone namely Gida Ayana and Jima Arjo Districts and Chewaka District of Buno Bedelle Zone (Table 1). The annual mean minimum and maximum temperature of the area is 12^0C and 27.4^0C, respectively, while the annual rainfall is 1415.2 mm. The the surveyed areas are geographically located in a range of latitude and longitude of $08^0$34.70'- $09^0$40.41'N and $036^0$06.47'- $037^0$29.30'E, respectively.

Field survey

Field survey was conducted in six districts of four zones to assess diseases of pulses and oil crops. The six districts lie in lowland, midland and highland agro-ecologies. The study area lies in altitude range of 1219-2788 m.a.s.l in four Administrative Zones (Table 1). The disease Survey was conducted to assess the prevalence, incidence and severity of major pulse and oil crops (faba bean, field pea, soybean, sesame and ground nut). In most of the areas, the survey was conducted after dough to maturity growth stages of crops. The survey was conducted from 20^{th} to 27^{th} September for low land, from 16^{th} to 23^{rd} October for mid land and $1^{st}$to 8^{th} November 2019 and 2020.

In this area most farms are covered by faba bean followed by field pea, soybean and oil crops. The survey was conducted in 41 Kebeles and 90 fields in the five districts of the four Zones. Purposive sampling technique was applied for Zones and Districts. Kebeles were randomly selected from each district and based on the representativeness of pulse and oil seeds production of the area. As a result, crops were assessed as follows: faba bean 31 samples, field pea 19 samples, soybean 20 samples, sesame 12 samples and groundnut 8 samples (Table 1). Any two sonsecutive locations forsimilar sample or crop were at least 4-6 km apart depending on the topography and the relative importance of theparticular crop within each location. The disease assessment was made along the two diagonals (in an "X" pattern) of the field from five points using 1m × 1m (1 m^2) quadrates with their GPS and soil types recorded.

Farmers were interviewd using pre-developed questionarrie to collect information onmanagement practices, variety sown,preceeding crop, planting date (sowing), weed management, fertilizer type and rate, fungicide used and therir general perception of crop diseases. In each field, plants within the quadrates were counted and recorded as healty and diseased.

Table 1: Characteristic features of surveyed pulse and oil seed fields in four Zones, Western Oromia

Zones	Districts	Crops	Altitude (m.a.s.l)*	No. field assessed
West Shoa	Chalia	Faba bean	2435-2614	9
		Field Pea	2464-2619	8
	Ilu Galan	Soybean	1704-2615	7
		Mean	1704-2619	24
Horro Guduru Wollega	Horro	Faba bean	2377-2788	13
		Field Pea	2370-2717	11
		Mean	2370-2788	24
East Wollega	Jima Arjo	Faba bean	2347-2476	9
	Gida Ayana	Soybean	1345-2451	6
		Groundnut	1350-1469	8
		Mean	1350-2476	23
Buno Badalle	Chawaka	Sesame	1219-1270	12
		Soybean	1222-1250	7
		Mean	1219-1270	19
		Over all mean	1219-2788	90

*m.a.s.l= meters above sea level

Disease scoring

Visual identification of the disease was used on all visited fields. The assessment was done for disease prevalence, incidence and severity for each crop.

Disease Prevalence was calculated using the formula:

$$\text{Disease prevalence (\%)} = \frac{\text{Number of locations showing plant disease}}{\text{Total number of location or fields}} \times 100$$

Disease Incidence

Disease incidence was determined in each field on the basis of visual symptoms and by counting the number of symptomatic or infected plants in a sample of total plants. An overall disease incidence value was obtained by averaging the incidence among all the fields (including disease free fields). Disease incidence was calculated using the forumula:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of Diseased plants in the quardateor field}}{\text{Total number of plant in the quardate or field}} \times 100$$

Disease Severity was calculated using the formula:

$$\text{Disease Severity (\%)} = \frac{\text{Area of plants tisseu affected}}{\text{Total number of plants affected}} \times 100$$

Data analysis

Data was analyzed using SPSS. Analysis was conducted by disaggregating important relevant information by district and region so that comparison could be made.

Results and Discussion

Faba bean Diseases

A total of 31 faba bean fields were surveyed across three districts during 2019 and 2020 cropping season to document the occurrence of faba bean diseases.Chocolate spot (*Botrytis fabae* S.), Ascochyta blight (*Ascochyta fabae*), Rust (*Uromyces fabae*), and Gall (*Olpidium species*) were the major diseases recorded in the three districts i.e Horro, Jimma Arjo and Chalia (Table 2).

The prevalence and incidence level of chocolate spot disease was found to be 100% in all the three districts while its severity ranged from 35.4% to 54%. Likewise, the prevalence and incidence of Ascochyta blight was 100% in Jimma Arjo and Horro districts while prevalence and incidence of Ascochyta blight were 80% and 90%, respectively in Chalia district. Ascochyta blight severity generally ranged from 30% to 47% in the three districts. Faba bean rust prevalence, incidence and severity were generally found to be lower as compared to the other two diseases but were quite high in Jimma Arjo (Table 2). Faba bean gall disease was observed in Horro district with 37.5%, 40% and 22.3% of prevalence, incidence and severity levels, respectively.

Field pea disease

Major diseases of field pea recorded during this survey are indicated in Table 2 along with their prevalence, incidence and severity values scored. Powdery mildew (*Erysiphe pisi* var.), down mildew (*Peronospora viciae*), Septoria blotch (*Septoria pisi*) and Ascochyta blight (*Ascochyta mycosphaerella*) were the major diseases recorded.

Powdry mildew was 100% prevalent in both districts- Chalia and Horro surveyed for field pea diseases where as its mean incidence was 100% and 89.17%, respectively. The correspondeing severity level was 46% and 34% in that order. Downy mildew mean prevalence was 66% and 50% for Chalia and Horro districts, respectively where as mean incidence level of the disease in the two districts was 80% and 100% in that order. The mean severity level rather appeared to be lower – 30% for Chalia and 11% for Horro districts. Ascochyta blight mean prevalence level was 90% and 72% in Chalia and Horro districts, respectively; its incidence level was 86% and 60% where as the severity was 42% and 32% in that order. Septoria blotch of field pea was 100% prevalent in both surveyed districts while its incidence level was 75% and 76.17% for Chalia and Horro districts, respectively; the severity level appeared to be lower – 38% and 24.83% in that order.

Table 2: Prevalence, Incidence and Severity Index of Faba bean and field pea diseases

Zones	Districts	types of crops assessed	types of disease	Prevalence%	Incidence %	Severity %
West Shoa	Chalia	faba bean	Chocolate spot	100	100	54
			Ascochyta blight	80	92	47
			Rust	27	38	26
		Field pea	powdery mildew	100	100	46
			down mildew	66	80	30
			Septora blotch	100	75	38
			Ascochyta blight	90	86	42
Horro Guduru Wollega	Horro	faba bean	Chocolate spot	100	100	45
			Ascochyta blight	100	100	34
			Rust	62.5	43.63	11.2
			Gall	37.5	40	22.3
		Field pea	powdery mildew	100	89.17	34
			down mildew	50	100	11
			Septora blotch	100	76.17	24.83
			Ascochyta blight	72	60	32
East Wollega	Jima Arjo	faba bean	Chocolate spot	100	100	35.4
			Ascochyta blight	100	100	30
			rust	80	75	41.4

Soybean Diseases

Soybean (*Glycine max L. Merr*) disease prevalence, incidence and severitysurveyed on 20 farms in three districts is presented in Table 3. Frogeye leaf spot (*Cercospora sojina*), bacterial pustule (*Xanthomonas axonopodis* pv. *glycines*), brown spot (*Septoria glycines*) and cecospora leaf blight (*Cercospora kikuchii.*) were the major diseases recored in the three districts – Ilu Galan, Gidda Ayana and Chawaka surveyed for soybean.

Frogeye leaf spot and bacterial pustule diseases of soybean were 100% prevalent in all the three districts. The incidence of both diseases was also 100% in Ilu Galan district; the incidence of forage leaf spot and bacterial pustule were 100% and 67% , respectively in Gidda Ayana where as it was 86.5% and 100% in and chawaka ditrict in that order. The severity of both diseases appeared to show little variation across the districts. Brown spot and cercospora leaf blight of soybean occurred only in Ilu Galan district with lower severity level.

Groundnut Diseases

Ground nut (*Arachis hypogeaL.*) diseases were assessed in Gida Ayana district on nine farms. The results of disease assessment are shown in Table 3. Four major diseases were recored: early leaf spot (*Cercospora arachidicola*), late leaf spot (*Cercosporidium personatum*), irregular leaf spot and leaf scroch. Early leaf spot and irregular leaf spot both had high mean prevalence and incidence but lower severity level. On the other hand late leaf spot and leaf scrotch both appered to have mean lower prevalence and severity. However incidence of late blitht was high.

Sesame Diseases

Sesame (*Sesamum indicum L.*) diseases were assessed in Chawaka district on 12 farms. The results of disease assessment are shown in Table 3. Two major diseases were recored: bacterial blight (*Xanthomonas campestris* pv. Sesame*)* and bacterial leaf spot (*Pseudomonas syringae pv. Sesame*) with high and nearly equal level of disease prevalence and incidence. Severity was 45.43% and 32% for bacterial blight and bacterial leaf spot, respectively.

Table 3: Percentage of Prevalence, Incidence and Severity Index of soybean, ground nut and sesames diseases

Zones	Districts	types of crops assessed	types of disease	Prevalence%	Incidence %	Severity %
West Shoa	Ilu Galan	Soybean	Frogeye leaf spot	100	100	46
			Bacterial pustule	100	100	43
			Brown spot	60	50	25
			Cecospora leaf blight	60	55	23
East Wollega	Gida Ayana	Soybean	Frogeye leaf spot	100	100	56
			Bacterial pustule	100	67	40.6
		Groundnut	Early leaf spot	85.71	83.33	47
			late leaf spot	14.29	100	30
			Irregular leaf spot	84	50.67	39
			Leaf scroch	28.57	43	41
Buno Bedelle	Chawaka	Soybean	Frogeye leaf spot	100	86.5	44.5
			Bacterial pustule	100	100	47
		Sesame	Bacterial blight	100	100	45.43
			Bacterial leaf Spot	100	89	32

Conclusion

In the current study, a total of 83 pulse and oil seeds fields were assessed and different diseaseswere identified. The importance of each disease was determined by calculating the prevalance, incidence and severity values. Major pulse and oil seeds; Faba bean, Field pea, Soybean, Sesame and Groundnut fields were assessed and different diseases were identified. From faba bean fields, Chocolate spot, Ascochyta blight, Rust and Galldiseasewere recorded and quantified.From field pea fields' powdery mildew, down mildew, Septora blotch and Ascochyta blight diseases were assessed and quantified. Diseases of soybean observed in the current study include Frogeye leaf spot, Bacterial pustule, Brown spot and Cecospora leaf blight.From sesame fields; Bacterial blight and Bacterial leaf spotdisease were assessed and quantified. From groundnut fields; early leaf spot, late leaf spot, Irregular leaf spot and Leaf scorchdiseases were assessed and quantified.

The current field survey has enabled to identify major diseases of faba bean, field pea, soybean, ground nut and sesame crops in selected districts. In the future other districts that offer high potential for a particular crop but which was not addressed through this study need to be assessed to get complete information on the particular crop-disease combinations. Moreover, yeield loss assessments should be conducted for those crop-disease combinations that lack this information in order to further categorize diseases into economically important and less important in an effort to enhance proritzation of future research work.

References

Atnaf, M., Tesfaye, K., & Dagne, K. (2015). The importance of legumes in the Ethiopian farming system and overall economy: An overview. American Journal of Experimental Agriculture, 7(6), 347–358. doi:10.9734/ AJEA/2015/11253

Campbell, C. A. Zentner, R. P., Selles, F., Biederbeck V. O., & Leyshon, A. J. (1992).Comparative effects of grain lentil-wheat and monoculture wheat on crop production, N economy and N fertility in a Brown Chernozem. Canadian Journal of Plant Science, 72(4), 1091-1107. https://doi.org/10.4141/cjps92-135

Davidson JA, Kimber RBE. (2007). Integrated disease management of Ascochyta blight in pulse crops. Eur J Plant Pathol.; 119:99–110.

Degaga, J., & Angasu, B. (2017).Assessment of Indigenous knowledge of smallholder farmers on intercropping practices in West Hararghe Zone; Oromia National Regional State, Ethiopia. Journal of Agricultural Economics and Rural Development, 3(3), 270–278.

IFPRI (International Food Policy Research Institute), 2010. Seed System Potential in Ethiopia: Constraints and Opportunities for Enhancing the Seed Sector.

Monti, L. M. and Grillo, S. 1983. Legume seed improvement for protein content and quality. Qualitas plantarum: plant foods and human nutrition 32: 253-266

WHO (2008). The World Health Organization

Schwenke, G. D., Peoples, M. B., Turner, G. L., & Herridge, D. F. (1998). Does nitrogen fixation of commercial, dryland chickpea and faba bean crops in north-west New South Wales maintain or enhance soil nitrogen? Australian Journal of Experimental Agriculture, 38(1), 61-70. https://doi.org/10.1071/EA97078

Survey of Distribution and Status of Major Cereal Crops Weed in West Shoa, Horro Guduru Wollega And East Wollega Zones, Ethiopia

Abay Guta, Getu Abera and Megersa Kebede
Bako Research center, P. O. box 3, Bako, Shoa, Ethiopia
Corresponding author: abbayg12@gmail.com

Abstract

Field survey was conducted to assess weeds of six major cereals i.e maize, sorghum, wheat, barley, Tef and rice in representative districts of West Showa, Horro Guduru Wollega, East Wollega and Buno Bedelle Zones of Western Oromia. Key parameters such as density, frequency, relative frequency and similarity index have been analysed for each crop. Generally, for most crops and districts, annual broad leaf weeds dominated over grass and sedge type of weeds. The most dominant family that contained the highest number of weed species for all crops and fields asseassed was Poaceace followed by Asteracae and Commelinaceae families. In most cases weeds of a crop were similar across the various districts as indicated by similarty index.The frequency of individual weed species in maize, sorghum, wheat, barley, tef and rice fields ranged from 2.56% up to 69.23%, 0.13% up to 100%, 9.09% up to 54.55%, 18% up to 66.67%, 8.33% up to 50% and 11.25% up to 100%, respectively while the dominance value ranged from 0.3% up to 28%, 0.13% up to 26.63%, 0.09% up to 4.18%, 0.08% up to 3.58% and 0.11% up to 26.33%, in that order. The most frequent and dominant weedswereAgratum conyzoides and Guizotia scarabfor maize and sorghum; Oplismenus compositus *and Guizotia scaraba for wheat; Guizotia scarab and* Galisoga *parviflora for Barley; Phalaris paradoxa and* Oplismenus compositus*for Tef and Agratum conyzoides and* Commelina benghalensis *for rice crop.*

Keywords: Family, Distribution, Status, major Cereals, Weed

Introduction

Weed is the most underestimated pest in tropical agriculture, but influencing human activities more than other crop pests contributing towards lowering the harvestable yields (Akobundu, 1987). The distribution and density of weeds in an arable field is the result of ecological reactions to previous management practices, soil characteristics of the site and the regional climate (Froud-Williams et al., 1983; Andersson and Milberg, 1998). Weeds not only reduce the crop yield, but also deteriorate the quality offarm produce that trim down the market value of the grain.

The low acreage and yield are attributed to diverse and complex abiotic, and biotic factors, of which weeds often pose a serious problem. Weeds have a direct influence on the affairs of humans more than any other pest in developing countries, like Ethiopia. They not only cause severe crop losses but also compel farmers and their families to spend a considerable proportion of their time for weeding, limiting further development in other areas of the rural economy. The weed flora of Ethiopia is highly diverse and it is composed of a wide range of perennial and annual grasses and broadleaved weeds, sedges, parasitic and invasive weed species (Fasil, 2006).

Weeds compete with cultivated food crops for limited resources such as water, nutrients, space and light (Akobundu, 1987:Adesina*et al*., 2015:Adesina*et al*., 2016). Weeds infestation also encourage disease problems, serve as alternate host for deleterious insects and diseases, slow down harvesting operation, increase the cost of production, reduce the market value of crops and increase the riskof fire in perennial crops, plantation and forest reserves (Tena *et al*., 2012).

Although most farmers are less concerned about the negative impact that weeds impose on their crop, study results indicate that weeds share up to 45% of the total annual losses of agricultural products (Belachew and Tessema, 2015). Weed flora composition is strongly associated with regional climate, soil characteristics, and management methods. Previously some studies have been conducted on weed flora and their distribution in Ethiopia (Hedberg *et al*., 2004; Ermias, 2011), in Eastern Harerge (Tamado and Milberg, 2000), in mid-rift valley of Ethiopia and in Southwestern Ethiopia.

However, surveys are commonly used to characterize weed populations in cropping systems (Uddin *et al*., 2010). Therefore, to develop an effective weed management program, a detailed survey is necessary to address the current weed problems in the field. In addition, survey information is entirely important in building target oriented research programs. Hence, this study was undertaken to determine the relative occurrence, distribution and status of major cereal weeds across study area.

Materials and Methods

Description of Study Area

The weed survey was conducted in West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedelle Zones of Oromia Reginal state during 2019 and 2020 main cropping season starting mid-August to early September and endof-September to mid-October. Weed Survey was conducted to assess abundance, dominance andfrequency of major cereal crops' weeds. The annual mean minimum and maximum temperature of the the study area is 12^{0}C and 27.4^{0}C, respectively, while the annual rainfall is 1415.2 mm. The surveyed areas are located in latitude and longituderange of 08^{0}55'10.89"- 09^{0}05'13.13"N and 36^{0}44'29.08"- 037^{0}60'22.73"E, respectively.

Table 1: Characteristic features of surveyed Cereal field in four Zones with their altitude, in Western Oromia

Zone	Districts	Crops	Altitude (m.a.s.l)	No. field assessed
West Shoa	Ilu Galan	Maize	1711-1874	9
		Tef	1743-1868	3
	Chalia	Wheat	2485-2630	7
		Barley	2435-2632	6
		Tef	2421-2498	3
		Mean	1711-2632	28
H/G/Wollega	Guduru	Maize	2286-2396	9
		Wheat	2315-2446	8
		Barley	2292-2349	7
	Horro	Wheat	2451-2757	8
		Barley	2350-2751	6
		Tef	2415-2727	5
		Mean	2286-2757	43
East Wollega	Gida Ayyana	Maize	1290-2469	9
	Guto Gida	Maize	1333-1379	7
	Sibu Sire	Maize	1744-1841	7
	Jima Arjo	Maize	2170-2345	6
	Diga	Sorghum	2113-2286	6
		Mean	1290-2469	35
Buno Bedelle	Chawaka	Maize	1231-1291	8
		Sorghum	1204-1256	8
		Rice	1202-1265	10
		Mean	1202-1265	26
		Over all of mean	1202-2757	132

m.a.s.l.= meters above sea level

Field survey

The survey was conducted in 57 Kebeles and 132 fields in the ten districts of the four zones. Purposive sampling technique was applied to select Districts. Kebeles were randomly selected from each district and based on the representativeness of cereal production of the area. About 55samples of Maize, 14 samples of Sorghum, 23 samples of Wheat, 19 samples of Barley, 11 samples of Tef and 10 samples of Rice were examined (Table 1). Consecutive sample sites for the same crop were 4-6 km apart depending on the topography and the relative importance of the crop within each location. Weed assessment was made along the two diagonals (in an "X" pattern) of the field from five points using 1m × 1m (1 m^2) for small cereals and 2m × 2m (4m^2) quadratesfor maize and sorghum.

Frequency (F), Abundance (A), Dominancy (D) and Similarity Index (SI)were computed for each species of weedsusing the method of Thomas (1985). The collected weed data were combined and summarized. In each field, weeds specie and their numbers within the quadrates were counted and recorded.

Farmers were interviewd using pre-structured questinarriesto record information on farmers' practices such as management practices, variety/ies grown, preceeding crop, planting date,seed rate, fertilizer type and rate, disease type observed and herbicides use.

Data Analyses

Density, Relative density, Frequency, Relative frequency and Similarity index were calculated by the following formula. The collected weed data were compined and summarized using SPSS software.

Density (D) $= \frac{Total\ number\ of\ individuals\ of\ a\ species\ in\ all\ quadrate}{\text{Total number of quadrates used}}$

Frequency (F) = $\frac{\boldsymbol{Number\ of\ quadrates\ in\ which\ a\ given\ species\ occurs}}{\text{Total number of quadrates used}}$

Relative Density (RD) =$\frac{\text{Density of a given species}}{\text{Total density for all species}} \times 100\%$

Relative Frequency (RF) = $\frac{\text{Frequency of a given species}}{\text{Total frequency for all specie}} \times 100\%$

Similarity Index (SI) = 100 × Epg/ (Epg + Epa + Epb)

Where; SI = Similarity index, Epg = number of species found in both locations, Epa = number of species found only in location I. Epb = number of species found only in locations II

Result And Discussion

Maize Weeds

Diversity of weeds in maize fields

Fifty two species of weed, belonging to 17 familes were identified in maize fields. The greater majority of weeds (45 species) were annuals where as seven were found to be pernnials. Sixteen weed species belonged to the family *Poaceace*; 10 species belong to *Asteracae* and four species belonged to *Commelinaceae* families (Tables 2 and 3). Hence these three families accounted for 57.69% of the total weed species recoreded in maize fields in the current study. This could be perhaps due to their adapatablity to a wide range of environmental conditions and soil types. These families - *Poaceace, Asteraceae and Commelinaceae*have been reported to be important in the tropics.

Table 2: Number of weed families identified and number of species they comprise in maize fields.

Family	No of species	Families	No of species
Poaceace	16	*Convolvulaceae*	1
Asteraceae	10	*Euphorbiaceae*	1
Commelinaceae	4	*Lamiaceae*	1
Cyperaceae	3	*Leguminosae*	1
Amaranthaceae	4	*Oxalidaceae*	1
Polygonaceae	3	*Phyllanthaceae*	1
Solanaceae	2	*plantaginaceae*	1
Capparidaceae	1	*Rubiaceae*	1
Caryophyllaceae	1	-	-
Total			52

Weed Flora of Maize Fields

The result of assessments showed that, broad leaf weeds dominate over grass and sedge weed species (Table 3). Thirty- three weed species (63.46%) were broad- leafed;16 weed speceies (30.77%) were grass types and the remaining three (5.77%) were found to be sedge types. The frequency of occurrence of individual weed species ranged from 2.56%-69.23% (Table 3).Dominant weeds were those species which occurred in relatively greater number than the other species. Eleven weed species *i.eAgratum conyzoides*, *Bidens pachyloma* (Oliv. & Hiern.),*Commelina benghalensis* L., *Cynodon dactylon* (L.), *Digitaria ternata* (A.Rich.),*Eleusine indica* (L.), *Galinsoga parviflora*,*Kyllinga nemoralis* (L.),*Guizotia scarba* (Vis), *Leucas cephalotes* (Roth) and *Nicandra physalodes* (L.) were widely distributed with higher than 30% frequency while 22 weed species had lower than 10% frequency value. The species that had the highest frequency of 69.23% was *Ageratum conyzoides* followed by frequency of 61.54% and 58.97% for *Guizotia scarba (Vis) Chiov* and *Eleusina indica*, respectively.

Weed Similarity Index

Similarity index (community index) is the similarity of plant species composition among different districts. The weed flora similarity index of Sibu Sire, Guto Gida, Gida Ayyana, Jima Arjo, Chawaka, Ilu Galana and Guduru Districts were above 60% which means 62%-83% similar weed management method can be used to control while weed species composition was mainly dissimilar between Chawaka and Jima Arjo; between Chewaka and Ilu Galan; Chewaka and Guduru Districts with similarity index of 51%, 57% and 53%, respectively.This might be because of the variation in soil, climatic and farm practices among these locations. Similarly, Chhokar and Malik (2002); Anderson and Beck (2007) and Dixit *et al*. (2008a&b) reported that weed flora of crop differs from area to area and field to field depending on environmental conditions, irrigation, fertilizer use, soil type, weed control practices and cropping sequences.

Table 3: Description of Density, Frequency, Relative Densty, and Relative Frequency of weed in maize fileds.

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Achyranthes aspera	*Amaranthaceae*	Broad leaf	Annual	0.51	17.95	0.80	1.88
Ageratum conyzoides	*Asteraceae*	Broad leaf	Annual	*13.14*	69.23	20.62	7.26
Anagalis arvense	*Commelinaceae*	Broad leaf	Annual	0.21	10.26	0.33	1.08
Andropogon abyssinicus	*Poaceace*	Grass	Annual	0.05	2.56	0.08	0.27
Bidens pachyloma	*Asteraceae*	broad leaf	Annual	*1.54*	33.33	2.42	3.50
Bidens pilosa	*Asteraceae*	broad leaf	Annual	*0.49*	20.51	0.77	2.15
Celosia trigyna	*Amaranthaceae*	Broad leaf	Annual	0.26	17.95	0.41	1.88
Cersium arvense.	*Asteraceae*	broad leaf	Perennial	0.08	2.56	0.13	0.27
Chenopodium album	*Amaranthaceae*	broad leaf	Annual	0.08	5.13	0.13	0.54
Chrysocephalum semipapposum	*Amaranthaceae*	broad leaf	Annual	0.08	5.13	0.13	0.54
Cleome viscosa	*Capparidaceae*	broad leaf	Annual	0.03	2.56	0.05	0.27
Commelina benghalensis	*Commelinaceae*	Broad leaf	Annual	*2.33*	48.72	3.66	5.11
Commelina subulata	*Commelinaceae*	Broad leaf	Annual	0.54	15.38	0.85	1.61
Cyanotis cristata	*Commelinaceae*	Broad leaf	Annual	0.62	23.08	0.97	2.42
Cynodon dactylon	*Poaceace*	Grass	Perennial	*1.87*	33.33	2.94	3.50
Cyperus esculenta	*Cyperaceae*	Sedge	Perennial	0.05	5.13	0.08	0.54
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	0.26	7.69	0.41	0.81
Datura stramonium	*Solanaceae*	broad leaf	Annual	0.03	2.56	0.05	0.27
Digitaria abvssinica	*Poaceace*	Grass	Annual	0.56	10.26	0.88	1.08
Digitaria ischaemum	*Poaceace*	Grass	Annual	*0.31*	15.38	0.49	1.61
Digitaria ternata	*Poaceace*	Grass	Annual	*0.59*	30.77	0.93	3.23
Dinebra retroflexa	*Poaceace*	Grass	Annual	0.03	2.56	0.05	0.27
Eleusine indica	*Poaceace*	Grass	Annual	*1.72*	58.97	2.70	6.19
Eraqrostis cilianensis	*Poaceace*	Grass	Annual	0.08	2.56	0.13	0.27
Euphorbia hirta	*Euphorbiaceae*	broad leaf	Annual	*0.05*	5.13	0.08	0.54
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	*5.66*	53.85	8.88	5.65
Galium aparine	*Rubiaceae*	broad leaf	Annual	0.21	2.56	0.33	0.27
Gnaphalium purpureum	*Asteraceae*	Broad leaf	Annual	0.05	5.13	0.08	0.54
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	*4.03*	61.54	6.33	6.46
Ipomea lacunosa	*Convolvulaceae*	broad leaf	Perennial	13	7.69	10.40	4.30
Kyllinga nemoralis	*Cyperaceae*	sedge	Perennial	2.28	53.85	3.58	5.65
Leucas cephalotes	*Lamiaceae*	broad leaf	Annual	*0.69*	30.77	1.08	3.23
Medicago polymorpha	*Poaceace*	Grass	Annual	0.05	2.56	0.08	0.27
Nicandra physalodes	*Solanaceae*	Broad leaf	Annual	*0.69*	35.90	1.08	3.77
Oplismenus compositus	*Poaceace*	Grass	Annual	3.21	28.21	5.04	2.96
Oplismenus hirtellus	*Poaceace*	Grass	Annual	*1.1*	25.64	1.73	2.69
Oxlis martiana Zucc.	*Oxalidaceae*	Broad leaf	Annual	*0.03*	2.56	0.05	0.27
Oxygonum sinuatum	*Polygonaceae*	Broad leaf	Annual	0.05	5.13	0.08	0.54
Penisitum polystachian	*Poaceace*	Grass	Annual	0.13	5.13	0.20	0.54
Phalaris paradoxa	*Poaceace*	Grass	Annual	0.36	12.82	0.57	1.35
Plantago lanceolata	*plantaginaceae*	Broad leaf	Annual	0.62	15.38	0.97	1.61
Polygnom nepalens	*Polygonaceae*	Broad leaf	Annual	0.64	12.82	1.00	1.35
Polygnom nepalensi.	*Polygonaceae*	Broad leaf	Annual	0.72	15.38	1.13	1.61
Rhyllanthus niruri	*Phyllanthaceae*	broad leaf	Perennial	1	28.21	1.57	2.96

Setaria faberi	*Poaceace*	Grass	Annual	0.18	10.26	0.28	1.08
Setaria pumila	*Poaceace*	Grass	Annual	0.28	17.95	0.44	1.88
Snowdenia polystachya	*Poaceace*	Grass	Annual	1.28	23.08	2.01	2.42
Sonchus asper	*Asteraceae*	Broad leaf	Annual	0.1	2.56	0.16	0.27
Spergula Avensis	*Caryophyllaceae*	Broad leaf	Annual	0.59	2.56	0.93	0.27
Spilanthes mauritiana	*Asteraceae*	Broad leaf	Annual	0.1	2.56	0.16	0.27
Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	0.41	17.95	0.64	1.88
Xanxhium strumarium	*Asteraceae*	Broad leaf	Annual	0.18	5.13	0.28	0.54
Others				0.56	17.95	0.88	1.88

Table 4: Characteristic feature of similarity index of weed species compositionin in maize fields.

Districts (%)	Sibu Sire	Guto Gida	Gida Ayyan	Jima Arjo	Chawaka	Ilu Galan	Guduru
Sibu Sire	100	83	69	77	82	74	70
Guto Gida		100	72	67	64	71	73
Gida Ayyana			100	68	71	68	61
Jima Arjo				100	51	64	75
Chewaka					100	57	53
Ilu Galan						100	62
Guduru							100

Sorghum weeds

Diversity of weeds

In the surveyed sorghum fields, 26 weed species that belonged to nine familes were recorded of which 24 species were annuals and two were found to be perennials. About 57.69% of the species were broad leafed; 38.46% were grass types and 3.85% were sedge types. Ten species of the weeds belonged to family *Poaceae*; six species belonged to family *Asteraceae* and four weed species belonged to *commelinaceae* family (Table 5). This means that 76.63% of the weed species recorded in sorghum fields belonged to the three families: *Poaceae*, *Asteraceae* and *Commelinaceae*.

Weed flora of sorghum fields

The frequency of occurrence of individual weed species ranged from 0.13%-100% (Table 6).Dominant weeds were those species which occurred in relatively greater number than the other species. Nine of the weed species recorded in sorghum fields i.e*Agratum conyzoides*, *Bidens plosa*, *Commelina subulata* Rott.,*Commelina benghalensis* L., *Digitaria ischaemum (Schreb.)*, *Digitaria ternata* (A.Rich.), *Galinsoga parviflora*, *Oplismenus compositus* and *Stellaria media (L.) Vill.* were widely distributed with higher than 30% frequency while 12 weed species haveless than 15% frequency value. The species that had the highest frequency 100% was *Agratum conyzoides* followed by*Digitaria ternate*,*Digitaria ischaemum (Schreb.)* and *Stellaria media.*

Table 5: Number of weed families identified and number of species they comprise in sorghum fields.

Family	No of Species	Family	No of Species
Poaceae	10	*Cyperaceae*	1
Asteraceae	6	*Lamiaceae*	1
Commelinaceae	4	*plantaginaceae*	1
Amaranthaceae	1	*Solanaceae*	1
Caryophyllaceae	1	-	
Total			26

Weed Similarity Index

Similarity index (community index) is the similarity of plant species composition among different districts.The survey result showed that similarity index value between Diga and Chawaka Districts was 64% which mean greater than 60% (Table 7); it can be conculuded that the locations exhibited similar weed community and thus require similar management options.

Table 6: Description of Density, Frequency, Relative Density, and Relative Frequency of of weed in sorghum fields.

Botanical name	Family	Category	Life cycle	Density	Frequencey	Relative density	Relative Frequency
Achyranthes aspera	*Amaranthaceae*	Broad leaf	Annual	0.75	25.00	1.17	3.03
Agratum conyzoides	*Asteraceae*	Broad leaf	Annual	24.63	100.00	38.36	12.12
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	0.75	12.50	1.17	1.52
Bidens pachyloma	*Asteraceae*	broad leaf	Annual	4.38	25.00	6.82	3.03
Bidens plosa	*Asteraceae*	broad leaf	Annual	3.50	50.00	5.45	6.06
Commelina subulata.	*Commelinaceae*	Broad leaf	Annual	3.00	37.50	4.67	4.55
Commonina Bangilansis	*Commelinaceae*	Broad leaf	Annual	1.88	50.00	2.92	6.06
Cynodon dactylon	*Poaceace*	Grass	Perennial	0.50	12.50	0.78	1.52
Cyanotis cristata	*Commelinaceae*	Broad leaf	Annual	0.13	12.50	0.19	1.52
Digitaria ternata	*Poaceace*	Grass	Annual	0.13	0.13	0.20	1.52
Digitaria ischaemum	*Poaceace*	Grass	Annual	2.88	62.50	4.48	7.58
Digitaria ternata	*Poaceace*	Grass	Annual	1.75	75.00	2.73	9.09
Eleusina indica	*Poaceace*	Grass	Annual	2.25	12.50	3.51	1.52
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	1.44	37.50	2.24	4.55
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	0.13	12.50	0.19	1.52
Kyllinga nemoralis	*Cyperaceae*	sedge	Perennial	0.13	0.13	0.20	1.52
Leucas cephalotes	*Lamiaceae*	broad leaf	Annual	0.50	0.13	0.75	1.52
Nicandra physalode.	*Solanaceae*	Broad leaf	Annual	0.38	12.50	0.58	1.52
Oplismenus compositus	*Poaceace*	Grass	Annual	4.00	50.00	6.23	6.06
Pennisetum polystachian	*Poaceace*	Grass	Annual	0.38	12.50	0.58	1.52
Plantago lanceolata	*plantaginaceae*	Broad leaf	Annual	0.75	25.00	1.17	3.03

Rottboellia cochinchinensis	*Poaceae*	Grass	Annual	0.38	12.50	0.58	1.52
Setaria pumila	*Poaceace*	Grass	Annual	0.25	12.50	0.39	1.52
Snowdenia polystachya	*Poaceace*	Grass	Annual	1.88	25.00	2.92	3.03
Sonchus asper	*Asteraceae*	Broad leaf	Annual/Bi	1.13	25.00	1.75	3.03
Stellaria media	*Caryophyllaceae*	Broad leaf	Annual	2.50	62.50	3.89	7.58
Others				3.50	37.50	5.45	4.55

Table 7: Characteristic feature similarity index of weed species composition in sorghumfields.

Districts (%)	Diga	Chewaka
Diga	100	64
Chawaka		100

Weeds of wheat

Diversity

Twenty nine weed species that belonged to 10 familes were identified from wheat fields of which 26 species were annuals and three wereperennials. Thirteen species of the weeds identified from wheat fields belonged to family *Poaceace;* four speciesbelonged to family *Asteraceae*;six species belonged to *Caryophyllaceae*,*Commelinaceae* and *Polygonaceae* families, each family containing two species. Family *Poaceae* was, thus the most abundant followed by family Asteraceae (Table 8).

Table 8: Number of weed families identified and number of species they comprise in wheat fields.

Family	No of Species	Family	No of Species
Poaceae	13	*Brassicaceae*	1
Asteraceae	4	*Convolvulaceae*	1
Caryophyllaceae	2	*Cyperaceae*	1
Commelinaceae	2	*Lamiaceae*	1
	2	*Leguminosae*	1
Amaranthaceae	1	-	-
Total			29

Weed flora of wheat fields

The survey result revealed that both broad leaf and grass weeds were quite very important in wheat fields (Table 9). Broad leafed species comprised 48.28%; grass weeds comprised 44.83% and sedge species comprised 6.89% of the total weed species recored in wheat fields.

The frequency of occurrence of individual weed species generally ranged from 9.90%-54.55% (Table 9). Eight species i.e *Avena abyssinicus,Commelina subulata Rott., Galinsoga parviflora, Commelina subulata Rott.,Guizotia scarba (Vis) Chiov, Lolium temulentum, Oplismenus compositus,* and *Spergula avensis* were widely distributed with higher than 30% frequency while 10 weed species were lower than 10% in frequency value; other species lie in between these -highest and lowest values. The species that had the highest frequency 54.55% was *Oplismenus composites* followed by frequency values of 45.45% and 45.45% for*Guizotia scarba* and *Avena abyssinicus*species,respectively.

Table 9: Description of Density, Frequency, Relative Density and Relative Frequency of weeds in wheat fields

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Freqency
Agratum conyzoides	*Asteraceae*	Broad leaf	Annual	2.73	27.27	8.57	3.85
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	0.64	18.18	2.00	2.56
Andropogon abyssinicus	*Poaceace*	Grass	Annual	0.45	9.09	1.43	1.28
Avena abyssinicus	*Poaceace*	Grass	Annual	4.18	45.45	13.14	6.41
Avena fatua	*Poaceace*	Grass	Annual	0.45	18.18	1.43	2.56
Bidens plosa	*Asteraceae*	broad leaf	Annual	0.36	27.27	1.14	3.85
Celosia trigyna	*Amaranthaceae*	Broad leaf	Annual	0.09	18.18	0.29	2.56
Commelina subulata	*Commelinaceae*	Broad leaf	Annual	0.18	36.36	0.57	5.13
Convolvulus arvensis	*Convolvulaceae*	Sedge	Perennial	0.27	9.09	0.86	1.28
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	0.27	18.18	0.86	2.56
Digitaria abvssinica	*Poaceace*	Grass	Annual	2.45	27.27	7.71	3.85
Digitaria ternata	*Poaceace*	Grass	Annual	0.27	9.09	0.86	1.28
Dinebra retroflexa	*Poaceace*	Grass	Annual	1.09	27.27	3.43	3.85
Eragrostis celianesis	*Poaceace*	Grass	Perennial	0.64	9.09	2.00	1.28
Eleusina indica	*Poaceace*	Grass	Annual	0.82	18.18	2.57	2.56
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	1.64	36.36	5.14	5.13
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	2.64	45.45	8.29	6.41
Leucas cephalotes	*Lamiaceae*	broad leaf	Annual	0.09	9.09	0.29	1.28
Lolium temulentum	*Poaceae*	Grass	Annual	1.36	36.36	4.29	5.13
Oplismenus compositus	*Poaceace*	Grass	Annual	1.64	54.55	5.14	7.69
Oxygonum sinuatum	*Polygonaceae*	Broad leaf	Annual	0.55	9.09	1.71	1.28
Penisitum polystachian	*Poaceace*	Grass	Annual	2.55	36.36	8.00	5.13
Phalaris paradoxa	*Poaceace*	Grass	Annual	1.09	27.27	3.43	3.85
Polygonum nepalense	*Polygonaceae*	Broad leaf	Annual	0.27	9.09	0.86	1.28
Raphanus raphanistrium	*Brassicaceae*	Broad leaf	Annual	0.55	9.09	1.71	1.28
Setaria pumila	*Poaceace*	Grass	Annual	1.73	27.27	5.43	3.85
Spergula Avensis	*Caryophyllaceae*	Broad leaf	Annual	0.18	36.36	0.57	5.13
Stellaria media	*Caryophyllaceae*	Broad leaf	Annual	0.36	9.09	1.14	1.28
Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	0.27	9.09	0.86	1.28
Others				2.27	45.45	7.14	6.41

Weed Similarity Index

The weed flora similarity index of Chalia, Guduru and Horro Districts were above 60% which means 74%-90% that similar weed management method can be used to control weed species composition (Table 10). Similarly, Chhokar and Malik (2002); Anderson and Beck (2007) and Dixit *et al*. (2008a&b) reported that weed flora of crop differs from area to area and field to field depending on environmental conditions, irrigation, fertilizer use, soil type, weed control practices and cropping sequences.

Table 10: Characteristic feature similarity index of weed species composition in wheat fields.

Districts	Chalia	Guduru	Horro
Chalia	100	74	82
Guduru		100	90
Horro			100

Barley weeds

Diversity of weeds

Thirty two weed species that belonged to 11 familes were identified from barley fields; 30 species were annuals and twoof them were perennials. Fourteen species belonged to family Poaceae; six species belonged to Asteraceae and Commelinaceae families, each family containing three species and eight species belonged to four families – Brassicaceae, Caryophyllaceae, Cyperaceae and polygonaceae, each family contining two species (Table 11).

Table 11: Number of weed families identified and number of species they comprise in barley fields

Families	No of species	Families	No of species
Poaceae	14	*Polygonaceae*	2
Asteraceae	3	*Amaranthaceae*	1
Commelinaceae	3	*Leguminosae*	1
Brassicaceae	2	*plantaginaceae*	1
Caryophyllaceae	2	*Rubiaceae*	1
Cyperaceae	2		
Total			32

Weed flora of barley fields

The study result revealed that broad leaf weeds were slightly dominant over grass weeds –broad leaf weeds, grass weeds and sedges comprised 50%, 43.75% and 6.25% of the weed species, respectively. The frequency of occurrence of individual weed species ranged from 0.18%- 66.67 % (Table 12).Nine species i.e*Guizotia scarba (Vis) Chiov,Galisoga parviflora, Commelina benghalensis L., Plantago lanceolate,Spergula avensis,Digitaria abvssinica (A. Rich.), Anagallis arvensis, Oplismenus compositus and Raphanus raphanistrium L.* were widely distributed with higher than 30% frequency while 12 weed species had lower than 10% frequency value. The species that had the highest frequency of 66.67% was *Guizotia scarba* followed by 58.33% and 50.0% frequency values for *Galisoga parviflora*and *Plantago lanceolate*species.respectively.

Table 12: Description of Density, Frequency, Relative Density and Relative Frequency of weeds in barley fields.

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	1.75	33.33	5.37	4.60
Andropogon abyssinicus	*Poaceace*	Grass	Annual	0.17	8.33	0.51	1.15
Avena abyssinicus	*Poaceace*	Grass	Annual	2.25	25.00	6.91	3.45
Avena fatua	*Poaceace*	Grass	Annual	0.42	16.67	1.28	2.30
Celosia trigyna	*Amaranthaceae*	Broad leaf	Annual	0.33	8.33	1.02	1.15
Commelina benghalensis	*Commelinaceae*	Broad leaf	Annual	0.67	41.67	2.05	5.75
Commelina subulata.	*Commelinaceae*	Broad leaf	Annual	2.50	25.00	7.67	3.45
Cyperus esculenta	*Cyperaceae*	Sedge	Perennial	0.25	16.67	0.77	2.30
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	0.17	8.33	0.51	1.15
Digitaria abvssinica	*Poaceace*	Grass	Annual	1.42	33.33	4.35	4.60
Digitaria ternata	*Poaceace*	Grass	Annual	1.27	0.18	3.44	2.3
Eleusina indica	*Poaceace*	Grass	Annual	0.17	8.33	0.51	1.15
Eraqrostis cilianensis	*Poaceace*	Grass	Annual	0.50	16.67	1.53	2.30
Erucustrium arabicum	*Brassicaceae*	Broad leaf	Annual	0.08	8.33	0.26	1.15
Glebionis segetum	*Asteraceae*	Broad leaf	Annual	1.17	16.67	3.58	2.30
Galisoga parviflora	*Asteraceae*	broad leaf	Annual	2.00	58.33	6.14	8.05
Galium spurium	*Rubiaceae*	broad leaf	Annual	0.58	25.00	1.79	3.45
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	2.83	66.67	8.70	9.20
Lolium temulentum	*Poaceae*	Grass	Annual	0.67	8.33	2.05	1.15
Medicago polymorpha	*Poaceace*	Grass	Annual	0.17	8.33	0.51	1.15
Oplismenus compositus	*Poaceace*	Grass	Annual	1.42	33.33	4.35	4.60
Oxygonum sinuatum	*Polygonaceae*	Broad leaf	Annual	0.58	16.67	1.79	2.30
Penisitum polystachian	*Poaceace*	Grass	Annual	2.50	25.00	7.67	3.45
Phalaris paradoxa	*Poaceace*	Grass	Annual	2.08	25.00	6.39	3.45
Plantago lanceolata	*plantaginaceae*	Broad leaf	Annual	2.33	50.00	7.16	6.90
Polygnom nepalensi.	*Polygonaceae*	Broad leaf	Annual	0.33	8.33	1.02	1.15
Raphanus raphanistrium	*Brassicaceae*	Broad leaf	Annual	2.00	33.33	6.14	4.60
Setaria pumila	*Poaceace*	Grass	Annual	0.58	8.33	1.79	1.15
Snowdenia polystachya	*Poaceace*	Grass	Annual	0.17	8.33	0.51	1.15
Spergula Avensis	*Caryophyllaceae*	Broad leaf	Annual	1.75	41.67	5.37	5.75
Stellaria media	*Caryophyllaceae*	Broad leaf	Annual	0.17	8.33	0.51	1.15

Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	0.50	16.67	1.53	2.30
Others				2.17	50.00	6.65	6.90

Weed Similarity Index

Similarity index (community index) is the similarity of plant species composition among different districts. The weed flora similarity index of Chalia, Guduru and Horro Districts were above 60% which means 69%-87% that similar weed management mothed can be used to control weed species composition (Table 13).

Table.13 Characteristic feature similarity index of weed species composition inbarley fields.

Districts	Chalia	Guduru	Horro
Chalia	100	69	87
Guduru		100	85
Horro			100

Tef Weeds

Diversity of Weeds

Resulsts of the study revealed that 29 species of weed that belonged to 12 families were recorded from tef fields of which 27 species were annuals and the remaining twowere perennials. About 11 species belonged to family of*Poaceace;* six species belonged to*Asteraceae*and*Commelinaceae* families, each family containing three species; six species belonged to *Brassicaceae*, *Cyperaceae* and *polygonaceae* families, each family containing two species (Table 14). Theerefore, 58.62% of the species belong to the three families – *Poaceace, Asteraceae* and *Commuelinaceae* families.

Table 14: Number of weed families identified and number of species they comprise in tef fields.

Families	No of species	Families	No of species
Poaceace	11	*Amaranthaceae*	1
Asteraceae	3	*Caryophyllaceae*	1
Commelinaceae	3	*Lamiaceae*	1
Brassicaceae	2	*Leguminosae*	1
Cyperaceae	2	*plantaginaceae*	1
Polygonaceae	2	*Rubiaceae*	1
Total			29

Weed flora of Tef fields

Broad leaf weeds dominate over grass and sedge weed species in tef fields (Table 15). Broad leaf, grass and sedge species accounted for 55.17%, 37.93% and 6.90%, respectively. The frequency of occurrence of individual weed species ranged from 8.33- 50.0 % (Table 15). Eleven weed species i.e*Phalaris paradoxa*, *Guizotia scarba* (Vis) Chiov, *Plantago lanceolate*, *Oplismenus compositus*, *Commelina benghalensis*, *Raphanus raphanistrium* L. *Penisitum polystachian*, *Oxygonum sinuatum*, *Cyperus rotudus* L, *Andropogon abyssinicus* and *Galisoga parviflora*, L. were widely distributed with higher than 25% frequencywhile 12 weed species had lower than 10% frequency.The species that had the highest frequency 50.0% was *Phalaris paradoxa*followed by frequency values of 33.33% and 33.33% for *Oplismenus compositus* and *Plantago lanceolate*species.respectively.

Table 15: Description of density, frequency, relative density, and relative frequency of weed in tef fields.

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	1.00	8.33	3.58	1.54
Andropogon abyssinicus	*Poaceace*	Grass	Annual	0.17	25.00	0.60	4.62
Avena Abyssinicus	*Poaceace*	Grass	Annual	0.67	8.33	2.39	1.54
Avena fatua	*Poaceace*	Grass	Annual	0.50	16.67	1.79	3.08
Bidens pachyloma	*Asteraceae*	broad leaf	Annual	1.33	16.67	4.78	3.08
Celosia trigyna	*Amaranthaceae*	Broad leaf	Annual	0.08	8.33	0.30	1.54
Commelina benghalensis	*Commelinaceae*	Broad leaf	Annual	0.67	25.00	2.39	4.62
Commelina subulata.	*Commelinaceae*	Broad leaf	Annual	0.08	8.33	0.30	1.54
Cyperus esculenta	*Cyperaceae*	Sedge	Perennial	0.08	8.33	0.30	1.54
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	2.33	25.00	8.36	4.62
Digitaria ternata	*Poaceace*	Grass	Annual	0.67	16.67	2.39	3.08
Dinebra retroflexa	*Poaceace*	Grass	Annual	1.08	8.33	3.88	1.54
Eleusina indica	*Poaceace*	Grass	Annual	0.83	16.67	2.98	3.08
Erucustrium arabicum	*Brassicaceae*	Broad leaf	Annual	0.08	8.33	0.30	1.54
Galisoga parviflora	*Asteraceae*	broad leaf	Annual	0.83	25.00	2.98	4.62
Galium spurium	*Rubiaceae*	broad leaf	Annual	0.17	8.33	0.60	1.54
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	3.08	33.33	11.04	6.15
Leucas cephalotes	*Lamiaceae*	broad leaf	Annual	0.33	8.33	1.19	1.54
Oplismenus compositus	*Poaceace*	Grass	Annual	2.33	33.33	8.36	6.15
Oxygonum sinuatum	*Polygonaceae*	Broad leaf	Annual	0.92	25.00	3.28	4.62
Penisitum polystachian	*Poaceace*	Grass	Annual	0.58	25.00	2.09	4.62
Phalaris paradoxa	*Poaceace*	Grass	Annual	3.58	50.00	12.83	9.23
Plantago lanceolata	*plantaginaceae*	Broad leaf	Annual	1.50	33.33	5.37	6.15
Polygnom nepalensi.	*Polygonaceae*	Broad leaf	Annual	0.08	8.33	0.30	1.54
Raphanus raphanistrium	*Brassicaceae*	Broad leaf	Annual	1.33	25.00	4.78	4.62
Setaria pumila	*Poaceace*	Grass	Annual	0.25	8.33	0.90	1.54
Snowdenia polystachya	*Poaceace*	Grass	Annual	0.33	8.33	1.19	1.54
Spergula Avensis	*Caryophyllaceae*	Broad leaf	Annual	1.58	16.67	5.67	3.08

Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	0.42	16.67	1.49	3.08
Others				1.17	33.33	4.18	6.15

Weed Similarity Index

Similarity index (community index) is the similarity of plant species composition among different districts. The weed flora similarity index of Chalia, Guduru and Horro Districts were above 60% which means 70%-93% that similar weed management method can be used to control weed species composition (Table 16). This suggests that the weed species composition among the different Districts were similar.

Table 16: Characteristic feature similarity index of weed species composition in Tef fields.

Districts	Ilu Galan	Chalia	Horro
Ilu Galan	100	70	88
Chalia		100	93
Horro			100

Survey of Rice field

Diversity of weeds

Among identified 16 weeds species, 15 species were annuals, and 1of of them was Perennials. Five species belonged to family*Poaceace;* six species belonged to *Asteraceae* and *Commelinaceae* families, each family containing three species. Two species belong to*Amaranthaceae.*

Table 17: Number of weed families identified and number of species they comprise in Rice fields

Families	No of species	Families	No of species
Poaceace	5	*Caryophyllaceae*	1
Asteraceae	3	*Cyperaceae*	1
Commelinaceae	3	*Solanaceae*	1
Amaranthaceae	2	-	-
Total			16

Weed flora of rice fields

The result ofassessments shows that, Broad leaf weeds dominate over grass and sedge weed species (Table 18); 62.5% of the species were broad leaf, 31.25% grass types and 6.25% sedge types.The frequency of occurrence of individual weed species ranged from 11.25%- 100 % (Table 18). Nine weed species i.e*Agratum conyzoides,Stellaria media (L.) Vill.,Oplismenus compositus, Bidens plosa, Digitaria ternata (A.Rich.)Stapf, Digitaria ischaemum (Schreb.), Cyanotis cristata (L.) D. Don., Kyllinga nemoralis L.* and *Sonchus asper* (L.) Hill was widely distributed with higher than 30% frequency. While six weed species had lower than 15% frequency value. The species that had the highest frequency of 100% was *Agratum conyzoides* followed by frequency values of 87.5% and 75% for*Commonina Bangilansi*s and *Stellaria media (L.)*species, respectively.

Table 18: Description of Density, Frequency, Relative Density and Relative Frequency of weeds in Rice fields.

Botanical name	Family	Category	Life cycle	Density	Freq.	Relative density	Relative Freq.
Achyranthes aspera	Amaranthaceae	Broad leaf	Annual	4.89	25	8.45	3.03
Agratum conyzoides	Asteraceae	Broad leaf	Annual	26.33	100	45.50	12.12
Amaranthus spinosus	Amaranthaceae	Broad leaf	Annual	0.22	12.5	0.38	1.52
Anagallis arvensis	Commelinaceae	Broad leaf	Annual	7.56	11.25	13.06	13.64
Bidens plosa	Asteraceae	broad leaf	Annual	1.44	50	2.49	6.06
Commonina Bangilansis	Commelinaceae	Broad leaf	Annual	2	87.5	3.46	10.61
Cyanotis cristata	Commelinaceae	Broad leaf	Annual	1	37.5	1.73	4.55
Digitaria ternata	Poaceace	Grass	Annual	1.67	50	2.89	6.06
Digitaria ischaemum	Poaceace	Grass	Annual	1.22	37.5	2.11	4.55
Eleusina indica	Poaceace	Grass	Annual	5.67	12.5	9.80	15.15
Kyllinga nemoralis	Cyperaceae	sedge	Perennial	1.44	37.5	2.49	4.55
Nicandra physalodes	Solanaceae	Broad leaf	Annual	0.22	12.5	0.38	1.52
Oplismenus compositus	Poaceace	Grass	Annual	0.22	12.5	0.38	1.52
Setaria pumila	Poaceace	Grass	Annual	0.11	12.5	0.19	1.52
Sonchus asper	Asteraceae	Broad leaf	Annual/Bi	1.44	37.5	2.49	4.55
Stellaria media	Caryophyllaceae	Broad leaf	Annual	2.44	75	4.22	9.09

Conclusion

In the field survey, weeds of the major cereal crops – maize, sorghum, wheat, barley tef and rice were assessed and quantifed with regard to key parameters. The importance of each species was determined by calculating the frequency, abundance and dominance values. In the study, different weed family and weed species were identified for each crop. The most dominant family according to frequency and number of weed species was*Poaceace* followed by *Asteraceae* and *Commelinaceae*families.The frequency and dominance value ranges of individual weed species of maize, sorghum, wheat, barley, tef and rice fields were quantified and summarized. The most frequent and dominant weed species was *Agratum conyzoides* and *Guizotia scarab* for maize and sorghum;*Oplismenus compositus* and *Guizotia scarab* for wheat;*Guizotia scarab* and *Galisoga parviflora*for Barley;*Phalaris paradoxa*and *Oplismenus compositus*for Tef and *Agratum conyzoides* and *Commelina benghalensis*for rice crop.

The current study has documented important weeds of major cereals - maize, sorghum, wheat, barley, tef and rice in representative and potential districts of the respective crops. As the weeds recorded have been described in detail, this information can be a useful tool for weed management research and strategies to pursue in the future for the various crops and districts. The information generated through this study is further useful to recommend low-cost, effective and easily available weed management methods for farmers, including Integrated Weed Management.

References

Akobundu IO (1987) Weed Science in the Tropics.Principles and Practices.(2nd edn), John Wiley and Sons Inc. New York, USA, p. 522.

Anderson TN and P Milberg. 1998. Weed flora and the relative importance of site, crop, crop

Anderson RL and Beck DL (2007). Characterizing weed communities among various rotations in central south Dakota. Weed Technology 21: 76-79

Adesina GO, Akinyemiju OA, Ola OT (2015) Assessment of frequency, density and abundance of weed species in different Cropping Systems. Journal of Natural Sciences Research 2(9): 107-119.

Belachew K, Tessema T (2015) Assessment of Weed Flora Composition in Parthenium (Parthenium hysterophorus L.)Infested Area of East Shewa Zone, Ethiopia. Malaysian Journal of Medical and Biological Research 2: 63-70.

Chhokar RS and Malik RK (2002).Isoproturon resistant Phalaris minor and its response to alternate herbicides. Weed Technology 16: 116-123

Dixit A, Gogoi AK and Varshney JG (2008b). Weed Atlas- District-wise distribution pattern of major weed flora in prominent crops. Vol II, National Research Centre for Weed Science, Jabalpur, India, Pp 88.

Ermias, D. 2011. Natural database for Africa (NDA) On CDROM Version 2.0.Addis Ababa University, Ethiopian.

Fasil Reda,2006. Weed Management Research Experience in Ethiopia. Proceedings of Planning Workshop on “Facilitating the Implementation and Adoption of Integrated Pest Management (IPM)

Froud-William RJ. 1987. Change in weed flora with different tillage and agronomic management systems. In: Altieri M and M Liebman, (eds.). Weed management in agro-ecosystem: ecological approach. CRC Press, Inc., Florida. pp. 213 – 236.

Gidesa A, Tadesse T, Dabi A (2016) Quantitative Determination of Weed Occurrence on Upland Rice of Bambasi, Ethiopia. Ecology and Evolutionary Biology 1(3): 53-56.

Hedberg, I., Friis, I. and Edwards, S. 2004. Flora of Ethiopia and Eritrea, Asteraceae (Compositae).Addis Ababa University and Uppsala University. 4 (2): 24-36.

Mennan H, Isik D (2003) Invasive weed species in onion production systems during the last 25 years in Amasya, Turkey. Pak J Bot 35(2): 155-160.

Moeini MM, Baghestani MA, Ashhadi HR (2008) Introducing An Abundance Index For Assessing Weed Flora In Survey Studies. Weed biology and management 8(3): 172-180.

Takim FO, Amodu AA (2013) Quantitative Estimate of Weeds of Sugarcane (Saccharum Officinarum L.) Crop In Ilorin, Southern Guinea Savanna of Nigeria. Ethiopian Journal Environmental studies and management 6(6): 611-619.

Uddin MK, Juraimi AS, Ismail MR, Brosnan JT. Characterizing weed populations in different turfgrass sites throughout the Klang Valley of Western Peninsular Malaysia. Weed Technol. 2010;24:173-181.

Tamado, T. and Milberg, P. 2000. Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of Parthenium hysterophorus. Weed Res. 40(6): 507-521.

Tena E, Hiwet AG, Dejene M (2012) Quantitative and Qualitative Determination of Weeds in Cotton-Growing Areas of Humera and Metema, Northwestern Ethiopia. Ethioian Journal of Applied Science Technology 3(1):57- 69.

Survey of Distribution and Status of Major Pulse and Oil Crops Weeds in West Shoa, Horro Guduru Wollega and East Wollega Zones, Ethiopia

Abay Guta*, Getu Abera and Megersa Kebede
Bako Research center, P. O. box 3, Bako, Shoa, Ethiopia
***Corresponding author: abbayg12@gmail.com**

Abstract

The Field survey of major pulse oil crops: faba bean, field pea, soybean, ground nut and sesame was conducted in part of Western Oromia in West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedele Zones during 2019 and 2020 main cropping season covering six districts, 41 Kebeles and 91 fields. Frequency, Abundance, Dominancy and Similarity Index, were computed for each weed species. The most dominant families according to frequency and number of weed species were Poaceace, Asteraceae, Commelinaceae and Amaranthaceae. Generally Annual weeds were dominant in all crops and broad leaf weeds dominated over grass and sedge types for most crops. The most frequent and dominant weed species consisted of Guizotia scaraba and Spergula avensis for faba bean; Guizotia scaraband Raphanus raphanistrium for field pea; Ageratum conyzoides and Digitaria ternata for sesame; Ageratum conyzoides and Guizotia scaraba for groundnut; Ageratum conyzoides, and Guizotia scaraba for soybean crops fields.

Keyword: Family, Species, Distribution, Frequency, Abundance, pulses, Oil seeds

Introduction

Weeds are one of the major constraints to crop cultivation that can affect crop yield based on their species composition and density (Kropff *et al*., 1992). Weed infestations also enhance disease developement, serve as alternate host for insects and diseases, slow down harvesting, restricting operations, increase the cost of production, reduce the market value of crops and increase the risk of fire in perennial crops, plantation and forest reserves (Palumbo, 2013; Tena *et al*., 2012).

Some weeds also show allelopathic effects on agricultural crops by secreting allelochemicals that suppress their growth and germination (Vissoh *et al*., 2004; Jabran *et al*., 2010; Farooq *et al*., 2011). Although crop yield losses to weeds vary from crop to crop and from region to region, because of various biotic and abiotic factors, it has been estimated that weeds cause a yield loss of about 10% in the less developed country and 25% in the least developed countries (Khan *et al.*, 2015).

It has been estimated that farmers in developing countries devote 20 to 50% of their time to weed management. A study by Vissoh *et al*. (2004) found that weeds are an important agricultural constraint to farmers in general, and that weed impact is an important contributing factor to keeping smallholders in a vicious circle of poverty. According to Labrada (2009), almost 40% of the activities on African crop fields are dedicated to weed control, which is often done at family level, at the expense of women and children who, instead, couldspend time and energy on family care and education.

Information on weed density, distribution and species composition may help to predict yield losses and such information helps in deciding whether it is economical to control a specific weed problem (Kropff*et al*., 1991; Belachew*et al*., 2015). There is meager information available about the quantity of crop yield losses due to weeds in Ethiopia. Furthermore, the relative importance of common weed species for the major crops and cropping systems is not well documented (Stroud*et al*., 1989) especially in Western Ethiopia. Surveys are commonly used to characterize weed populations in cropping systems (Uddin*et al*., 2010). Therefore, to develop an effective weed management program, a detailed survey is necessary to address the current weed problems in the field. In addition, survey information is entirely important in devisingproblem oriented research programs. Hence, this study was initiated to determine the weed flora, distribution and status for the major pulses and oil seeds crops in parts of Western Oromia.

Materials And Methods

Description of the Study Area

The Field survey was conducted in parts of Western Oromia in West Shoa, Horro Guduru Wollega, East Wollega and Buno Bedele Zones during 2019 and 2020 main cropping season. The survey was conducted in two districts of West Shoa Zone Chalia and Ilu Galan; in one district of Horro Guduru Wollega Zone-Horro; in two districts of East Wollega Zone namely Gida Ayana and Jima Arjo Districts and Chewaka District of Buno Bedelle Zone (Table 1). The annual mean minimum and maximum temperature of the area is 12^0C and 27.4^0C, respectively, while the annual rainfall is 1415.2 mm. The geographical locations of the surveyed areas were in the range of latitude and longitude of $08^0$34.70'- $09^0$40.41'N and $036^0$06.47'- $037^0$29.30'E, respectively.

Field survey

The six districts had almost near to lowland, midland and highland agro-ecologies lying in altitude range of 1219-2788 m.a.s.l (Table 1). The survey was conducted from 20^{th} to 27^{th} September for low land; from 16^{th} to 23^{rd} October for mid land and $1^{st}$to 8^{th} November 2019 and 2020 for highland areas.

In this area, faba bean production followed by field pea dominates among other pulse and oil seeds. The survey was conducted in 41 Kebeles and 91 fields in the six districts of the four zones. Purposive sampling technique was applied to select Districts. Kebeles were randomly selected from each district based on their representativeness for pulse and oil seeds production in the area. Thirty one faba bean, 19 field pea, 21 soybean, 12 sesame and eight groundnut samples were (Table 1) assessed for weeds. Adjucent samples of the same crop were at least 4-6 km apart. The weed assessment was made along the two diagonals (in an "X" pattern) of the field from five points using 1m × 1m (1 m^2) quadrates with their GPS and soil types.

Farmers were interviewed suing pre-structured questinoarrie to collect some relevant information such as weed management practice, varieties, preceeding crop, planting date, fertilizer use and herbicide use and others. Most of sesame and soybean fields were planted toimproved varieties whereas faba bean, field pea and ground nut were more of local cultivars.

Frequency (F), Abundance (A), Dominancy (D) and Similarity Index (SI) were computed for each weed species using the method of Thomas (1985). In each field, weed species and their numbers within the quadrates were counted and recorded.

Table 1: Characteristic features of surveyed pulse and oil seeds fields in two Zones, Western Oromia

Zones	Districts	Crops	Altitude (m.a.s.l)	No. field assessed
West Shoa	Chalia	Faba bean	2435-2614	9
		Field Pea	2464-2619	8
	Ilu Galan	Soybean	1704-2615	8
		Mean	1704-2619	24
H/G/Welloga	Horro	Faba bean	2377-2788	13
		Field Pea	2370-2717	11
		Mean	2370-2788	24
East Wollega	Jima Arjo	Faba bean	2347-2476	9
	Gida ayyan	Soybean	1345-2451	6
		Groundnut	1350-1469	8
		Mean	1350-2476	23
Buno Badalle	Chawaka	Sesame	1219-1270	12
		Soybean	1222-1250	7
		Mean	1219-1270	19
		Over all mean	1219-2788	91

m.a.s.l= meters above sea level

Data Analyses

After the quantitative weed measurements, Density, Relative density, Frequency, Relative frequency and Similarity Index were calculated by using the following formulae. The collected data were summarized and analyzed by using SPSS statistical software.

$$\text{Density (D)} = \frac{\textit{Total number of a species in all quadrate}}{\text{Total number of quadrates used}}$$

$$\text{Frequency (F)} = \frac{\textbf{\textit{Number of quadrates in whcih a given species occurs}}}{\text{Total number of quadrates used}}$$

Relative Density (RD) $= \frac{\text{Density of a given species}}{\text{Total density for all species}} \times 100\%$

Relative Frequency (RF) = $\frac{\text{Frequency of a given species}}{\text{Total frequency for all specie}}$ X 100%

Similarity Index (SI) = 100 × Epg/(Epg + Epa + Epb)

Where; SI = Similarity index, Epg = number of species found in both locations, Epa = number of species found only in location I. Epb = number of species found only in locations II

Results and Discussion

Survey of Faba Bean Fields

Diversity Of Weeds In Faba Bean Fields

In faba bean fields,37 weed species belonging to 11 families were identified.Of these, 40.54% and 16.23% of the species belonged to *Poaceac*e and *Asteraceae* families, respectively. Family *Commelinaceae* comprised of 8.11% or three weed species. Families *Amaranthaceae*, *Cyperaceae*, *Polygonaceae*, *Brassicaceae* and *Caryophyllaceae* altogether comprised of 27.03% of the weed species recorded in faba bean fields, each family consisting of two species (Table 2).

Table 2: Number of weed families and species identified in faba bean fields

Family	No. of Species
Poaceace	15
Asteraceae	6
Amaranthaceae	2
Commelinaceae	3
Cyperaceae	2
Polygonaceae	2
Leguminosae	1
plantaginaceae	1
Rubiaceae	1
Brassicaceae	2
Caryophyllaceae	2
Total	37

Weed flora of faba bean fields

The survey results also show thatbroad leaf weeds dominated over grass and sedge weed species. Of the total weed species recored in faba bean fields, 54.05% were broad leaf; 40.54% were grass types and 5.4% were sedge type species (Table 3). Thirty three weed species were annuals and the remainining were found to be perennials.

Ten weed species,namely *Spergula avensis*,*Guizotia scarab, Oplismenus compositus, Oxygonmn sinuatum*,*Plantago lanceolata*,*Dinebra retroflexa, Raphanus raphanistrium, Galinsoga parviflora, Pennisetum polvstachion*and *Rumex abvssinicus*occurred at higher frequency value, exceeding 30% whereas 16 species had frequency values of about 15% and 23%; the remaining 11 species had frequency values of 7%.*Spergula Avensis*and*Guizotia scaraba*had the highest frequency value of 69.23% follwed by *Oplismenus compositus* (Table 3).

Table 3: Description of Density, Frequency, Relative Density and Relative Frequency of weeds in faba bean fields.

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Ageratum conyzoides	*Asteraceae*	Broad leaf	Annual	4.46	15.38	9.25	1.79
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	1.31	23.08	2.72	2.68
Andropogon abyssinicus	*Poaceace*	Grass	Annual	0.46	15.38	0.95	1.79
Avena Abyssinicus	*Poaceace*	Grass	Annual	0.38	15.38	0.79	1.79
Bidens pachyloma	*Asteraceae*	broad leaf	Annual	1.23	15.38	2.55	1.79
Bidens plosa	*Asteraceae*	broad leaf	Annual	0.31	7.69	0.64	0.89
Celosia trigyna	*Amaranthaceae*	broad leaf	Annual	0.38	23.08	0.79	2.68
Chenopodium procerum	*Amaranthaceae*	broad leaf	Annual	0.31	7.69	0.64	0.89
Commelina benghalensis	*Commelinaceae*	Broad leaf	Annual	0.46	15.38	0.95	1.79
Commelina subulata	*Commelinaceae*	Broad leaf	Annual	0.38	15.38	0.79	1.79
Cynodon dactylon	*Poaceace*	Grass	Perennial	0.23	7.69	0.48	0.89
Cyperus esculntus	*Cyperaceae*	Sedge	Perennial	0.85	7.69	1.76	0.89
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	0.62	7.69	1.29	0.89
Digitaria abvssinica	*Poaceace*	Grass	Annual	1.07	15.38	2.22	1.79
Digitaria ternata	*Poaceace*	Grass	Annual	0.54	15.38	1.12	1.79
Dinebra retroflexa	*Poaceace*	Grass	Annual	1.38	38.46	2.86	4.46
Eleusina indica	*Poaceace*	Grass	Annual	0.46	15.38	0.95	1.79
Eraqrostis cilianensis	*Poaceace*	Grass	Annual	1.43	23.08	2.97	2.68
Erucastrium arabicum	*Brassicaceae*	Broad leaf	Annual	0.08	7.69	0.17	0.89
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	3.69	38.46	7.66	4.46
Galium spurium	*Rubiaceae*	broad leaf	Annual	0.15	7.69	0.31	0.89
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	4.50	69.23	9.34	8.04
Kyllinga nemoralis	*Poaceace*	Grass	Annual	0.43	7.69	0.89	0.89
Medicago polymorpha	*Poaceace*	Grass	Annual	0.85	15.38	1.76	1.79
Oplismenus compositus	*Poaceace*	Grass	Annual	3.81	61.54	7.90	7.14

Oxygonmn sinuatum	*Polygonaceae*	Broad leaf	Annual	0.38	53.85	0.79	6.25
Pennisetum polvstachion	*Poaceace*	Grass	Annual	1.42	30.77	2.95	3.57
Phalaris paradoxa.	*Poaceace*	Grass	Annual	2.38	23.08	4.94	2.68
Plantago lanceolata.	*plantaginaceae*	Broad leaf	Annual	1.31	46.15	2.72	5.36
Raphanus raphanistrium	*Brassicaceae*	Broad leaf	Annual	1.85	38.46	3.84	4.46
Rumex abvssinicus.	*Polygonaceae*	Broad leaf	Perennial	0.08	30.77	0.17	3.57
Setaria pumila	*Poaceace*	Grass	Annual	0.34	7.69	0.71	0.89
Snowdenia polystachya	*Poaceace*	Grass	Annual	4.19	7.69	8.69	0.89
Spergula Avensis	*Caryophyllaceae*	Broad leaf	Annual	0.46	69.23	0.95	8.04
Spilanthes mauritiana	*Asteraceae*	Broad leaf	Annual	1.31	15.38	2.72	1.79
Stellaria media	*Caryophyllaceae*	Broad leaf	Annual	0.43	15.38	0.89	1.79
Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	2.51	7.69	5.21	0.89
Others				1.77	23.08	3.67	2.68

Weed Similarity Index

The weed flora similarity index of Chalia, Jima Arjoand Horro Districts were above 60% which means 67%-83% similar weed management mothed can be used to control weed species composition (Table 4). This suggests that the weed species composition among the different Districts were similar.

Table 4: Characteristic feature similarity index of weed species composition faba bean fields.

Districts	Chalia	Jima Arjo	Horro
Chalia	100	79	83
Jima Arjo		100	67
Horro			100

Survey of field pea fields

Diversity of Weeds

In field pea fields, 30 weed species belonging to 10 families were identified. Of these, 50% and 13.33% of the species belonged to *Poaceac*e and *Asteraceae* families, respectively. Families, *Commelinaceae*, *Polygonaceae* and *Caryophyllaceae* comprised of 20% of the weed species recorded in field pea fields, each family consisting of two species (Table 5).

Table 5: Number of weed families and species identified in field pea fields

Families	No of species	Families	no of species
Poaceace	15	*Brassicaceae*	1
Asteraceae	4	*Cyperaceae*	1
Caryophyllaceae	2	*Leguminosae*	1
Commelinaceae	2	*plantaginaceae*	1
Polygonaceae	2	*Rubiaceae*	1
Total			30

Weed flora of field pea fields

The survey results also showed that broad leaf and grass weeds were nearly equally important while only one sedge species was encountered (Table 6). On the onther hand, twenty nine weed species were annuals while onley one species was found to to be perennial.

Five weed species,namely *Raphanus raphanistrium*,*Guizotia scaraba*,*Plantago lanceolata*,*Galinsoga parviflora* and *Spergula avensis*,occurred at higher frequency value, exceeding 30% whereas six species had frequency values of about 27% and the remaining species had frequency values of less than 20%. *Raphanus raphanistrium* and *Guizotia scaraba*had the highest frequency value of 63.64 follwed by *Plantago lanceolata* (Table 6).

Table 6: Description of Density, Frequency, Relative Density and Relative Frequency of weeds in field pea fields

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Freqquency
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	1.00	27.27	3.11	3.66
Andropogon abyssinicus	*Poaceace*	Grass	Annual	0.73	27.27	2.26	3.66
Avena abyssinicus	*Poaceace*	Grass	Annual	0.55	18.18	1.70	2.44
Avena fatua	*Poaceace*	Grass	Annual	0.36	18.18	1.13	2.44
Commelina subulata.	*Commelinaceae*	Broad leaf	Annual	0.09	9.09	0.28	1.22
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	0.82	18.18	2.54	2.44
Digitaria abvssinica	*Poaceace*	Grass	Annual	0.73	18.18	2.26	2.44
Digitaria ternata	*Poaceace*	Grass	Annual	0.75	0.13	65.01	1.30
Dinebra retroflexa	*Poaceace*	Grass	Annual	2.00	18.18	6.22	2.44
Eleusina indica	*Poaceace*	Grass	Annual	0.18	9.09	0.57	1.22
Eraqrostis cilianensis	*Poaceace*	Grass	Annual	0.45	18.18	1.41	2.44
Glebionis segetum .	*Asteraceae*	broad leaf	Annual	1.82	18.18	5.65	2.44
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	1.82	45.45	5.65	6.10
Galium spurium	*Rubiaceae*	broad leaf	Annual	0.18	9.09	0.57	1.22
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	*5.00*	63.64	15.54	8.54
Lolium temulflntuni	*Poaceace*	Grass	Annual	0.09	9.09	0.28	1.22
Medicago polymorpha	*Poaceace*	Grass	Annual	0.55	18.18	1.70	2.44

Oplismenus compositus	*Poaceace*	Grass	Annual	2.00	27.27	6.22	3.66
Oxygonmn sinuatum	*Polygonaceae*	Broad leaf	Annual	0.45	18.18	1.41	2.44
Pennisetum polvstachion	*Poaceace*	Grass	Annual	0.55	18.18	1.70	2.44
Phalaris paradoxa	*Poaceace*	Grass	Annual	0.45	27.27	1.41	3.66
Plantago lanceolata	*plantaginaceae*	Broad leaf	Annual	1.27	45.45	3.96	6.10
Polygonum nepalense	*Polygonaceae*	Broad leaf	Annual	0.36	18.18	1.13	2.44
Raphanus raphanistrium	*Brassicaceae*	Broad leaf	Annual	3.00	63.64	9.32	8.54
Setaria pumila	*Poaceace*	Grass	Annual	0.09	9.09	0.28	1.22
Snowdenia polystachya	*Poaceace*	Grass	Annual	1.09	27.27	3.39	3.66
Spergula avensis	*Caryophyllaceae*	Broad leaf	Annual	2.18	36.36	6.78	4.88
Spilanthes mauritiana	*Asteraceae*	Broad leaf	Annual	0.18	9.09	0.57	1.22
Stellaria media	*Caryophyllaceae*	Broad leaf	Annual	0.45	18.18	1.41	2.44
Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	1.27	27.27	3.96	3.66
Others				2.45	54.55	7.63	7.32

Weed Similarity Index

The survey result showed that similarity index value between Diga and Chawaka Districts was 64% whichis greater than 60% (Table 7); it can be conculuded that the locations exhibited similar weed community and thus, require similar management options.

Table 7: Characteristic feature similarity index of weed species composition in field pea fields.

Districts	Chalia	Horro
Chalia	100	82
Horro		100

Survey of soybean fields

Diversity of weeds

In soybean fields, 25 weed species belonging to 10 families were identified. Of these, 52% of the species belonged to *Poaceace* and *Asteraceae* families, each family containing seven and six species, respectively; 12% of the species belonged to family *Commelinaceae* and 16% belonged to *Amaranthaceae* and *Cyperaceae* families, each family comprising of two species. Family *Poaceace* appeared to be dominant of all weed families found in soybean fields (Table 8).

Table 8: Number of weed families and species identified in soybean fields

Families	No of species	Families	No of species
Poaceace	7	*Caryophyllaceae*	1
Asteraceae	6	*Euphorbaceae*	1
Commelinaceae	3	*Lamiaceae*	1
Amaranthaceae	2	*Leguminosae*	1
Cyperaceae	2	*Solanaceae*	1
			25

Weed flora of soybean fields

The results of the survey also showed that broad leaf weeds were dominant over grass and sedge type weeds; 64% of the weeds were broad leaf types, 28% of the species were grass types and 8% were sedge type weeds (Table 9). On the other hand, 23 weed species were annuals while onley two species was found to to be perennials. Eight weed species had frequency value of greater than or equal to 25%, while the remaining 17 species had frequency value of less than or equal to 20%. The species that had maximum frequency value (58.3%) was found to be *Ageratum conyzoides* followed by *Elusine indica* (Table 9).

Table 9: Description of Density, Frequency, Relative Density and Relative Frequency of weed in soybean fields

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Achyranthes aspera	Amaranthaceae	Broad leaf	Annual	0.25	8.33	0.53	1.69
Ageratum conyzoides	Asteraceae	Broad leaf	Annual	18.46	58.33	39.42	11.86
Anagallis arvensis	Commelinaceae	Broad leaf	Annual	1.88	16.67	4.00	3.39
Bidens pilosa	Asteraceae	broad leaf	Annual	1.00	25.00	2.13	5.08
Chenopodium procerum	Amaranthaceae	broad leaf	Annual	0.75	8.33	1.60	1.69
Commonina Bangilansis	Commelinaceae	Broad leaf	Annual	1.38	16.67	2.94	3.39
Cyanotis cristata	Commelinaceae	Broad leaf	Annual	2.63	16.67	5.60	3.39
Cyperus esculntus	Cyperaceae	Sedge	Perennial	0.63	8.33	1.33	1.69
Cyperus rotudus	Cyperaceae	Sedge	Perennial	0.38	8.33	0.80	1.69
Digitaria abvssinica	Poaceace	Grass	Annual	1.13	16.67	2.40	3.39
Digitaria ternata	Poaceace	Grass	Annual	0.25	16.67	0.53	3.39
Eleusine indica	Poaceace	Grass	Annual	3.00	50.00	6.40	10.17
Eraqrostis cilianensis	Poaceace	Grass	Annual	0.13	8.33	0.27	1.69
Galinsoga parviflora	Asteraceae	broad leaf	Annual	0.25	8.33	0.53	1.69
Guizotia scarba	Asteraceae	Broad leaf	Annual	5.38	41.67	11.48	8.47
Kyllinga nemoralis	Poaceace	Grass	Annual	1.75	41.67	3.74	8.47
Leucas cephalotes	Lamiaceae	broad leaf	Annual	0.50	25.00	1.07	5.08
Nicandra physalodes	Solanaceae	Broad leaf	Annual	0.38	8.33	0.80	1.69

Oplismenus compositus	Poaceace	Grass	Annual	2.63	25.00	5.60	5.08
Rhyllanthus niruri	Euphorbaceae	Broad leaf	Annual	0.13	8.33	0.27	1.69
Setaria pumila	Poaceace	Grass	Annual	1.00	25.00	2.13	5.08
Sonchus asper	Asteraceae	Broad leaf	Annual	0.50	8.33	1.07	1.69
Stellaria media	Caryophyllaceae	Broad leaf	Annual	1.25	16.67	2.67	3.39
Trifolium rueppellianum	Leguminosae	broad leaf	Annual	1.13	16.67	2.40	3.39
Xanxhium strumarium	Asteraceae	Broad leaf	Annual	0.13	8.33	0.27	1.69

Weed Similarity Index

Similarity index (community index) is the similarity of plant species composition among different districts. The survey result showed that similarity index value between Ilu Galan and Chawaka Districts was 58% whichis below 60% (Table 10); it can be conculuded that the locations exhibited dissimilar weed community and thus require different management options.

Table 10: Characteristic feature of similarity index of weed species composition in soybean fields

Districts	Ilu Galen	Chawaka
Ilu Galan	100	58
Chewaka		100

Survey of groundnut fields

Diversity of weeds

In ground fields, 19 weed species belonging to seven families were identified. Of these, 63.16% of the species belonged to *Asteraceae* and *Poaceace families*, each family comprising of six species; 21.05% of the species belonged to *Amaranthaceae* and *Commelinaceae* families, each family comprising of two species. The remaining three families had each one species. Unlike in other crops, family *Poaceace* appeared to be less dominant in ground nut fields and only six species of it were recorded (Table 11).

Table 11: Number of weed families and species identified in groundnut fields

Families	No of species	Families	no of species
Asteraceae	6	*Euphorbaceae*	1
Poaceace	6	*Lamiaceae*	1
Amaranthaceae	2	*Polygonaceae*	1
Commelinaceae	2		
Total			19

Weed flora of groundnut fields

The assessment results also showed broad leaf weeds were dominant over grass weeds; 68.42% of the weeds were broad leaf types, 26.32% of the species were grass types where as only one species of sedge type was encountered (Table 12). On the onther hand, 18 weed species were annuals while only one species was found to to be perennial.Thirteen weed species had frequency value of greater than 40%, while the remaining six species had frequency value of less than 30%. Three weed species: *Digitaria ternate*, *Guizotia scarab* and *Ageratum conyzoides* had the highest frequcy value of 85.71% (Table 12).

Table 12: Description of Density, Frequency, Relative Density and Relative Frequency of weed in groundnut fields

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Ageratum conyzoides	*Asteraceae*	Broad leaf	Annual	12.57	85.71	33.75	8.82
Amaranthus hybridus	*Amaranthaceae*	Broad leaf	Annual	0.14	14.29	0.38	1.47
Bidens pilosa	*Asteraceae*	broad leaf	Annual	2.29	57.14	6.14	5.88
Chrysocephalum semipapposum	*Amaranthaceae*	broad leaf	Annual	0.29	28.57	0.77	2.94
Commelina benghalensis	*Commelinaceae*	Broad leaf	Annual	3.14	71.43	8.44	7.35
Cynodon dactylon	*Poaceace*	Grass	Perennial	1.43	71.43	3.84	7.35
Cyanotis cristata	*Commelinaceae*	Broad leaf	Annual	2.29	57.14	6.14	5.88
Digitaria ternata	*Poaceace*	Grass	Annual	2.00	85.71	5.37	8.82
Eleusine indica	*Poaceace*	Grass	Annual	3.00	71.43	8.05	7.35
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	0.86	42.86	2.30	4.41
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	3.43	85.71	9.20	8.82
Kyllinga nemoralis	*Poaceace*	sedge	Annual	1.86	71.43	4.99	7.35
Leucas cephalotes	*Lamiaceae*	broad leaf	Annual	0.71	42.86	1.92	4.41
Oplismenus hirtellus	*Poaceace*	Grass	Annual	0.29	28.57	0.77	2.94
Polygnom nepalensi	*Polygonaceae*	Broad leaf	Annual	0.29	14.29	0.77	1.47

Rhyllanthus niruri	*Euphorbaceae*	Broad leaf	Annual	1.71	71.43	4.60	7.35
Setaria pumila	*Poaceace*	Grass	Annual	0.43	42.86	1.15	4.41
Sonchus asper	*Asteraceae*	Broad leaf	Annual/Bi	0.43	14.29	1.15	1.47
Xanxhium strumarium	*Asteraceae*	Broad leaf	Annual	0.14	14.29	0.38	1.47

Survey of sesame fields

Diversity of weeds

In sesame fields, relatively fewer weed species were recordecd -14 species belonging to seven families were identified. Of these, 28.57% of the species belonged to family*Asteraceae* where as 57.14% of the species belonged to, *Amaranthaceae*, *Commelinaceae, Euphorbiaceae* and *Poaceace*families, each family comprising of two species. Unlike in other crops, family *Poaceace* appeared to be less dominant in sesame fields and only two speciesof it were recorded (Table 13).

Table 13: Number of weed families and species identified in sesame fields

Families	No of species	Families	no of species
Asteraceae	4	*Poaceace*	2
Amaranthaceae	2	*Convolvulaceae*	1
Commelinaceae	2	*Leguminosae*	1
Euphorbiaceae	2		
Total			14

Weed flora of sesame fields

Broad leaf weeds were dominant over grass weeds; 85.71% of the weeds were broad leaf types where as the remaining were grass types (Table 14). On the onther hand, 13 weed species were annuals while onley one species was found to to be perennial.

Nine weed species,namely *Digitaria ternata*,*Rhyllanthus niruri*,*Ageratum conyzoides*,*Eleusine indica, Bidens pilosa, Ipomea lacunose*,*Cyanotis cristata*,*Cylusia tegrina* and*Commelina benghalensis*occurred at higher frequency value, exceeding 40% where as the remaining species had frequency values of less than 30%. The first three species*viz Ageratum conyzoides, Digitariaternata* and *Rhyllanthus niruri*had 100% frequency value (Table 14).

Table 14: Description of Density, Frequency, Relative Density and Relative Frequency of weed in sesame fields

Botanical name	Family	Category	Life cycle	Density	Frequency	Relative density	Relative Frequency
Ageratum conyzoides	*Asteraceae*	Broad leaf	Annual	15.39	100.00	46.74	14.00
Bidens pilosa	*Asteraceae*	broad leaf	Annual	2.1	71.43	6.38	10.00
Chenopodium album	*Amaranthaceae*	broad leaf	Annual	0.14	14.29	0.43	2.00
Commelina benghalensis	*Commelinaceae*	Broad leaf	Annual	1.04	42.86	3.16	6.00
Cylusia tegrina	*Amaranthaceae*	Broad leaf	Annual	1.04	42.86	3.16	6.00
Cyanotis cristata	*Commelinaceae*	Broad leaf	Annual	0.57	42.86	1.73	6.00
Digitaria ternata	*Poaceace*	Grass	Annual	5.39	100.00	16.37	14.00
Eleusine indica	*Poaceace*	Grass	Annual	2.9	71.43	8.81	10.00
Euphorbia hirta	*Euphorbiacea*	broad leaf	Annual	0.43	28.57	1.31	4.00
Ipomea lacunosa	*Convolvulaceae*	broad leaf	Perennial	0.43	42.86	1.31	6.00
Rhyllanthus niruri	*Euphorbaceae*	Broad leaf	Annual	2.53	100.00	7.68	14.00
Spilanthes mauritian.	*Asteraceae*	Broad leaf	Annual	0.43	14.29	1.31	2.00
Trifolium rueppellianum	*Leguminosae*	broad leaf	Annual	0.25	14.29	0.76	2.00
Xanxhium strumarium	*Asteraceae*	Broad leaf	Annual	0.29	28.57	0.88	4.00

Conclusions

In the current study, a total of 91 fieldswere surveyed for weed flora and fauna of pulses and oil crops, and different weed families and species were identified. The importance of each species was determined by calculating the frequency, abundance and dominance values. Generally, annual boroad weed leaves dominated over grass and sedge types for most crops. The most dominant families according to frequency and number of weed species were *Poaceace*, *Asteraceae*, *Commelinaceae*and*Amaranthaceae*.The most frequent and dominant weed species consisted of*Guizotia scaraba* and *Spergula Avensis* for faba bean;*Guizotia scaraba*and *Raphanus raphanistrium* for field pea; *Ageratum conyzoides* and *Digitaria ternata* for sesame; *Ageratum conyzoides* and *Guizotia scaraba* for groundnut;*Ageratum conyzoides* and *Guizotia scarab* for soybean crops fields.

The current study has documented important weeds of faba bean, field pea, soy bean, ground nut and sesame in representative and potential Agro-ecologies of the respective crops. As the weeds recorded were described in detail - by families, species and frequency, this information can be useful to proritize weed management research and management strategies to pursue in the future for the various crops and districts. The information generated through this study is further useful to recommend low-cost, effective and easily available weed management methods for farmers.

References

Belachew K, Tessema T (2015) Assessment of Weed Flora Composition in Parthenium (Parthenium hysterophorus L.)Infested Area of East Shewa Zone, Ethiopia. Malaysian Journal of Medical and Biological Research 2: 63-70.

Farooq, M., Jabran, K., Cheema, Z.A., Wahid, A. and Siddique, K.H. 2011.The role of allelopathy in agricultural pest management.Pest Managmnt. Sci. 67(5): 493-506.

Khan, M.J., Malik, M.A., Ansar, M., Quershi, R. and Brodie, G.I. 2015. Integrated weed management in wheat under subtropical rain-fed conditions. Glob. J. Agricult. Innov. 9(2): 49-58.

Kropff MJ, Spitters CJJ (1991) A simple model of crop loss by weed competition from early observation on relative area of the weed. Weed Res 31: 97-105.

Kropff MJ, Weaver SE, Smits MA, (1992). Use of eco-physiological models for crop-weed interference: relations amongst weed density relative time of weed emergence, relative leaf area and yield loss. Weed Science 40:296-301.

Jabran, K., Farooq, M., Hussain, M. and Ali, M. 2010.Wild oat (Avena fatua L.) and canary grass (Phalaris minor Ritz.) management through allelopathy. J. Plant Protect. Res. 50(1): 41-44.

Labrada, R. 2009. Manejo mejorado de malezas para mitigar la crisis de alimentos. XII Congresso SEMh/ XIX Congresso ALAM/ II Congresso IBCM, Instituto Superior de Agronomia, Lisboa, 1:319-323.

Mennan H, Isik D (2003) Invasive weed species in onion production systems during the last 25 years in Amasya, Turkey. Pak J Bot 35(2): 155-160.

Moeini MM, Baghestani MA, Ashhadi HR (2008) Introducing An Abundance Index For Assessing Weed Flora In Survey Studies. Weed biology and management 8(3): 172-180.

Palumbo JC (2013). Insect weed interactions in vegetable crops. VegIPM Update 4(13):1-3.

Stroud A, Parker C (1989) A Weed identification guide for Ethiopia.FAO, Rome, Italy.

Takim FO, Amodu AA (2013) Quantitative Estimate of Weeds of Sugarcane (Saccharum Officinarum L.) Crop In Ilorin, Southern Guinea Savanna of Nigeria. Ethiopian Journal Environmental studies and management 6(6): 611-619.

Tena E, Hiwet AG, Dejene M (2012) Quantitative and Qualitative Determination of Weeds in Cotton-Growing Areas of Humera and Metema, Northwestern Ethiopia. Ethioian Journal of Applied Science Technology 3(1):57- 69.

Uddin MK, Juraimi AS, Ismail MR, Brosnan JT. (2010). Characterizing weed populations in different turfgrass sites throughout the Klang Valley of Western Peninsular Malaysia. Weed Technol.; 24:173-181.

Vissoh, P.V., Gbehounou, G., Ahanchede, A., Kuyper, T.W. and Roling, N.G. 2004. Weeds as agricultural constraint to farmers in Benin: results of a diagnostic study. NJASWageningen J. Life Sci. 52(3-4): 305-329.

Major Weeds of Hot Pepper (*Capsicum annuum* L) In West Shoa and East Wollega Zones, Ethiopia

Abay Guta*, Getu Abera and Feyera Chimdessa
Bako Research center, P. O. box 3, Bako, Shoa, Ethiopia
Corresponding author: abbayg12@gmail.com

Abstract

A survey was conducted in West Shoa and East Wollega Zones of Oromia Regional State during 2020 main cropping season to assess and identify important weeds of hot pepper. Abundance, Dominance and Frequency of major hot pepper weeds were described. The survey result showed that 15 weed families and 39 weed species were recorded and identified. The assessments result also showed that, Broad leaf weeds dominate over grass and sedge weed species - 76.92% of the species were broad leaf; 17.95% were grass types and 5.13% were found to be sedge types. The frequency of individual weed species in hot pepper ranged from 2.78% to 97.22% while the dominance value ranged from 0.3% to 28%. The most frequent and dominant weeds in hot pepper crop were found to be Ageratum conyzoidesand *Guizotia scarba.*

Keywords: Assessments, Distribution and status, Major weed, Hot pepper

Introduction

Hot pepper (*Capsicum annuum* L.) is an important vegetable crop belonging to the family Solanaceae and grown in different parts of the world. Pepper is an important source of nutrients and addresses food needs and job creation throughout its value chain in developing countries (Shiferaw *et al*., 2014; Beyene *et al*., 2010). It is also one of the major income- generating crops for most households of the pepper producing areas and plays a vital role in food security (Roukens, 2005). People consume pepper for intake enhancement as well as to supplement the dietary needs.

The total land area covered by hot pepper is estimated at 29% (EEPA. 2003). However, the productivity of the crop in Ethiopia is far below the world average and thus demands to implement measures that enhance productivity through managing major bottlenecks.

Hot pepper is one of the important cash crops to Ethiopian smallholder farmers and an important agricultural commodity which contributes to export earnings (Beyene *et al*., 2007). The nutritional value of hot pepper merits special attention. It is rich source of vitamin A, E and contains five to six times as much vitamin C as an orange or a lemon, making it an ideal vegetable to prevent flu colds more than any other vegetable crop (Boselad *et al*., 2000). The color (oleoresin) and flavor extracts from hot pepper are used in both food and feed industries. The average daily consumption of hot pepper by an Ethiopian adult is estimated at 15 g which is higher than tomatoes and most other vegetables (MARC, 2004), indicating the significance of the crop in the country.

Peppers cultivation in the field is subject to biotic and a biotic stresses that influence the yield. Some of the factors that negatively affect crop growth, development and yield are the plant density, presence of weeds and low soil fertility (Adesina *et al*., 2014). Chilli pepper culture is extremely susceptible to the interference of these plants because it has slow initial growth and low index of leaf area in relation to it (Coelho, 2013).

Weeds emerge fast and grow rapidly competing with the crop for growth resources viz., nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of chilli. The wide space provided in between chilli plants allows fast growth of different weed species, causing considerable reduction in yield. Weeds emerge fast and grow rapidly competing with the crop for growth resources viz., nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of chilli. The wide space provided inbetween chilli plants allows fast growth of different weed species, causing considerable reduction in yield.

Weeds emerge fast and grow rapidly competing with the crop for growth resources *viz*., nutrients, moisture, sunlight and space during the entire vegetative and early reproductive stages of hot pepper. The wide space provided in between hot pepper plants allows fast growth of different weed species, causing considerable reduction in yield. Optimum plant spacing ensures proper growth and development of plant resulting in maximum yield of crop and economic use of land. Yield of hot pepper has been reported to be dependent on the number of plants accommodated per unit area of land (Duimovic *et al*., 2008).

Thus it is crucial to undertake assessment of major weeds of hot pepper. Information on weed flora and diversity is key to researching and recommendation of management options that can be available to smallholders at relatively lower cost; thus this survey work was undertaken with the objective of assessing and identification of major hot pepper weeds in East Wollega and West Showa zones of West Oromia.

Materials and Methods

Description of the Study Area

The weed survey was conducted in West Shoa and East Wollega Zones of Oromia Regional State during 2020 main cropping season at early vegetative and pod setting stages of hot pepper. The weed assessment survey was conducted in two Districts of West Shoa Zone- Ilu Galan and Bako Tibe; and similarly in two Districts of East Wollega Zone, Sibu Sire and Bilo Boshe. The survey was conducted to assess Abundance, Dominance and Frequency of major Hot pepper weeds. The annual mean minimum and maximum temperature of the area is 14.5^0C and 19.3^0C, respectively, while the annual rainfall is 1605.7 mm (Table 1). The geographical locations of the surveyed areas were in latitudinal and longitudinal range of $08^{0}55'10.89''$- $09^{0}05'04.87''$N and $036^{0}44'35.44''$-$037^{0}60'22.73''$E, respectively (Figure 1).

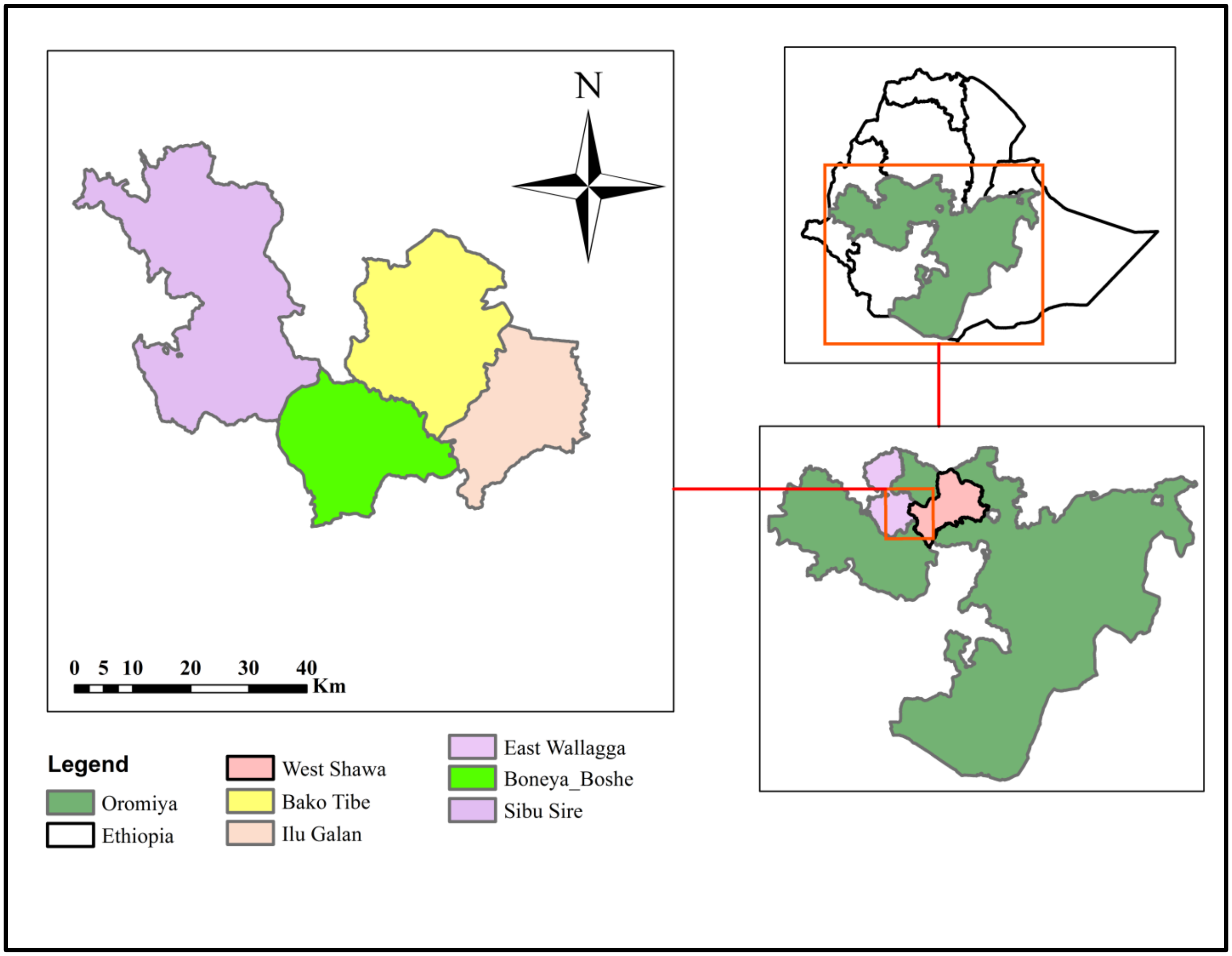


Figure 1. Map of survey site

Table 1: Meteorological data of the last ten years for the study area

Year	Annual Mean Minimum Temperature	Annual Mean Maximum Temperature	Annual Mean Rain Fall
2011	13.5	27.3	1425.5
2012	13.7	28.7	889.8
2013	12.9	29	1432.6
2014	13.4	28.4	1066.4
2015	12.4	29.9	931.4
2016	14.1	29.7	1330.7
2017	12.7	29.1	1599.5
2018	14	30	1267.1
2019	14.2	29	1342.3
2020	14.5	29.3	1605.7

Hot pepper field survey

Hot pepper weed survey was conducted in four districts of two zones during the main season. The four districts had almost near to midland and highland agro-ecologies lying in altitude range of 1610-2083 m.a.s.l.elevation (Table 2). In this area, most farms' of hot pepper cover large area next to cereals. The survey was conducted in 32 Kebeles and 46 fields in the four districts of the two zones. Random sampling technique was applied in the survey. Kebeles were randomly selected from each district and based on the representativeness of hot pepper production of the area (Table 2). The locations were at least 4-7 km apart depending on the topography and the relative importance of crop production within each location. The weed assessment was made along the two diagonals (in an "X" pattern) of the field from five points using 1m × 1m (1 m^2) quadrates and some questioner rise to farmers.

Data were collected on crop stage, the weeds available, types of infestation, infestation level, the level of farmers' knowledge about the problem of weeds and the control options. Data for the two times survey of weeds were combined and summarized. Frequency (F), abundance (A), dominancy (D) and similarity index (SI) were computed for each species using the method of Thomas (1985). Data on variety planted, preceding crop (cereals, pulses or vegetables), planting date, crop density, altitude, weed density per meter square, fertilizer type and rate, soil type, growth stage, weeds type observed and herbicides used were collected using structured questionarrie. Most of hot pepper fields were planted to local cultivars. In each field, weeds species and their numbers within the quadrates were counted and recorded.

Table 2: Characteristic features of surveyed hot pepper fields in two Zones of study area

Zones	Districts	Altitude (m.a.s)	No. field assessed
East Shoa	Ilu Galan	1705-1793	5
	Bako Tibe	1610-1768	14
	Mean	1610-1793	19
East Wollega	Sibu Sire	1711-2083	18
	Bilo Boshe	1655-1778	8
	Mean	1655-2083	26
	Over all mean	1610-2083	45

m.a.s.l= meters above sea level

Data analyses

After the quantitative weed measurements parameters such as density, reelative density, frequency, relative frequency and similarity index were calculated by using SPSS software and using the following formulae.

Density (D) = $\frac{Totalnumberofindividualsofaspeciesinall\boldsymbol{quadrate}}{\text{Total number of quadrates used}}$

Frequency (F) = $\frac{\boldsymbol{Numberofquadratesinwhichagivenspeciesoccurs}}{\text{Total number of quadrates used}}$

Relative Density (RD) =$\frac{\text{Density of a given species}}{\text{Total density for all species}} \times 100\%$

Relative Frequency (RF) = $\frac{\text{Frequency of a given species}}{\text{Total frequency for all specie}} \times 100\%$

Summed Dominant Ratio (SDR) = $\frac{\text{Relative density}}{\text{Relative frequency}} \times 100\%$

Similarity Index (SI) = 100 x Epg /(Epg + Epa + Epb)

Where; SI = Similarity index, Epg = number of species found in both locations, Epa = number of species found only in location I. Epb = number of species found only in locations II

Results and Discussion

Diversity of Weeds in Hot Pepper

A total of 46 weed fields were surveyed from hot pepper farms of Ilu Galan, Bako Tibe, Sibu Sire and Boneya Boshe Districts. Fifteen weed families and 39 weed species were recorded and identified. Results show that 61.54% of the species belonged to four families namely Asteraceae, Poaceace, Commelinaceae and Amaranthaceae which accounted for eight, seven, five and four species, respectively (Table 4). Asteraceae, Poaceace and Fabaceae were also found to be most important in the other studies of tropics (Belachew *et al*., 2015). The greater majority of weeds recorded in this crop, as it appeared for many other crops was annuals – 87.4% of the species were annuals while only 10.26% of the species were perennials.

Table 3. Weed families and species identified in hot pepper fields

Family	No. of species	Family	No. of species
Asteraceae	8	*Brassicaceae*	1
Poaceace	7	*Capparaceae*	1
Commelinaceae	5	*Lamiaceae*	1
Amaranthaceae	4	*Nyctaginaceae*	1
Caryophyllaceae	2	*Papavaraceae*	1
Cyperaceae	2	*plantaginaceae*	1
Polygonaceae	2	*Portulacaceae*	1
Solanaceae	2	-	
Total		-	39

Weed flora of hot pepper fields

The greater majority of weeds recorded in this crop, as it appeared for many other crops was annuals - 87.4% of the species were annuals while only 10.26% of the species were perennials. The survey results also showed that broad leaf weeds dominate over grass and sedge weed species -76.92% of the species were found to be broad leaf, 17.95% grass types and the remaining 5.13% were found to be sedge type species. (Table 4).

Generally, frequency of occurrence of individual weeds showed wide variation ranging from 2.78% to 97.22%. Ten weed species namely*Agratum conyzoides, Guizotia scarba, Eleusina indica*, *Galinsoga parviflora, Commonina Bangilansis, Polygnom nepalensi, Oplismenus compositus, Cynodon dactylon, Setaria pumila, Anagallis arvensis* had frequceny value higher than 30%. On the other hand 15 species had frequency value of less than 10%. The species that had the highest frequency of 97.22% was *Agratum conyzoides* followed by *Guizotia scaraba and Eleusina indica* which had frequency value *of* 88.89% and 63.89%, respectively. Dominant weeds were those species which occurred in relatively greater number than the other species.

Infestation level (dominance) ranged from 0.03%- 28% and most of the weeds associated with hot pepper production were found to be weeds that emerge with or before the crop. Weeds that emerge later than the crop are much less competitive and result in less crop yield loss but still may be considered as important if they reduce yield and quality. Weed density is an important factor in the control of weed species as explained by (Wicks *et al*., 2003), who found out that weeds were considerably important when they occur over nine weeds per m^2.

Table 4.Weed species that were recorded in hot peper fields in the survey area

Botanical name	Family	Category	Life cycle	Density	Freq.	Relative Density	Relative Freq.
Achyranthes aspera	*Amaranthaceae*	Broad leaf	Annual	0.19	13.89	0.34	1.57
Agratum conyzoides	*Asteraceae*	Broad leaf	Annual	28	97.22	49.53	11.01
Amaranthus spinosus .	*Amaranthaceae*	Broad leaf	Annual	0.39	5.56	0.69	0.63
Anagallis arvensis	*Commelinaceae*	Broad leaf	Annual	1.69	30.56	2.99	3.46
Argemone mexicana	*Papavaraceae*	Broad leaf	Annual	0.08	2.78	0.14	0.31
Bidens plosa	*Asteraceae*	broad leaf	Annual	0.05	2.78	0.09	0.31
Boerhavia erecta	*Nyctaginaceae*	broad leaf	Annual	0.11	5.56	0.19	0.63
Celocia trigyna	*Amaranthaceae*	Broad leaf	Annual	0.42	16.67	0.74	1.89
Chenopodium procerum	*Amaranthaceae*	broad leaf	Annual	0.22	11.11	0.39	1.26
Cleome monophylla L.	*Capparaceae*	Broad leaf	Annual	0.11	5.56	0.19	0.63
Commonina Bangilansis	*Commelinaceae*	Broad leaf	Annual	1.47	52.78	2.6	5.98
Commonina sublulata	*Commelinaceae*	Broad leaf	Annual	0.39	11.11	0.69	1.26
Conyza Canadensis	*Asteraceae*	broad leaf	Annual	0.03	2.78	0.05	0.31
Cynodon dactylon	*Poaceace*	Grass	Perennial	1.97	41.67	3.48	4.72
Cyanotis cristata	*Commelinaceae*	Broad leaf	Annual	0.97	27.78	1.72	3.15
Commelina subulata	*Commelinaceae*	Broad leaf	Annual	0.28	8.33	0.5	0.94
Cyperus rotudus	*Cyperaceae*	Sedge	Perennial	0.53	22.22	0.94	2.52
Datura stramnninm	*Solanaceae*	broad leaf	Annual	0.28	2.78	0.5	0.31
Digitaria abvssinica	*Poaceace*	Grass	Annual	0.42	16.67	0.74	1.89
Digitaria ternata	*Poaceace*	Grass	Annual	0.78	27.78	1.38	3.15
Eleusina indica	*Poaceace*	Grass	Annual	2.08	63.89	3.68	7.24
Erucastrium arabicum	*Brassicaceae*	Broad leaf	Annual	0.69	16.67	1.22	1.89
Galinsoga parviflora	*Asteraceae*	broad leaf	Annual	2.53	61.11	4.48	6.92
Guizotia scarba	*Asteraceae*	Broad leaf	Annual	5.83	88.89	10.31	10.07
Kyllinga nemoralis	*Cyperaceae*	sedge	Perennial	1.05	13.89	1.86	1.57

Leucas cephalotes	*Lamiaceae*	broad leaf	Annual	0.19	11.11	0.34	1.26
Nicandra physalodes	*Solanaceae*	Broad leaf	Annual	0.72	25	1.27	2.83
Oplismenus compositus	*Poaceace*	Grass	Annual	2.08	47.22	3.68	5.35
Oxygonmn sinuatum	*Polygonaceae*	Broad leaf	Annual	0.06	2.78	0.11	0.31
Plantago lanceolata	*plantaginaceae*	Broad leaf	Perennial	0.36	8.33	0.64	0.94
Polygnom nepalensi	*Polygonaceae*	Broad leaf	Annual	2.36	47.22	4.17	5.35
Portulaca oleracea .	*Portulacaceae*	Broad leaf	Annual	0.03	2.78	0.05	0.31
Setaria pumila	*Poaceace*	Grass	Annual	1.81	38.89	3.2	4.4
Snowdenia polystachya	*Poaceace*	Grass	Annual	0.03	2.78	0.05	0.31
Spergula avensis	*Caryophyllaceae*	Broad leaf	Annual	0.33	11.11	0.58	1.26
Spilanthes mauritiana	*Asteraceae*	Broad leaf	Annual	0.03	2.78	0.05	0.31
Stellaria media	*Caryophyllaceae*	Broad leaf	Annual	0.33	8.33	0.58	0.94
Tagetes minatu	*Asteraceae*	Broad leaf	Annual	0.03	2.78	0.05	0.31
Xanxhium strumarium.	*Asteraceae*	Broad leaf	Annual	0.61	22.22	1.08	2.52

Weed Similarity Index

The weed flora similarity index of Ilu Galan, Bako Tibe, Sibu Sire and Bilo Boshe Districts were above 60% which means that 63-91% of similar weed management method can be used to control weed species (Table 5). This suggests that the weed species composition among the different Districts were similar. The difference in altitude, climate, soil types and field management practices applied to the different district could be the cause that affected the distribution, abundance and dominance of the weed species (Mennan, 2003; Moeini *et al*., 2008; Takim *et al*., 2013).

Table 5: Characteristic feature similarity index of weed species composition in hot pepper fields.

Districts	**Ilu Galan**	**Bako Tibe**	**Sibu Sire**	**Bilo Boshe**
Ilu Galan	100	79	66	63
Bako Tibe		100	87	77
Sibu Sire			100	91
Bilo Boshe				100

Conclusion

A total of 46 hot pepper fields were surveyed to ass weeds that occur in hot peper. Fifteen weed families consisting of 39 weed species were recorded and identified. The importance of each species was determined by calculating the frequency, abundance and dominance values. The most dominant families according to frequency and number of weed species were *Poaceace*, *Asteraceae*, *Commelinaceae* and *Amaranthaceae*. The frequency value of individual weed species in hot pepper generally ranged from 2.78% to 97.22% while the dominance value ranged from 0.3% up to 28%. The most frequent and dominant weeds were *Ageratum conyzoides* and *Guizotia scaraba* in hot pepper fields. Among the study districts similarity index was found to be in the range of 63%-91% which show that, similar weed management methods can be applied to control weed species in all the surveyed districts.

The current study has documented important weeds of hot papper in representative and potential Agro-ecologies of the crop. As the weeds recorded have been described in detail, this information can be a useful tool for weed management research and strategies to pursue in the future. The information generated through this study is further useful to recommend low-cost, effective and easily available weed management methods for farmers, including Integrated Weed Management.

References

Adesina JM, Sanni KO, Afolabi LA, Eleduma AF (2014) Effect of Variable Rate of Poultry Manure on the Growth and Yield of Pepper (Capsicum annum) in South Western Nigeria. Academic Arena 6: 9-13.

Belachew K. Tessema T (2015) Assessment of of Weed Flora Composition in Parthenium (*Parthenium hysterophoru L.*) Infested area of East Shewa Zone, Ethiopia. Malaysia Journal of Medical and Biological Research 2:63-70.

Beyene Tadesse, Worku Tessema and Gebrehaweria Gebregziabher (2010). Agricultural Water Management (AWM). Briefing note on the situation analysis conducted in Ethiopia in 2009. websitehttp://awm-solutions.iwmi.org

Beyene T. and David Phillips (2007).Ensuring Small Scale Producers in Ethiopia to Achieve Sustainable and Fair Access to Pepper Market. Uganda Journal of Agriculture, 3(2): 113-119.

Bosland. P. W. and E. J. Votava (2000). Peppers, Vegetables and Spices Capsicum.CABI Publishing. New York. 198p.

Coelho M (2013) Interference of weeds in the growth of sweet pepper in no-tillage and Conventional systems. Rev Caatinga 26: 19-30.

CSA (2018).Agricultural sample survey of 2017/18 year. Report on area and production of major crops (private peasant holdings, meher season), Bulletin 586, vol I, Addis Abeba Ethiopia.

Duimovic MA, Bravo MA (2008) Effects of nitrogen and spacing on the yields and quality of bell pepper. Investigation Agraria 6: 99-103.

EEPA (2003). Spice potential and market study. Addis Ababa. Ethiopia, pp. 103.

MARC (Melkassa Agricultural Research Center). 2004. Progress Report Addis Ababa. Miller JJ.1946. Taxonomy *Fusarium* with particular reference to section Elegans.

Mennan H, Isik D (2003) Invasive weed species in onion production systems during the last 25 years in Amasya, Turkey. Pak J Bot 35(2): 155-160.

Moeini MM, Baghestani MA, Ashhadi HR (2008) Introducing An Abundance Index For Assessing Weed Flora In Survey Studies. Weed biology and management 8(3): 172-180.17

Monti, L. M. and Grillo, S. 1983. Legume seed improvement for protein content and quality. Qualitas plantarum: plant foods and human nutrition 32: 253-266.

Roukens, O. (2005). Export Potential of Ethiopian Oleoresins. Ethiopian Export Promotion Department, Ethiopia. pp. 7-14.

Shiferaw Mekonen and Alemayehu Chala (2014) Assessment of Hot Pepper (Capsicum species).Diseases in Southern Ethiopia International Journal of Science and Research (IJSR). Vol. 3:3

Takim FO, Amodu AA (2013) Quantitative Estimate of Weeds of Sugarcane (Saccharum Officinarum L.) Crop In Ilorin, Southern Guinea Savanna of Nigeria. Ethiopian Journal Environmental studies and management 6(6): 611-619.

Thomas AG (1985). Weed survey System used in Saskatchewan for cereal and oilseed crops. Weed Science 33:34-43.

Wicks GA, Popken DH, Mahnken GW, Hanson GE, Lyon DJ. Survey of winter wheat (Triticum aestivum) stubble fields sprayed with herbicides in 1998: Weed control. Weed Techno. 2003; 17:475-484.

Management of Rice Brown Spot (*Bipolaris oryzae)* (Breda de Haan) Shoemaker) through Integration of Host Resistance and Foliar Fungicides at Chewaka, Western Oromia

Megersa Debela*, Geleta Gerema, Abraham Negera, Megersa Kebede, Abay Guta

***Corresponding Author**

Abstract

A study was conducted to determine the effect of the integration of rice varieties with fungicides on rice brown spot ***(Bipolaris oryzae)****severity. Highly significant differences (P < 0.01) were observed across the* ***years*** *and on main effect variety and Fungicides for yield produced and brown spot terminal severity.The Highest rice grain yield produced, highest yield loss recorded and the highest marginal rate of return calculated depended on varieties used and respective fungicides applied. The highest yield (23.9 Qt/h) was recorded from Chewaka variety and on Natura sprayed plot (25.309 Qt/h). The lowest yield (13.7 Qt/ha) was attained from Idget variety and on Shega fungicide sprayed plot (16.540 Qt/ha).The highest MRR was calculated from Hiddassie variety sprayed with Natura SC 300. The highest yield loss was recorded from spraying of Shega on Chewaka and Hiddassie varieties.Chewaka variety shows tolerance mechanism of reaction to brown spot severity. Due to this, application of fungicide did not show any significant change in severity and yield on this variety. Thus, the application of fungicide on the Chewaka variety is not recommended for farmers unless the severity becomes very high.Growing Hiddassie variety needs spraying of fungicide due to the highest MRR calculated from the yield produced. Therefore, applying Natura Sc 300 on Hiddassie variety to reduce brown spot severity and to produce a reasonable yield is recommended.*

Key words: Rice Brown Spot, Severity, Yield, *Bipolaris oryzae*, Variety, Fungicide

Introduction

Rice (*Oryza sativa* L.) is the main source of food for approximately half of the world's population (Maclean *et al.,* 2002). For rice consumers, whole grains free from defects are preferred and this factor determines the price that growers will receive. Grain quality is affected by several abiotic and biotic factors (Ou, 1985). The biotic damage is related to fungal and bacterial incidence and injuries caused by insects (Marchetti *et al*., 1984).

Out of the various biotic stresses which influence the performance of rice crop, brown spot of rice caused by *Cochliobolus miyabeanus* (*Bipolaris oryzae*, *Drechslera oryzae*, *Helminthosporium oryzae*) is a disease that impairs grain quality and results in about 67% yield reduction (Jones *et al.*, 1993). Brown spot was responsible for the "Bengal Famine" in India in 1942 and 1943 (Padmanabhan, 1973).

The disease becomes more severe under stress conditions, causes seed discoloration, reduced seedling vigor and yield loss. In India, brown spot occurs every year on most of the cultivated rice varieties. At present, there are very limited strategies for the control of brown spots and cultivars with an adequate level of resistance are not available (Srinivasachary *et al*., 2011). Application of fungicides for the control of brown spot is the most effective management option, but under high disease pressure effective control may not be achieved (Lore *et al*., 2007).

The disease is known to occur on the fields of resource-poor farmers where there is deficiency of water supply and nitrogenous fertilizers (Zadoks, 1974). Currently, the major management strategies available for brown spot include the use of rice cultivars partially resistant, appropriate plant nutrition and fungicide application.

In western Oromia, rice cultivation was recently introduced and is currently produced by smallholders. Around Chewaka area nowadays, rice production is common and farmers are benefiting from it. The major challenges for Rice production in this area are due mainly to soil fertility and crop pests. The objective of this study was to determine the effect of the integration of rice varieties with fungicides on rice brown spot disease severity.

Materials and Methods

Fifteen treatment combinations which comprise five levels of fungicides and three levels of host resistance was arranged using factorial RCBD at Chewaka subsite of Bako Agricultural Research Center for two years. Varieties used were adapted upland rice varieties. Five levels of fungicides were sprayed once on first year and twice on second year with fungicide Natura, Shega, Itisa, Dipricon, and unsprayed control. Each plot consisted of 8 rows of 3 m long spaced at 0.2 cm apart. All the trial management practices were based on the recommendation for the location Brown spot incidence and severity on rice plants was assessed frequently.

Data analysis

Analysis of Variance

Data on brown spot terminal severity and yield were subjected to analysis of variance (ANOVA) using SAS software, SAS 2009. Mean separation was made based on LSD at 5% probability level and interaction effects were separated by SAS extension software *PLGLM800* (P=0.05).

Cost and Benefit Analysis

A price of grain (Birr ton^{-1}) was obtained from local market and total sale from one hectare was computed. The price of seeds of each variety was collected from the local market as well and farmer's unions in the localities. The price of Fungicides per liters was assessed and the total price incurred to spray one hectare of wheat was also calculated. Labor to spray those chemicals was computed. Cost-benefit analysis was performed using partial budget analysis. The marginal rate of return is a criterion that measures the effect of additional capital invested on net returns using new managements compared with the previous one (CIMMYT,1988). It provides the value of the benefit obtained per the amount of additional cost incurred percentage. The formula is as follows:

$$\mathrm{MRR} = \frac{\mathrm{DNI}}{\mathrm{DIC}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where, MRR is the marginal rate of returns, DNI, is the difference in net income compared with control, DIC, and is the difference in input cost compared with control.

Results and Discussion

Highly significant differences ($P \leq 0.01$) were observed across the **years** for yield and brown spot terminal severity (Table 1). The main effect variety showed highly significant difference ($P \leq 0.01$)

on the yield produced and reaction to brown spot severity. Application of fungicide significantly (P < 0.01) reduced brown spot severity but non-significant difference (P > 0.05) was observed on grain yield. Two way interactions of variety and fungicide did not show any significant difference (P > 0.05) on grain yield as well as on brown spot severity (Table 1).

Table 1. Mean squares of Variety and Fungicide on Rice yield and brown spot tested over years

Traits	Year	Variety.MS	Fungicide.MS	Variety*Fungicide	MSE		
	(df=1)	(df=2)	(df=4)	(df=8)	(df=57)	Mean	CV (%)
Yield	400.8**	893.9**	49.1	61.6	36.2	18.15	22.299
Brown spot	23.52**	5.033**	7.243**	0.651	1.375	5	22

Non-significant difference (P > 0.05) was observed on grain yield and terminal severity as influenced by fungicide application in the first assessment year. However, the use of different varieties resulted in highly significant difference(P $\leq$ 0.01) in yield produced and brown spot severity. In the second assessment year, application of fungicide highly influenced both grain yield and brown spot terminal severity. This is probably due to increase in spraying frequency on the second year as compared to first year (Table 2).

Table 2. Mean of grain yield and brown spot severity as influenced by main effects

Main effects		Year 1		Year 2	
		Yield	Brown spot	Yield	Brown spot
Variety	Chewaka	20	6.31	23.9	4.4
	Hidassie	17.1	5.27	23.2	5.1

	Idget	10.3	5.07		13.7	4
	F.test	**	**		**	NS
	LSD (0.05)	5.54	0.806		3.36	
Fungicide	unsprayed	14	6.5		21.883	5.67
	Natura	15.4	5.69		25.309	3.44
	Shega	18.9	5.67		16.540	5.56
	Itisa	15.2	5.67		19.147	4.56
	Dipricon	15.3	5.22		18.376	3.22
	F.test	Ns	Ns		**	**
	LSD (0.05)				4.33	2.042
	CV%	10	19.4	24.2	22.21	28.2

The Highest rice grain yield produced, highest yield loss recorded and the highest marginal rate of return calculated depended on varieties used and respective fungicides applied (Table 2&3). The highest yield (23.9 Qt/h) was recorded from Chewaka variety and on Natura sprayed plot (25.309 Qt/h). The lowest yield (13.7 Qt/ha) was produced from Idget variety and on Shega fungicide sprayed plot (16.540 Qt/ha).

Chewaka Variety showed tolerance for brown spot disease and also produced the highest yield. Although Fungicide application on Chewaka rice variety reduced the severity of brown spot, it did not show significant yield increments over unsprayed plots. Very low MRR% was recorded on sprayed Chewaka variety. The highest MRR was calculated from Hiddassie variety sprayed with Natura SC 300. The highest yield loss was recorded from spraying of Shega on Chewaka and Hiddassie varieties (Table 3).

Table 3. Mean of yield, brown spot and Neck blast as influenced by interaction effects of Varieties and Fungicides

Varieties	Fungicides	Yield	Yield loss (%)	MRR%
Chewaka	Natura	32.72a	0	3.135135
	Itisa	22.46abcd	31.35697	D

	Dipricon	18.16bcd	44.49878	D
	unsprayed	30.6ab	6.479218	0
	Shega	15.48cd	52.68949	D
Hiddassie	Natura	28.85abc	0	220.5946
	Itisa	23.73abcd	17.74697	28.4466
	unsprayed	22.26abcd	22.84229	D
	Dipricon	22.16abcd	23.18891	0
	Shega	19.05bcd	33.9688	D
Idget	Shega	15.1d	0	44.75524
	Dipricon	14.8d	1.986755	9.090909
	Natura	14.36d	4.900662	D
	unsprayed	12.8d	15.23179	0
	Itisa	11.3d	25.16556	D
CV%		20.25		

Conclusions and Recommendations

Brown spot severity varies across the years and also depends on the type of host used and fungicide applied. Application of systemic fungicide such as Natura and Dipricon reduces the severity of rice brown spot and also increases the yield. The severity difference across the year was due to the differences in fungicide frequencies. Chewaka variety shows tolerant reaction to brown spot severity. Due to this application of fungicide did not show any significant change in severity and yield on this variety.

Thus, the application of fungicide on variety Chewaka is not recommended for farmers unless the severity becomes very high. Idget variety shows very low yield as compared to Chewaka and Hiddassie. Growing Hiddassie variety needs spraying of fungicide due to the highest MRR calculated on the yield produced from this variety. Therefore, applying Natura Sc 300 on the Hiddassie variety to reduce brown spot severity and to produce a reasonable yield is recommended. Furthermore, testing of different fungicides and evaluating the rate and frequencies of different fungicides is important in the future.

References

CIMMYT (International Maize and Wheat Improvement Center). 1988. Farm Agronomic data to farmers' recommendations: Economic training manual. Completely revised edition. CIMMYT, Mexico, 124p.

Jones MP, Jeutong F, Tchatchoua J (1993). A survey of rice diseases in Cameroon. Plant Dis. 77:133-136.

Lore JS, Thind TS, Hunjum MS, Goel RK (2007).Performance of different fungicides against multiple diseases of rice.Ind. Phytol. 60:296-301.

Maclean JL, Dawe DC, Hardy B, Hettel GP (2002) Rice Almanac.Los Baños Philippines. International Rice Research Institute.

Marchetti MA, Petersen HD (1984) The role of *Bipolarisoryzae*in floral abortion and kernel discoloration in rice. Plant Disease. 68:288-291.

Ou SH (1985) Rice Diseases.Kew UK. CAB International Mycological Institute

Padmanabhan SY (1973). The Great Bengal famine. Ann Rev. Plant Pathol. 11:11-24

Srinivasachary, Willocquet L, Savary S (2011). Resistance to rice sheath blight (*Rhizoctoniasolani*Kuhn) [(teleomorph: *Thanatophoruscucumeris*(A.B Frank) Donk.] disease :current status and perspectives. *Euphytica*178:1-22.

Zadoks, J. C. 1974. The role of epidemiology in modern Phytopathology.*Phytopathology*. 64: 918–929.

Effect of Weed Management on Yield and Yield component of Barley (*Hordeum vulgare* L.) at Bore, Southern Oromia

Yared Tesfaye
Bore Agricultural Research Center
Oromia Agricultural Research Center

Abstract

A field experiment was conducted with the aim to investigate the effects of different weed management practices on weed density, growth, yield and yield attributes of barley on the highlands of Guji Zone during 2019-2020 main cropping season. The results indicated that among the weed management practices tested, Solan herbicide + Hand weeding and Solan applied alone significantly reduced the weed population and weed dry weight over the weedy check. The lowest weed population density and weed dry matter weight was recorded in Solan + hand weeding treatment but statistically at par with Solan alone treatment and twice hand weeding. The highest *panicle length (8.18cm), Thousand Kernel Weight (43.26g) and Grain Yield (4088kg ha^{-1}) were recorded from Solan + hand weeding treatment whereas the lowest spike length (5.74cm), thousand grain weight (31.16g), and grain yield(1677kg) were recorded from the weedy check, respectively. Solan + hand weeding and Solan alone treating had 58.9 per cent increase in grain yield over weedy check in barley crop. Application of Solan alone and Solan + hand weeding resulted in higher net return and marginal rate of return over other weed management practices studied. Therefore the application of Solan alone and Solan + hand weeding can be recommended for barley weed management in Guji Zone.*

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the major cereal crops that are largely produced in the mid- and high-altitudes of Ethiopia. It is the fifth most important cereal crop after tef, maize, wheat and sorghum (CSA, 2021). It is cultivated in almost all regions of the country with altitude rangeof 1,400–over 4,000 meters above sea level. It is the most desirable crop in the highlands where there is a limited alternative crop (Kuma*et al*., 2011).The most suitable areas for barley production, however, fall between 2000 and 3000 masl (kuma*et al*., 2011). In Ethiopia, barley covered an area of 1,876,845.85 ha with a total production of 4,717,114,850 kg with yield average of 2,513.5 kg ha^{-1} during 2021 cropping season (CSA, 2021). Barley plays a significant role in the national economy and currently both its area of production and productivity areon an increasing trend. Moreover, it is one of the major cereals of choice in Ethiopia dominantlyfor food consumption(Dessale *et al*., 2017). The annual average national yield of the crop is only 2513.5 kg/ha (CSA, 2021). The low national average yield, which is far below the world average (3.1t ha^{-1}), could be partially attributedtopoor weed management, which results in high competition for nutrients and other resources. Weed infestation is the main bottleneck in barley production in Ethiopia, especially during the rainy season.

Barley is very sensitive to weed competition and suffers the greatest yield reduction through competition duringthe third to sixth leaf stage (Stroud, 1989). Farmers in Ethiopia are aware of weed problem in their fields but often they cannot cope- up with heavy weed infestation during the peak-period of agricultural activities because of labor shortage, hence, most of their fields are weeded late or left un-weeded. Such ineffective weed management is considered as the main factor for low average yield of barley resulting in average annual yieldloss of 35% (Esheteu, *etal*., 2006). Manual and mechanical methods of weed control are laborious and expensive due to increasing cost of labor, draft animals and implements and weed cannot be effectively and timely managed.

There are many herbicides with various spectrum of activity registered in Ethiopia and availableto the farmers whenever they are opted for solely or in combination with other methods of management. The use of chemical weed control has become necessary and an integral component of Integrated Weed Management (IWM) (Marwat *et al*., 2008). Chemical weed control methods are most practical, effective, time saving and economical means of reducing early weed competition and crop production losses when they are properly used (Ashiq *et al*., 2007). But, the exclusive reliance on herbicides alone has resulted in pollution of the environment and some weed species becoming resistant and inter and intra- specific shifts. Integrating chemicalswith cultural methods is one of the best combinations for weed control (Hassan and Marwat, 2001). The objective of this study was to investigate the effectiveness of post emergency herbicides and herbicide combinations with hand weeding for the control of weeds in barley crop in Guji zone, Southern Oromia and to assess the economic feasibility of the management methods.

Materials and Methods

Description of the Study Area

The experiment was conducted at two high land districts of Guji Zone – Bore and Ana Sora for two consecutive years (2019 and 2020) to evaluate effects of IWM and identify economically feasible weed control methodsinfood barley. Bore and Ana Sora are located at 385 and 410 km from capital city of the country Addis Ababa to the South,respectively. The climatic conditions of both districts comprises an annual rain fall of 1250 mm/annual, meantemperature of 17.5-28 ^{o}c. Both districtsare selected forthis experiment based on the potential the offer for barley production and weed infestation history.

Treatments and Experimental Design

For this experiment four herbicides namely Solan, Ralon Super, Axial and Agro 2, 4-D alone and combined with hand weeding including weed free (twice hand weeding) and weedy check were evaluated. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each experimental plot had 3 m long and 4 m wide dimensions, with 15 rows that were 20 cm apart, giving a gross plot area of 12 m^2. The spacing between adjacent blocks was 1.5 m and the spacing between plots was 1 meter. Planting was done by hand drilling and covered lightly with soil. The seed rate and fertilizer rate were applied as per the recommendation for barley productionin the area. Herbicides were applied with the help of Knapsack sprayer 32days after sowing. All other agronomic practices were also applied as recommended for barley production in the study area.

Data collection

Weed data

The weed populations were counted two weeks after emergence until about 15 days before the expected crop harvest time. Population count was taken for broad-leaved and grass weed types using 0.5 m × 0.5 m quadrat thrown randomly at two places in each plot and was converted toper m^2 and calculated to evaluate the weed control efficiency. Weed data were calculated using the following formulae.

Weed Control Efficiency (WCE) was calculated as:

$$WCE = \frac{(WDC - WDT)}{WDC} \times 100$$

Where, WCE= Weed Control Efficiency; WDC=Weed population in weedy check; and

WDT= weed population in a particular treatment

Weed Index(WI) was calculated as:

$$WI = \left(\frac{X-Y}{X}\right) \times 100$$

Where, WI = Weed Index; X = Yield in complete weed free; and Y = Yield in a particular treatment

Agronomic Data

Phenology and Growth Parameters

Days to 50 % heading was recorded as the number of days required, counted from planting to reach 50 % of the plants heading. Days to physiological maturity was counted as the number of days required for 75% of the plants in a net plot to reach grain hardening, for the straw to be turned light yellow and become dry and brittle. Plant height (cm) was measured at harvest from 10 randomly pre- tagged plants in each net plot area from the base to the tip of the spike, excluding the awns of the main stem.

Yield and yield components

The total number and productive tillers were counted from 1m length of five randomly taken rows in each net plot area at harvest and were converted into per m^2. The number of grains per spike was determined from randomly taken 20 spikes per plot. Thousand grains were counted from the bulk of threshed produce from the net plot area and their weight was recorded. Total aboveground dry biomass (kg ha^{-1}) was determined by taking the weight of total harvest from each net plot area after sun-drying the whole above-ground biomass. Grain yield (kg ha) was measured after threshing the sun dried plants harvested from each net plot, adjusted at 12.5% grain moisture content.

Data analysis

Data were subjected to Analysis of Variance (ANOVA) using GenStat 18^{th} Version. Mean separation was carried out using Fisher's Protected Least Significant Difference (LSD) at 5% levels of significance.

Results and Discussions

Effect on weed parameters

Various broad leafed and grass weed species were observed in the experimental field. A total of 16 weed species belonging to 10 families were recorded; 10 species were broadleaf types where as six were found to be grass weed species (Table 1). Among grass weed species, *Phalaris paradoxa*,*Snodonia polystachia*,*Bromus pectinatus and Avena fatua* were the major ones. On the other hand, *Guizotia scarba*,*Galinsoga parviflora*,*Galium sporium*,*Polygonum nepalens and Erocustrum arabicum*were the major broad leaf weed species observed in the trial fields across the experimental locations. All of the weeds wee annuals.

Table 1. Dominant weeds species found in experimental fields

Scientific name	Family	Category	Life cycle
Galinsoga parviflora	Asteraceae	Broadleaved	Annual
Galium sporium	Rubiaceae	broadleaved	Annual
Guizotia scarab	Asteraceae	Broadleaved	Annual
Polygonum nepalense.	Polygnonaceae	Broadleaved	Annual
Trifolium rueppellianum	Leguminosae	Broadleaved	Annual
Oxalis latifolia	Oxalidaceae	Broadleaved	Annual
Commolina latifolia	Commelinaceae	Broadleaved	Annual
Erocustrum arabicum	Cruciferae	Broadleaved	Annual
Chenopodium album	Chenopodiaceae	Broadleaved	Annual
Anagallis arvensis	Primulaceae	Broadleaved	Annual
Phalaris paradoxa	Graminaea	Grass	Annual
Snodonia polystachia	Graminaea	Grass	Annual
Avena fatua	Graminaea	Grass	Annual
Bromus pectinatus	Graminaea	Grass	Annual
Digitaria abyssinica	Graminaea	Grass	Annual
Erogrostis spps	Graminaea	Grass	Annual

Total weed density

Density of total weeds was affected significantly by various weed management treatments. All weed management practices significantly (P = 0.05) reduced the weed population of prevailed weeds compared to weedy check (Table 2).

Statistical analysis of the data regarding weeds density m^{-2} at 15 days after application of weed management practices revealed that there were significant effects of different treatments on weed density. The highest weed density of 125.17m-215 days after treatment application was recorded fromthe weedy check whereas, the lowest weed density of 2.57$m^{-2}$was recorded from twice hand weeding. Twice hand weeding resulted in the lowest weed population of1.23m^{-2}90 days after spraying and was statistically at par with Solan + hand weeding and Solan spraying treatments; on the contrary, the highest weed population of 108.83m^{-2} was recorded from weedy check.

Among the different herbicidal treatments, lowest weed density was found in the application of Solan treatment. In general, all the weed management practices, significantly (P = 0.05) decreased weed population as compared to the weedy check at both 15 and 90 days after treatment weed population recording times. Twice hand weeding gave the highest reduction rate of 99.18% followed by Solan (95.45) andSolan + hand weeding(94.02%) treatments. Similar result was reported byEl-Kholy*et al.* (2013).

Table 2.Combined effect of different weed management methods on weed density at different growth stages of barley in Guji Zone.

Treatments	AWPBT 32DAE m^{-2}	AWPAT at 15 DAS m^{-2}	Reduction percentage (%)	AWPAT 90 DAS m^{-2}	Reduction percentage (%)	WDBM (g)	WCE (%)	WI (%)
Solan + Hand Weeding	91.12	3.67^{gh}	94.02	1.33^{f}	63.76	340^{g}	87.77	-10
Solan	111.12	3.89^{gh}	95.45	1.51^{f}	61.18	351^{g}	87.38	-9.63
Twice Hand Weeding	226.45	2.57^{h}	99.18	1.23^{f}	52.14	400^{g}	85.61	-
Ralon super + Hand Weeding	112.45	6.90^{fg}	94.66	3.75^{e}	45.65	559^{f}	79.90	4.17
Ralon super	112.11	8.91^{ef}	91.9	3.86^{e}	56.68	840^{e}	69.79	6.8
Agro 2,4-D	106.35	15.03^{c}	87.8	10.83^{c}	27.79	1503^{c}	45.94	14.93
Axial 045 EC X HW	102.67	13.40^{cd}	94.03	9.35^{c}	30.22	1549^{c}	40.30	17.03
Agro 2,4-D + Hand Weeding	104.33	11.28^{de}	86.10	6.67^{d}	40.87	1257^{d}	54.80	18.03
Axial 045 EC	93.62	21.19^{b}	68.73	13.5^{b}	26.34	1857^{b}	33.22	18.14
Weedy Check	102.47	125.17^{a}	-30.35	108.83^{a}	00.00	2781^{a}	00.00	54.87
LSD (5%)	Ns	3.33	-	1.52	-	79.76	-	-
CV (%)	14.3	5.5	-	8.2	-	6.0	-	-

Key AWPBT=Average weed population before spray (32DAE),AWPAT15= Average weed population at 15 DAS After spray, AWPAT 90=Average weed population at 90 DAS after spray,WDBM=weed dry biomass, WCE (%) = weed control efficiency, WI= weed index

Weed Control Efficiency (WCE %)

Both parameters – weed dry weight (g m$^-$2) and weed control efficiency (WCE %) were significantly affected by weed management treatments (Table 2). All treatments significantly reduced weed dry weight (g m^{-2}) as compared to weedy plot. This result is similar with the findings ofMegersa *et al.* (2017) who reported significant reduction in weed dry matter accumulation as a result of various weed control treatments. The maximum total weed dry weight (2781g) was recorded from un-treated plots. This weight might be attributed to a high weed density resulted from no weed management pursued which ultimately promoted theproliferous growth and development of weeds in these plots. Similarly, Megersa *et al*., (2017) reported that the maximum weed dry weight was recorded fromweedy control which was significantly higher than that of the other weed control practices. Gaurav Verma *et al*, (2018) also reported that the maximum total weed dry weight was observed in weedy check due to unchecked growth of weeds which compete for all the resources with crop until maturity.

In contrary, lower total weed dry weight (340g, 351g and 400g) was observed in Solan + hand weeding, Solan and twice hand weeding treatments, respectively. The lowest dry weight recorded in these treatments was due to removal of most of the weed plants that suppressed density of weeds and resulting in lower competition between the crop and weeds.

Results also showed that allthe treatments resulted in minimum weed population and weed biomass, i.e. gave good weed control efficiency as compared to the weedy check. These findings are in harmony with those reported by many researchers (Ahmad *et al*., 1991; Zand *et al*., 2006; El-Kholy and Abdelmonem, 2007; Knezevic *et al*., 2008; Shehzad *et al*., 2012) who concluded that the highest reduction in weed population and weed biomass of weeds differed according to weed management practices applied. The high efficacy of herbicides on weeds and combined with hand weeding than hand weeding alone in this study was supported by many research findings (Zand *et al.*, 2006; Marzouk, 2009; Marzouk *et al*., 2009; Shehazd *et al.*, 2012) who concluded that hand weeding is ineffective and expensive technique; so, herbicides used in on or another way are key component for weed management.

These results indicated that all the tested treatments completely controlled weeds in both seasons. For example, Solan + hand weeding and Solan gave the highest controlling rates against weeds (87.77%) and (87.38%), respectively, while Axial 045 EC gave lowest controlling rate against weeds (32.22), next to weedy check.The results agree with the findings of several researchers (Zand *et al*., 2006; Marzouk *et al*., 2009; Nasser Ud-din *et al*., 2011; Shehzad *et al*., 2012), who demonstrated that herbicides were more efficient and time saving than hand weeding.

Spike length (cm)

Analysis of variance revealed that spike length was significantly affected by weed management practices. Plots treated with Solan resulted in the highest spike length (8.18 cm) and statistically at par with the other treatments: Axial 045EC +HW, Ralon Super EW 144 +HW, Ralon Super EW 144, twice hand weeding and Solan + hand weedingwhereas the lowest (5.74 cm) was observed in the weedy check. The highest panicle length might be due to favorable environment that resulted from controlled weed and hence reduced competition with the crop for resources.This is similar with the findings of Khaliq (2013) who found out thatspike length was significantly influenced due to various weed management treatments.

Thousand grain weight (g)

Analysis of variance revealed that panicle length was also significantly affected by weed management practices and showed statistical variations among the treatments. All experimental treatments showedbetter weed control over the weedycheck. The maximum thousand grain weights (43.26g) was obtained from the plots treated with Solan + hand weeding followed by Solan (43.11g) and two times hand weeding (39.6) whereas the minimum (31.16g) was obtained from weedy check. This might be the result of easily accessible growth factors (nutrient, moisture and light) for individual plants that could retain more flowers and highernet assimilation rate in the absence of competition from weeds. Also the development of more vigorous leaves under low weed infestation might have helped to improve the photosynthetic efficiency of the crop and supported higher number of grains. Similar result was reported by (Chaudhry *et al*., 2008).Bostrom and Fogelfors, (2002) also reported that lowest grains weight found in un-treated plots might be due to severe weed competition between the weeds and crop which could prominently reduce the nutrient mobility towards grains and affected the grain development potential of barley crop. On the other hand, higher values of yield attributes were attained due to increased synthesis and translocation of metabolites for panicle development and grain formation. Besides, thousand grain weightwas also higher in treated plots because of high mobilization of nutrients from source to sink.

Grain yield

Results showed that there was significant difference among treatments in grain yield. Solan + Hand Weeding and Solan alone treatments gave maximum grain yield of 4088 and 4074 kg ha^{-} , respectively and were statistically at par with each other.This might be due to effective weed control achieved by these treatments that in turn reduced crop-weed competition for nutrients and other resources. In contrary, the lowest yield (1677 kg ha^{-1}) was recorded in weedy check.The lowest grain yield might be attributed to maximum infestation of weeds that could heavily compete with the crop for resources which adversely affected grain yield. This is in harmony with the work of Shoeran *et al* (2013) who reported that the presence of weeds throughout the growing season brought about 37.2 and 33.1% reduction in grain yield as compared to weed-free check. Similarly, Megersa*et al* (2017)found outthat weeds compete with crop plants for various resources such as water and nutrients, resulting in low yields. Gaurav Verma*et al*(2018) also reported that high weeds intensity and more competition time with crop plants cause more reduction in crop yield. This also indicates that weeding at proper time definitely enhances crop yields. Post-emergence application of Axial 045EC and Agro 2, 4-D alone showed lower (3042 and 3046 kg^{-1}) grain yield as compared with any other treatments except the weedy check.

The superior performance of Solan herbicide solely or in combination with hand weeding is due to the fact that it has broad spectrum activity, effective against bothbroadleaf and grass weeds. Combination of management practices provided better yield as compared with sole management practices. This yield performance might be due to effective weed control provided by integration of management options. This is in agreement with the findings of Singh, 2014; Kewat, 2014 and Megersa *et al*., 2017.

Table 1.Combined effect of different weed management methods on agronomic parameters of barley in Guji Zone.

Treatments	Days to Heading	Days to Maturity	Plant Height cm)	Spike Length	TKW (g)	Grain Yield (kg/ha)
Solan+ Hand Weeding	87.25	131.8^{ab}	115.4	7.64^{ab}	43.26^{a}	4088^{a}
Solan	87.25	131.6^{ab}	110.0	8.18^{a}	43.11^{a}	4074^{a}
Weed free	87.92	133.3^{a}	113.7	7.82^{ab}	39.60^{ab}	3716^{ab}
Ralon super + Hand Weeding	88.17	130.5^{bc}	111.2	7.84^{ab}	38.26^{b}	3561^{ab}
Ralon super	87.08	131.8^{ab}	113.1	7.83^{ab}	39.33^{ab}	3463^{bc}
Agro 2,4-D	87.33	130.2^{bc}	113.5	7.81^{ab}	36.15	3161^{bc}
Axial 045 EC + Hand Weeding	87.00	133.1^{a}	115.2	7.88^{ab}	37.54^{b}	3083^{c}
Agro 2,4-D + Hand Weeding	88.17	129.2^{c}	114.3	7.57^{b}	73.26^{b}	3046^{c}
Axial 045 EC	88.5	131.8^{ab}	111.0	7.84^{ab}	39.36^{ab}	3042^{c}
Weedy Check	87.5	132.1^{a}	110.8	5.74^{c}	31.16^{c}	1677^{d}
LSD (5%)	Ns	1.87	ns	0.58	4.81	306
CV (%)	0.4/14.7	1.8	6.1/2.2	9.5	15.5	22.8

Partial Budget Analysis

Attainment of maximum profitability lies not only in reducing use of N and blended fertilizers per unit area but also in lowering costs per unit crop production through higher yields. Farmers are profit-oriented, and therefore, they are interested in net returns than the gross returns. To assess the cost and benefit associated with different treatments, the partial budget analysis technique of CIMMYT (1988) was applied. From the final grain yield data, the gross yields of ten treatments were obtained. Then the recommended level of 10% was reduced from all treatments to obtain net grain yield. Net grain yield was multiplied by market price to obtain gross field benefit. All variable costs were calculated based on the current price of the herbicides as per the information obtained from local markets and unions. The cost of chemicals and labors for hand weeding are illustrated in table 4. The selling price of barley at the local market around Bore area was taken as Birr 3.6 kg^{-1} for grain yield. Variable costs were summed up and subtracted from gross benefits, which was taken as net benefit.

As indicated in Table 4, the highest net benefit of 145304Birr ha^{-1} with marginal rate of return (MRR) of 34.35% was obtained from application of Solan at the rate of 0.5Lha^{-1}. On the other hand, the lowest net benefit of 60012 Birr ha^{-1} was obtained for the control treatment (weedy check). Thus, applications of Solan alone and combined with hand weeding is economically feasible as compared to the other treatments because the highest net benefit and the marginal rate of return was above the minimum level (100%).

In similar studies, Megersa (2017) and Gaurav Verma (2018) indicated that an estimated net income for weed management is attractive as compared to growing barley without application of weed management practices, including the use of herbicides.

Table 4. Summary of partial budget analysis of the effects of integrated weed managementpractices on barley in Guji Zone

Treatment	Total grain yield (kg ha^{-1})	Adjusted straw yield (kg ha^{-1})	Total revenue (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Marginal rate of return (%)
Weedy Check	1677	1667	60012	0	60012	0
Agro 2,4-D	3161	3151	113436	600	112836	140.86
Ralon super	3463	3453	124308	975	123333	419.88
Axial 045 EC	3042	3032	109152	1000	108152	D
Solan	4074	4064	146304	1000	145304	51.24
Agro 2,4-D + Hand Weeding	3046	3036	109296	1725	107571	D
Ralon super + Hand Weeding	3561	3551	127836	1925	125911	366.8
Axial 045 EC + Hand Weeding	3083	3073	110628	1975	108653	D
Solan + Hand Weeding	4088	4078	146808	1975	144833	25.87
Two hand weeding	3716	3706	133416	3375	130041	D

Conclusion

Based on the results of experimentation, it can be concluded that all weed control treatments tested in this experiment proved to be effective in controlling the weeds in barley and gave significantly higher grain yield over weedy check.The highest net return (145304 Birr) with a marginal rate of return (51.24 Birr) was obtained from the application of Solan. Thus, the application Solan alone or interchangeably with Solan + hand weeding which have net return (144833 birr) with a marginal rate of return (25.87 Birr) should be promoted to farmers for barley weed management on the highlands of Guji Zone.

References

Ahmad, K., Z. Shah, I. Khan, M. Khan and M. Q. Khan .1993.Effect of post –emergence herbicides application and hand weeding on wheat and weed pressure.*Pak. J. Weed Sci. Res,* 6 (1-2): 40-45.

Ashiq, M., N. Muhammad and N. Ahmad. 2007.Comparative efficacy of different herbicides against broad leaf weeds in wheat. *Pak. J. Weed Sci. Res*. 13(3-4): 149-156.

Bostrom, U. and H. Fogelfors. 2002. Response of weeds and crop yield to herbicide dose decision support guidelines. *Weed Sci.* 50(2): 186-195.

Chaudhary, S.U., M. Hussain, M. A. Ali and J. Iqbal. 2008. Effect of weed competition period on yield and yield components of wheat. *J. Agric. Res*. 46(1):47-54.

Chaudhry, S., M. Hussain, M. A. Ali and J. Iqbal. 2008. Efficacy and economics of mixing of narrow and broad leaved herbicides for weed control in wheat. *J. Agric. Res.* 46(4): 355-360.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF, 79 pp.

CSA.2021. The Federal Democratic Republic of Ethiopia, Agricultural Sample Survey 2020/2021 (2013 E.C.) Vol. I. Report on Area and production of major Crops (Private peasant holdings ‘‘*Meher’’* season), Statistical Bulletin 590, Addis Ababa, Ethiopia.

Dessale, M., Beshir, D. and Tegegne, D. 2017. *Technical efficiency in teff production: the case of smallholder farmers in Jamma District, South Wollo Zone,* Doctoral dissertation, Haramaya University, Ethiopia.

EL-Kholy, R.M.A. and A.E. Abdelmonem. 2007. Evaluation of post emergence herbicides and hand weeding treatments for the control of annual broadleaved weeds in wheat. *J. Agric. Res,* Kafr ELSheikh Univ., 33(1): 229-248.

El-Kholy, R.M.A., W.L. Abouamer, and M.M. Ayoub, 2013.Efficacy of some herbicides for controlling broad-leaved weeds in wheat fields.*Journal of Applied Sciences Research*, 9(1): 945-951

Esheteu Bekele, E., Azerefegne, F and Abate, T. 2006. Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia.Planning Workshop, 13-15 October 2003, Melkassa Agricultural Research Center, EARO.Jointly organized by the Association for Advancement of IPM (ASAI) and the Ethiopian Agricultural Research Organization (EARO). DCG, Miljøhuset, Oslo.

Gaurav Verma, Vivek, RK Naresh, Lali Jat, DK Sachan and Richa Tiwari.,2018.Effect of weed management on weed dynamics, growth and yield of barley (*Hordeum vulgare* L.) under inceptisol of western Uttar Pradesh.*International Journal of Chemical Studies*, 6(6): 249-259

Georgiev M.2015. Investigation on wheat and barley weed infestation in the Stara Zagora region and effective solutions for chemical weed control. PhD thesis.Chirpan.

Hassan, G. and K.B. Marwat. 2001. Integrated Weed Management in Agricultural Crops. Proc. National Workshop on Technologies for Sustainable Agriculture, Sep.24-26, 2001 NIAB, Faisalabad, Pakistan, pp.27-34 (ISBN 969-8038-09-4).

Kewat, M. L. 2014. Improved weed management in Rabi crops. National Training on Advances in Weed Management pp. 22-25.

Khaliq A, Matloob A, Ihsan MZ, Abbas RN, Aslam Z, Rasul F. 2013. Supplementing herbicides with manual weeding improves weed control efficiency, growth and yield of direct seeded rice. *Int J Agri Biol*, 15(2):191-199.

Knezevic, M., L. Ranogajec and D. Samota, 2008.Effect of soil tillage and herbicides on weeds and winter wheat yields. Cereal Res. Comm., 36: 1403-1406.

Kuma, B., Ayele, S., Teklewolde, T. and Molla, Y. 2011.Achievements in barley technology transfer and extension in Ethiopia. *Barley Research and Development in Ethiopia*, *377*.

Marwat, K.B., Saeed, M., Hussain, Z., Gul, B. and Rashid, H. 2008. Study of various herbicides for weed control in wheat under irrigated conditions. *Pak. J. Weed. Sci. Res*, *14*(2), pp.1-8.

Marzouk, E.M.A., 2009. Studies on the filed efficiency and side effects of some herbicides. Ph.D. Thesis. Fac. of Agric., Al-Azhar Univ., pp: 191.

Marzouk, E.M.A., M.F. Abdel-Lateef, F.A.F. Ali and S.A. Abou-Donia, 2009.Evaluation of some herbicides in controlling weeds in wheat (Triticum aestivum L.).*J. Agric. Mansoura Univ*., 34(4): 2901-2913.

Megersa Kebede, Tigist Bidira, Geleta Gerama, Girma Chemeda, Kasa Mamo, Megersa Debela and Hailu Fayisa. 2017. Effect of Various Weed Management Options on Weeds and Yield of Barley (*Hordeum vulgare* L.) at Shambo and Gedo, Western Oromia. *Journal of Biology, Agriculture and Healthcare, 7(21)* 2224-3208

Nasser-Ud-din, G.M., M.A. Shehzad and H.M. Nasrullah.2011. Efficacy of various pre and postemergence herbicides to control weeds in wheat. *Pak. J. Agric. Sci*, 48(3):185-190.

Shehzad, M. A., Nadeem, M. A., Sarwar, M. A., Naseer-udDin, G. M. and Ilahi, F. 2012.Comparative efficacy of different post-emergence herbicides in wheat (*Triticum aestivum* L.).*Pakistan Journal of Agricultural Sciences*, 49 (1): 27-34.

Shoeran S, Punia S, Yadav, Ashok, Samunder Singh. 2013. Bio-efficacy of pinoxaden in combination with other herbicides against complex weed flora in wheat. *Indian J Weed Sci.* 45:90-92.

Singh, R. 2014. Weed management in major kharif and rabi crops. National Training on Advances in Weed Management. pp. 31-40.

Stroud, A. 1989. Weed Management in Ethiopia: an extension and training manual. FAO, Rome, Italy.

Zand, E.; Baghestani, M.A.; Soufizadeh, S.; PourAzar, R.; Veysi, M.; Bagherani, N.; Barjasteh, A.; Khayami, M.M.; Nezamabadi, N. 2006. Broadleaved weed control in winter wheat (Triticum aestivum L.) with post-emergence herbicides in Iran. *Crop Protection*, 26(5): 7

Critical time of fungicide spray for the management of stem rust (*Puccinia graminis* f.sp. *tritici*) and its effect on grain yield, yield components and protein content of Durum wheat (*Triticum durum* L.)

Ermias Teshome* and Dagne Kora
Sinana Agricultural Research Center
***Corresponding author: P.O. Box: 208, E-mail**: ermiastafa@gmail.com

Abstract

Stem rust caused by Puccinia graminis *f.sp.* tritici *is one of the most important biotic constraints of durum wheat production in Ethiopia. It causes substantial yield losses if not properly controlled. Therefore, this discusses the appropriate fungicide spray time for stem rust management and effect of fungicide spray on grain protein content and the financial profitability of the fungicide spray practice for the management of stem rust. The field experiment was designed using RCB design in three replications involving two durum wheat varieties (Bulala and Bekelcha) and Rex® Duo sprayed at different time and frequency. The trial was conducted during the main season at Sinana Agricultural Research Centre (SARC) for two seasons (2020/21-2021/22). Results from this study revealed significant variations between fungicide spray timing and frequency on disease and agronomic parameters. Rex® Duo applications have reduced the stem rust severity significantly across all durum wheat varieties and spray times. The highest mean stem rust severity of 40.19% was recorded from unsprayed Bekelcha variety while the lowest stem rust severity of 0.81% was recorded from Bekelcha variety sprayed 3 times at 14 days interval before disease occurrence.. The highest protein content of 13.10% was recorded from Bekelcha variety sprayed twice at 14 days interval with the first spray being before disease occurrence and the lowest grain protein content (11.77%) was recorded from Bulala variety sprayed 3 times at 14 days interval with the first spray being before disease occurrence.. Correlation analysis showed that stem rust severity had significant strong negative correlation with TKW (r = -0.54922; P<0.0001) and grain yield (r = -0.76219; P<0.001). Similarly, simple regression model has depicted the association between the parameters was significant and explained by regression lines. The highest MRR of 4928.52% and 4456.78% were recorded from Bulala variety sprayed twice at 14 and 21 days interval, respectively with the first spray being before disease occurrence. Therefore, wheat growers in Bale and similar agro-ecologies are recommended to produce Bulala variety sprayed 2-3 times at 14 days interval, the first spray be started immediately as the first stem rust pustule is observed on the plant surface of the surrounding farms.*

Keywords: Stem rust, Disease severity, Durum wheat, Fungicide, Fungicide spray time

Introduction

Durum wheat (*Triticum durum* or *Triticum turgidum* subsp. *durum*) is among the very important food crops grown in the world, with an estimated 36 million tons of annual global production (Chris, 2017). Similarly, it is one of the most vital cereal crops widely cultivated in a wide range of altitudes in Ethiopia (Hailu, 1991; Ashenafi and Alemayehu, 2019). It is considered as one of the main staple food crops for about 36% of the Ethiopian population (CIMMYT, 2005; CSA, 2017/18). However, its production and quality is highly affected by various abiotic and biotic factors. Stem rust (*Puccinia graminis* f.sp. *tritici*) is becoming the major biotic factors constraining durum wheat production in Ethiopia (Ashenafi and Alemayehu, 2019). In the global scale, cereal rusts are the most destructive diseases of wheat in general and durum wheat in particular (Shaw, 1963; Haldore *et al.*, 1982). Stem rust or also called black rust is caused by the basidiomycete fungus *Puccinia gramini* sf. sp. *tritici*, has been the most devastating of all wheat diseases under favorable conditions. It mainly attacks wheat but can also infect many other small cereals including barley, oat, rye and forage grasses (Roelfs and Groth 1987). It is capable of severely affecting durum wheat (*Triticum turgidum L. var. durum*). Traditionally, it was assumed that the occurrence of stem rust epidemics is observed in areas where wheat is commonly cultivated (Van der Plank 1963). Fear for this pathogen has increased again after the emergence of Ug99 (TTKSK) race in Uganda in 1998, because this race and its derivatives overcame a number of resistance genes and converted the resistant cultivars in to susceptible (Pretorius *et al.,* 2000; Jin *et al.,* 2007, 2008).

Highlands of Bale is considered as one of the evolution center of stem rust races in Ethiopia because of the year round production of wheat. The second most dominant and devastative stem rust race was TKTTF evolved in Arsi and Bale areas and caused localized stem rust epidemics in Bale and Arsi in 2013 that has caused 100% loss of grains in most of the fields (Hailu *et al.,* 2015). To combat this challenging factor, use of fungicide is one of the most common durum wheat production packages in Bale. Currently, Bale farmers spray fungicides before the stem rust occurrence to protect the crop before its symptom appears on plants. Therefore, this study was initiated to determine the appropriate fungicide spray time, determine the financial profitability of fungicide spray practice and to examine the effect of stem rust on protein content of durum wheat.

Materials and Methods

Description of experimental area

The field experiment was conducted at Sinana Agricultural Research center (SARC) on-station trial site Bale, Ethiopia during 2020/21 and 2021/22 main cropping seasons. SARC is located at 463 km distance from the central city Addis Ababa to the south-east. Geographically SARC is located at 07^{o} 07' N latitude and 40^{o} 10'E longitude on an elevation of 2400 masl. The area receives 750-1000 mm mean annual rain fall and have mean annual temperature of 9-21 ^{o}C, (Nefo *et al.,* 2008).

Treatments and design

The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. Durum wheat varieties Bulala and Bekelcha that have moderate resistance and susceptible reactions, respectively to stem rust were used in this study.

Table 1: Treatment combination

Treat.	Treatment combination
1	Bulala with no fungicide
2	Bulala with once at tillering before disease occurrence
3	Bulala with twice at tillering at 14 days interval with the first spray starts before disease occurrence
4	Bulala with three times at tillering at 14 days interval with the first spray starts before disease occurrence
5	Bulala with twice at tillering at 21 days interval with the first spray starts before disease occurrence
6	Bulala with three times at tillering at 21 days interval with the first spray starts before disease occurrence
7	Bulala with once after the first observable symptom
8	Bulala with twice after the first observable symptom at 14 days interval
9	Bulala with three times after the first observable symptom at 14 days interval
10	Bulala with twice after the first observable symptom at 21 days interval
11	Bulala with three times after the first observable symptom at 21 days interval
12	Bekelcha with no fungicide
13	Bekelcha with once at tillering before disease occurrence
14	Bekelcha with twice at tillering at 14 days interval with the first spray starts before disease occurrence
15	Bekelcha with three times at tillering at 14 days interval with the first spray starts before disease occurrence
16	Bekelcha with twice at tillering at 21 days interval with the first spray starts before disease occurrence
17	Bekelcha with three times at tillering at 21 days interval with the first spray starts before disease occurrence
18	Bekelcha with once after the first observable symptom
19	Bekelcha with twice after the first observable symptom at 14 days interval
20	Bekelcha with three times after the first observable symptom at 14 days interval
21	Bekelcha with twice after the first observable symptom at 21 days interval
22	Bekelcha with three times after the first observable symptom at 21 days interval

The disease severity gradient was created by spraying a fungicide Rex® Duo at a rate of 0.5 l/ha in different combinations with the two durum wheat varieties (Table 1). The size of each plot was 1.8m x 1.5m which will contain 9 seeding rows. Between row, plot and block spaces were 0.2m, 1m and 1.5m, respectively. The seed rate was 150 kg/ha and fertilizers rates were 100 kg/ha NPS and 50 kg/ha UREA. All other field management practices including weeding were applied equally for all plots as non experimental variable.

Collected data

Stem rust severity data were collected on a plot bases according to the modified cobb-scale method (Peterson *et al.*, 1948). Thousand kernel weight (TKW (g)) was measured as a weight of 1000 randomly sampled grains. Whereas, grain yield (kg/ha) was measured as a total weight of durum wheat grains harvested from the five middle rows and adjusted to 12% moisture level. Effect of stem rust on durum wheat grains protein content was assessed by using near-infrared spectrometry at SARC grains quality laboratory.

Partial budget analysis

The overall production costs and benefits from each treatment were investigated following the method developed by CIMMYT (CIMMYT, 1988). According to this method, the partial budget analysis was performed through considering total variable costs (TVC). Sale revenue (SR) was calculated as total income from each treatment from the sale of durum wheat grains at 39 Ethiopian Birr (ETB) per kilogram of the grains. The marginal cost (MC) was computed from variable costs and marginal benefit (MB) was calculated as a difference between marginal costs sale revenue. The marginal rate of return (MRR) was calculated considering the SR and TVCs. The total costs spent on fungicide purchase, water purchase and transport, rent of sprayer, labor cost for fungicide spray, water supply and cleaning of equipments were the main TVCs considered in this analysis.

$\mathrm{MRR} = \frac{\mathrm{DNI}}{\mathrm{DIC}} \mathrm{x}\, 100$ ………………………………………….. 1 (CIMMYT, 1988)

Where: - DNI-Difference in net income compared with control,

DIC- Difference in input cost compared with control.

Data management and statistical analysis

Independent variables from each treatment were analyzed using the logistic model [ln[(Y/1Y)], (Van der Plank, 1963) following the statistical analysis system (SAS) Procedure (SAS, 1998). The mean separation technique LSD was used with a probability of 5% to identify the statistical difference between the means of the treatments. The area under the disease progress curves (AUDPC) and apparent infection rate (r) was calculated (Shaner and Finney, 1977). ANOVA was performed for the disease severity, AUDPC (Shaner and Finney, 1977), apparent infection rate (r) (Shaner and Finney, 1977), TKW and grain yield (kg/ha) according to the SAS procedure (SAS, 1998). Correlation and regression analyses were employed to assess the relationships between disease and agronomic parameters.

$\mathrm{AUDPC} = \sum_{\mathrm{i-1}}^{\mathrm{n-1}} 0.5(\mathrm{x_{i+1}} + \mathrm{x_i})(\mathrm{t_{i+1}} - \mathrm{t_i})$……………3 (Shaner and Finney, 1977)

Where, X_i= the PSI of disease at the i^{th} assessment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

Results and Discussions

The over years combined analysis of variance have shown statistically significant ($P \leq 0.05$) differences between fungicide spray time treatments on stem rust severity. In this trial, fungicide spray time has significantly influenced the progress of stem rust severity on the two varieties almost similarly (Fig. 1). At the initial stage, although the difference between treatments for stem rust severity was statistically significant ($P \leq 0.05$), the difference was highly negligible. This is common that at the early stage of disease development, the difference between treatments is small (Taffa and Balcha, 2022). The highest mean stem rust severity of 40.19% was recorded from unsprayed Bekelcha variety and the second highest stem rust severity of 29.23% was recorded from unsprayed Bulala variety (Table 2). In contrary, the lowest stem rust severities of 0.81% and 0.88% were recorded from Bekelcha variety that has received Rex® Duo sprays of 3 times at 14 days interval before disease symptom is developed on plants and 2 times at 21 days interval disease symptom is developed, respectively (Table 2).

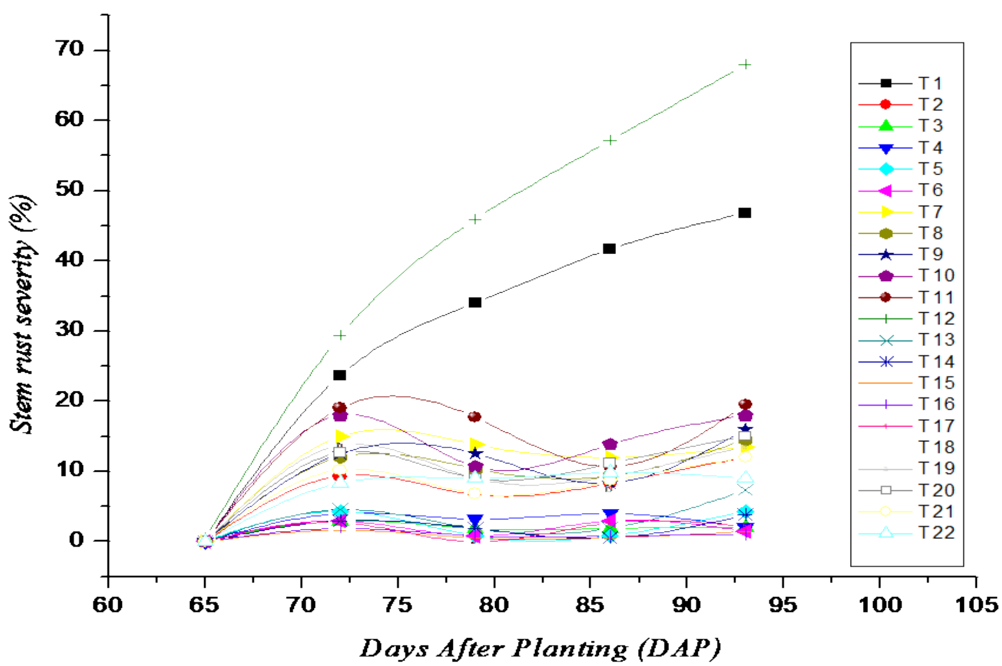


Fig.1: Stem rust severity progress as influenced by fungicide spray timing

Result similar to this was previously reported by Tadesse *et al.,* (2010), where a fungicide Tilt® 250 E.C. highly reduced the severity of stem rust infection on wheat. The role of fungicides in reducing the stem rust severity pressure and the time of fungicide application clearly created variability on stem rust disease severity and grain yield productivity of durum wheat. Experiments conducted so far focused on determining wheat growth stages at which spraying has to be commenced. In Kenya, it was reported that the lowest AUDPC was recorded from plots sprayed by fungicide at tillering and flowering growth stages sequentially (Wanyera *et al.*, 2016). However, the occurrence of stem rust these days is surprisingly at very early stage of wheat growth before tillering. To fill this gap, the laboratory experiment conducted resulted in very law level of rust when fungicide was applied before inoculation of the pathogen on the host plant compared with fungicide application after inoculating the pathogen on the host plant (Mueller *et al.,* 2004). In line with this, spraying the fungicide when very small level of stem rust pustule is observed on wheat is recommended (Ashenafi *et al.,* 2018).

ANOVA for grain protein content (%) showed the existence of statistically significant ($P\leq0.05$) difference. The highest protein content (13.10%) was recorded from Bekelcha variety that received fungicide application twice at 14 days interval with the first spray being before disease occurrence. Whereas, the lowest grain protein content (11.77%) was recorded from Bulala variety that received the fungicide spray 3 times at 14 days interval with the first spray being before disease occurrence (Table 2). As described by several researchers and this study as well, the effect of fungicide spray on grain protein content is reverse, *i.e.*, fungicide spray reduces the total grain protein content. In line with this result, the report indicated that stem rust increased the total grain content in durum wheat and low total grain protein was recorded from fungicide sprayed plots (Ashenafi and Alemayehu, 2019). Similarly, stripe rust and leaf rust resulted in shriveling of grains that results in an increased grain protein content (Ochoa and Parlevliet, 2007; Peturson *et al.*, 2011). Similarly, ANOVA showed statistically significant ($P\leq0.05$) difference between treatments for agronomic parameters evaluated. The highest TKW (50g) was recorded from Bekelcha variety sprayed twice at 14 days interval with the first being before disease symptom is observed. The second highest TKW (49.6g) was recorded from a variety Bekelcha that received fungicide sprays 3 times at 14 days interval and 2 times at 21 days interval with the first spray before disease symptom. Fungicide application and timing of fungicide spray highly influenced the TKW of each variety.

Table 2: Influence of fungicide spray on stem rust severity, TKW (g) and grain yield (kg/ha) at Sinana

Treatment	Initial SR (%)	Mean SR (%)	Final SR (%)	GPC	TKW (g)	Yield (q/ha)

Bulala 3A1stOS21DI	0^{a}	13.37^{c}	19.5^{c}	12.1^{bcde}	41.6^{gh}	4580.4^{abc}
Bekelcha 2A1stOS14DI	0^{a}	9.1f^{g}	13.5^{cd}	12.27^{abcde}	43.6^{efgh}	4167.3^{abcd}
Bulala 2A1stOS21DI	0.07^{b}	12.11^{d}	18^{c}	12.33^{abcde}	40.4^{h}	3682.4^{bcd}
Bulala 3A1stOS14DI	0.07^{b}	9.88^{f}	16^{c}	12.3^{abcde}	41.47^{h}	3804.9^{abcd}
Bulala no spray	0^{a}	29.23^{b}	46.83^{b}	12d^{e}	40.87^{h}	3324.7^{cd}
Bulala 2A1stOS14DI	0^{a}	9.23f^{g}	14.5^{c}	11.93^{e}	43.5^{efgh}	3752.7^{abcd}
Bekelcha 2A1stOS21DI	0^{a}	7.53^{h}	12cd^{e}	12.33^{abcde}	46.67^{abcde}	3989.8^{abcd}
Bulala 1A1stOS	0^{a}	10.87^{e}	13.5^{cd}	11.97^{de}	42.4^{fgh}	3831.6^{abcd}
Bekelcha 1A1stOS	0.27^{d}	8.29^{g}	12^{cde}	12.93^{abcd}	47.6^{abcd}	3554.9^{bcd}
Bekelcha no spray	0.5^{e}	40.19^{a}	68^{a}	12.83^{abcde}	44.73^{defg}	4585.6^{abc}
Bulala 1TBDO	0^{a}	7.25^{h}	12^{cde}	12.07^{bcde}	45.53^{cdef}	2986.7^{d}
Bekelcha 3A1stOS14DI	0^{a}	9.57^{fg}	15^{c}	12.87^{abcde}	45.33^{def}	4108.2^{abcd}
Bekelcha 3T21DI1stSBDO	0^{a}	1.49^{ijkl}	2.13^{cdefg}	12.27^{abcde}	47.87^{abcd}	4435.1^{abc}
Bekelcha 1TBDO	0^{a}	3.12^{i}	7.33^{cdefg}	12.43^{abcde}	49.00^{abc}	4752^{ab}
Bekelcha 3A1stOS21DI	0^{a}	7.23^{h}	9^{cdefg}	12.5^{abcde}	47.8^{abcd}	3731.6^{bcd}
Bulala 3T14DI1stSBDO	0^{a}	2.64^{ij}	2^{cdefgh}	11.77^{cdef}	44.67^{defg}	4859.1^{ab}
Bekelcha 2T14DI1stSBDO	0^{a}	1.83^{ijk}	3.8^{cdefg}	13.1^{a}	50.00^{a}	4768.7^{ab}
Bulala 2T21DI1stSBDO	0.13^{c}	2.07^{ij}	4.33^{g}	12.23^{abcde}	46.47^{bcde}	5129.3^{a}
Bekelcha 3T14DI1stSBDO	0^{a}	0.81^{ijkl}	1.4^{cdefg}	12.87^{abcde}	49.60^{ab}	4554.4^{abc}
Bulala 2T14DI1stSBDO	0^{a}	1.73^{ijk}	2^{cdefgh}	12.53^{abcde}	45.33^{def}	4349.1^{abcd}
Bekelcha 2T21DI1stSBDO	0^{a}	0.88^{ijkl}	0.93^{cdefg}	13.03^{abc}	49.60^{ab}	4691.8^{abc}
Bulala 3T21DI1stSBDO	0^{a}	1.63^{ijk}	1.47^{cdefg}	12de	46.33^{bcde}	4484.8^{abc}
CV(%)	4.6	7.11		5.14	4.64	20.27
LSD$_{(0.05)}$	0.03	0.74		1.05	3.47	1396.60

Note: Figures designated with the same letters within the same column are not statistically significant at P≤0.05; SR- Stem rust; GPC- Grain Protein Content; TKW-Thousand Kernel Weight

This was supported by the result from previous experiment when stem rust caused TKW losses ranging 15.3-19.3% on wheat at Sinana (Tadesse *et al.* (2010). Similarly, a TKW advantage of 38.67%-41.6% compared with unsprayed plot was reported when fungicide was sprayed at tillering and flowering stages (Wanyera *et al.*, 2016). Regarding grain yield, the highest grain yield of 5129.3kg/ha and 4859.1kg/ha was recorded from Bulala variety that received fungicide sprays 2 times at 21 days interval and 3 times at 14 days interval, respectively with the first spray before disease symptom observed. The effect of stem rust on grain yield was reported by several authors. Ashenafi *et al.* (2018), reported that stem rust reduced the grain yield of durum wheat tremendously in the absence of fungicide spray. Similarly Singh *et al.* (2008) reported that stem rust caused yield losses to the economic level regardless of the level of host resistance of the cultivars.

Correlation and Regression analysis

Correlation analysis

The Pearson's simple pair-wise correlation analysis was employed to assess the associations among the disease and agronomic parameters. The correlation between stem rust and TKW was found to be statistically very highly significant ($P \leq 0.0001$), strong and negative (r = -0.54922; $P<0.0001$) (Table 3). Similarly, there was highly significant ($P \leq 0.001$), strong and negative correlation (r = -0.76219; $P<0.001$) between stem rust and wheat grain yield (Table 3). It had long been reported how stem rust negatively influences agronomic parameters such as TKW and grain yield. Grain yield and TKW are highly negatively affected by stem rust (Ochoa and Parlevliet, 2007; Ashenafi and Alemayehu, 2019). On the other hand, although there was not statistically significant correlation between grain protein content and stem rust, the correlation was found to be positive (Table 3). Whereas, grain protein content had significant negative correlation with TKW (r=-0.36711; $P<0.05$) and durum wheat grain yield (r=-0.42739; $P<0.001$). This result was in line with Ashenafi and Alemayehu, (2019); they reported that the correlation of grain protein content with grain yield and TKW was strong and negative.

Table 3: Correlation between stem rust and agronomic parameters as detected by Pearson's simple pair-wise correlation analysis

	Stem rust (%)	GPC (%)	TKW (g)	Grain yield (kg/ha)
Stem rust (%)	1	0.19921^{NS}	-0.54922***	-0.76219**

GPC	1	-0.36711*	-0.42739**
TKW (g)		1	0.27273**
Grain yield (kg/ha)			1

Regression analysis

Simple regression analysis model was used to assess the relationship of stem rust with TKW, grain yield and grain protein content. The model showed that there was a significant association ($P \leq 0.05$) between grain yield and stem rust severity (Figure 2). The relationship between these parameters was explained by the regression line.

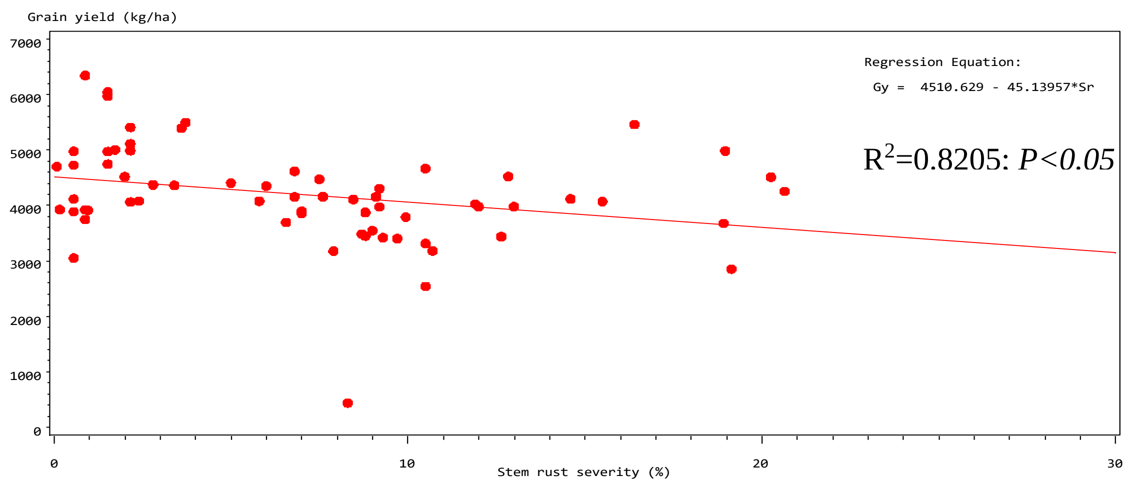


Fig. 2: Relationship between stem rust and wheat grain yield as explained by the regression line

Whereas, the relationship between above ground biomass yield and stem rust was assessed in similar way by using the simple linear regression model and it showed the existence of statistically significant association between the parameters and it has been explained by the regression line (Figure 3).

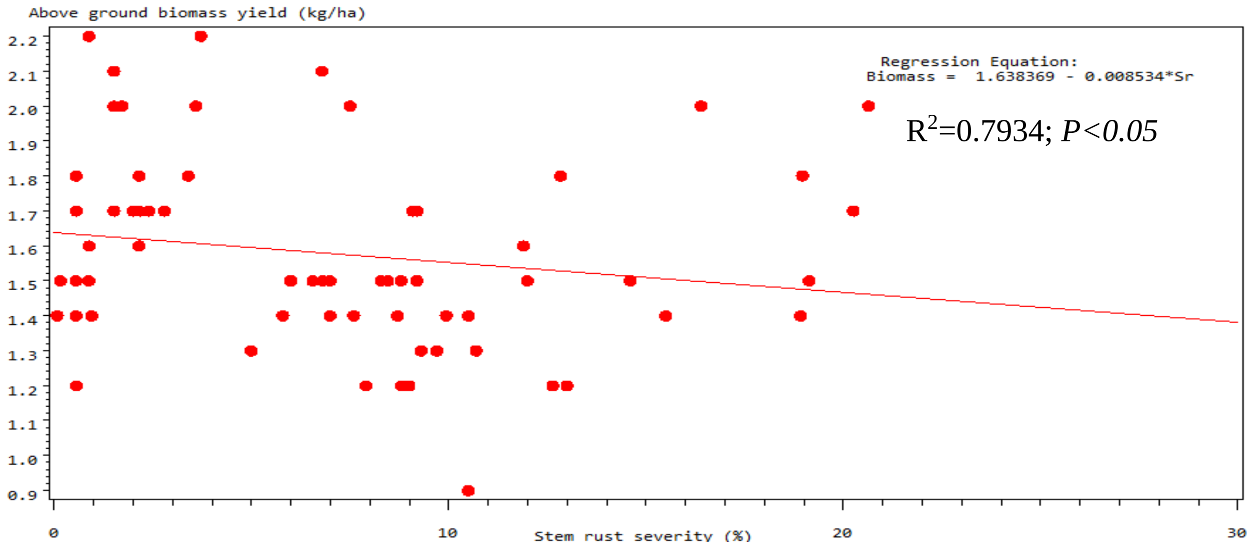


Fig. 3: Relationship between stem rust and above ground biomass yield as explained by the regression line

Financial Profitability analysis

The financial profitability analysis revealed that the highest MB of 198,498.2 ETB/ha was obtained from Bulala variety that was sprayed twice at 21 days interval with the first spray being before disease occurrence; which is followed MB of 187,188.2 ETB/ha that was calculated from Bulala variety sprayed 3 times at 14 days interval with the first spray being started before disease occurrence (Table 4).

Table 4: Effect of fungicide application regime for stem rust management in durum wheat production on financial profitability

Treatment	Yield (kgha^{-1})	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
Bulala 3A1stOS21DI	4580.40	178635.6	2316.75	176318.9	2013.84
Bekelcha 2A1stOS14DI	4167.3	162524.7	1544.50	160980.2	-1156.24
Bulala 2A1stOS21DI	3682.4	143613.6	1544.50	142069.1	803.22
Bulala 3A1stOS14DI	3804.9	148391.1	2316.75	146074.4	708.37
Bulala no spray	3324.7	129663.3	0.00	129663.3	0
Bulala 2A1stOS14DI	3752.7	146355.3	1544.50	144810.8	980.74
Bekelcha 2A1stOS21DI	3989.8	155602.2	1544.50	154057.7	-1604.45
Bulala 1A1stOS	3831.6	149432.4	772.25	148660.2	2459.94
Bekelcha 1A1stOS	3554.9	138641.1	772.25	137868.9	-5305.21
Bekelcha no spray	4585.6	178838.4	0.00	178838.4	0
Bulala 1TBDO	2986.7	116481.3	772.25	115709.1	-1806.95
Bekelcha 3A1stOS14DI	4108.2	160219.8	2316.75	157903.1	-903.65
Bekelcha 3T21DI1stSBDO	4435.1	172968.9	2316.75	170652.2	-353.35

Bekelcha 1TBDO	4752	185328	772.25	184555.8	740.36
Bekelcha 3A1stOS21DI	3731.6	145532.4	2316.75	143215.7	-1537.62
Bulala 3T14DI1stSBDO	4859.1	189504.9	2316.75	187188.2	2483.00
Bekelcha 2T14DI1stSBDO	4768.7	185979.3	1544.50	184434.8	362.34
Bulala 2T21DI1stSBDO	5129.3	200042.7	1544.50	198498.2	4456.78
Bekelcha 3T14DI1stSBDO	4554.4	177621.6	2316.75	175304.9	-152.52
Bulala 2T14DI1stSBDO	4349.1	169614.9	794.50	168820.4	4928.52
Bekelcha 2T21DI1stSBDO	4691.8	182980.2	794.50	182185.7	421.31
Bulala 3T21DI1stSBDO	4484.8	174907.2	2316.75	172590.5	1852.91

Note: See Table 1 for description of abbreviations in the treatments.

In contrary, the lowest MB (115,709.1 ETB/ha) was obtained from Bulala variety sprayed once before disease occurrence. On the other hand, the highest MRR (4,928.52%) was calculated from Bulala variety sprayed twice at 14 days interval fungicide spray being started before disease occurrence. This implies that for each 1.00 ETB invested in durum wheat production for stem rust management, there was a gain of 49.29 ETB/ha from Bulala variety (Table 4).

Conclusion and Recommendation

The results from this study have sufficiently justified the Bale farmers' practice of spraying ahead of symptom development on plant surface. The top six highest grain yields were recorded from those plots that have received at least one time fungicide spray before disease occurrence with financial profitability In this study, stem rust resulted in significant reduction in thousand kernel weight (TKW) and grain yield in the absence of fungicide spray or sprays that were done after disease occurrence on the plant surface. Reversely, the disease increased the total gain protein content in durum wheat. However, Rex® Duo application significantly reduced stem rust severity and there by significantly improved grain yield and TKW of durum wheat. However, the practical applications of the result of this study basically depend on an efficient disease forecasting and early warning systems that are not reliable in Ethiopia. Therefore, based on the result of this study and practical situation of Ethiopian farming system, wheat growers in Bale and similar agro-ecologies are recommended to produce Bulala variety and spray fungicides 2-3 times at 14 days interval, the first spray should start as the first stem rust pustule is observed on the plant surface in the surrounding farms.

References

Ashenafi Gemechu and Alemayehu Chala, 2019. Effects of stem rust (*Puccinia graminis* f.sp. *tritici*) on yield, physical and chemical quality of durum wheat varieties in East Shoa zone, Ethiopia. *American Journal of Agriculture and Forestry*. Vol. 7(2), pp. 78-83. doi: 10.11648/j.ajaf.20190702.15.

Ashenafi Gemechu Degete, Alemayehu Chala and Bekele Hundie. 2018. "Effect of Fungicide Spray Schedule on Stem Rust (*Puccinia graminis* f.sp. *tritici*) Development and Grain Physical Quality of Durum Wheat in Ethiopia", International Journal of Current Research, 10, (08), 72827-72832.

Chris G. World Durum Outlook. Available online: http://www.internationalpasta.org/resources/IPO%20BOARD%202013/2%20Chris%20Gillen.pdf (accessed on 7 April 2017).

CIMMYT (International Center for Maize and Wheat Improvement), 2005. Sounding the Alarm on Global Stem Rust. An assessment of race Ug99 in Kenya and Ethiopia and the potential for impact in neighboring regions and beyond. Prepared by the expert panel on the tem rust outbreak in Eastern Africa. 29 May 2005. CIMMYT, Mexico.

CIMMYT (International Maize and Wheat Improvement Center), 1988. From Agronomic data to farmers' recommendations: An Economic training manual. Completely revised edition. CIMMYT, Mexico, D.F. Link: https://bit.ly/3xBbQYO.

CSA (Central Statistical Authority), 2017/18.Agricultural survey sample. Report on area and production of crops (private peasant holdings, *meher* season). Statistical Bulletin No 586. Addis Ababa, Ethiopia.

Hailu E., Woldaeb G., Danbali W., Alemu W., and Abebe T., 2015. Distribution of stem rust (*Puccinia graminis* f. sp. *tritici*) races in Ethiopia. Adv Crop Sci Tech. Vol. 3, p. 173. doi:10.4172/2329-8863.1000173.

Hailu Gebre-Mariam . 1991. Bread wheat breeding and genetic research in Ethiopia. *In* Hailu Gebre-Mariam, Tanner D.G. and MangistuHuluka (eds). Wheat research in Ethiopia: A historical perspectives. Addis Ababa. IAR/CIMMYT. pp. 73-93.

Haldore, H., Borlang, N.E. and Anderson, R.G., 1982. Wheat in he Third World. West View Press. Boulders, Colorado, USA.

Jin Y., Singh R.P., Ward R.W., Wanyera R., Kinyua M., Njau P., Fetch T., Pretorius Z.A., Yahy aoui A., 2007. Characterization of seedling infection types and adult plant infection responses of monogenic Sr gene lines to race TTKS of Puccinia graminis f. sp. tritici. *Plant Dis*. Vol. 91(9), pp. 1096–1099. doi:10.1094/PDIS-91-9-1096.

Jin Y., Szabo L.J., Pretorius Z.A., 2008. Virulence variation within the Ug99 lineage. In: Appels R., Eastwood R., Lagudah E., Langridge P., Mackay M., McIntyre L., Sharp P., editors. Proceeding 11th international wheat genetic symposium. August 24–29; Brisbane, Queensland, Australia: Sydney University Press eScholarship Repository.

Mueller D.S., Jeffers S.N., and Buck J.W., 2004. Effect of timing of fungicide applications on development of rusts on daylily, geranium, and sunflower. *Plant Dis*. Vol. 88, pp. 657-661.

Nefo, Kedir; Geleto, Tilahun; and Aman, Allo (eds.), 2008. Fifteen years achievements: Oromia Agricultual Research Institute, Sinana Agricultural Research Center, Bale-Robe, Southeast Ethiopia.

Ochoa J. and Parlevliet J.E., 2007. Effect of partial resistance to barley leaf rust, *Puccinia hordei* on the yield of three barley cultivars. *Euphytica*. Vol. 153, pp. 309-312.

Peterson R.F., Campbell A.B., and Hannah A.E., 1948. A Diagrammatic Scale for Estimating Rust Intensity on Leaves and Stems of Cereals. *Canadian Journal of Research*. Vol. 26c (5).

Peturson B., Margaret N. and Whiteside A.G.O., 2011. The effects of leaf rust on yield and quality of wheat. *Canadian Journal of Research*. Vol. 23, pp. 105-114.

Pretorius Z.A., Singh R.P., Wagoire W.W., Payne T.S., 2000. Detection of virulence to wheat stem rust resistance gene Sr31 in Puccinia graminis. f. sp. tritici in Uganda. *Plant Dis*. Vol. 84(2) pp. 203. doi:10.1094/PDIS.2000.84.2.203B.

Roelfs, A. P., and Groth, J. V., 1987. A comparison of virulence phenotypes in wheat stem rust populations reproducing sexually and asexually. *Phytopathology* 70:855-862.

SAS Institute, 1998. SAS/STAT guide for personal computers, version 6.12 edition. Cary, NC:SAS Institute.

Shaner G. and Finney R.E., 1977. The effect of nitrogen fertilization in the expression of slow-mildewing resistance in Knox wheat. *Phytopathology*. Vol. 67, pp. 1051-1056. doi:10.1094/Phyto-67-1051.

Shaw, M, 1963. The physiology and host parasite relations of the rusts. *Ann. Rev. Phytopathol*. 1: 259-293.

Singh R.P., Hodson D.P., Huerta-Espino J., Jin Y., Njau P., Wanyera R., Herrera-Foessel, S.A., and Ward R.W., 2008. Will Stem Rust Destroy the World's Wheat Crop? In"Advances in Agronomy Volume 98. (Sparks D. L. Eds). Elsevier Inc, USA. Pp.271-309.

Tadesse K., Ayalew A. and Badebo A., 2010. Effect of fungicide on the development of wheat stem rust and yield of wheat varieties in highlands of Ethiopia. *African Crop Science Journal*. Vol. 18(1), pp. 23-33.

Taffa E.T., Balcha D.K., 2022. Effect of Fungicide Application Rate and Frequency on development of Major Faba bean Diseases, Grain Yield and Yield Components of Faba Bean (Vicia Faba L.) at Southeastern Oromia, Bale. *Open J Plant Sci.* Vol. 7(1), pp. 001-008. DOI: 10.17352/ojps.000044.

Van der Plank J.E., 1963. Epidemiology of Plant Disease.New York and London Academic publishers. 206p.

Wanyera R., Wamalwa M., Odemba M., Wanga H., Kinyanjui P., Onyango V. and Owuoche J., 2016. Management of wheat rusts at different growth stages using Nativo 300 SC (trifloxystrobin 100g/L+tebuconazole 200g/L) fungicide. Australia Journal of Crop Science. Vol. 10(9), pp. 1273-1280. DOI: 10.21475/ajcs.2016.10.09.p7676.

Stem rust (*Puccinia graminis* f.sp. tritici and f.sp. secalis) resistance and yielding performance of some malt barley (Horduem vulgare L.) varieties released and registered in Ethiopia

Ermias Teshome and Dagne Kora
Sinana Agricultural Research Center
Corresponding author: Tel.: +251-912174666, P.O. Box: 208, E-mail: **ermiastafa@gmail.com**

Abstract

*Ethiopia is facing shortage of malt barley varieties that meet the quality standard and annual malting barley grain demand set by the malting and brewing industries. The objective of this study was to identify malt barley varieties resistant to stem rust (*Puccinia graminis*). Fourteen released and registered malt barley varieties were evaluated using randomized complete block design (RCBD) in three replications at three locations during the main seasons of 2020/21 and 2021/22. There was highly significant ($P \leq 0.05$) variations between malt barley varieties for stem rust resistance. The lowest stem rust severity (1.96%) was recorded from a variety Holker and the highest stem rust severity (19.44%) was recorded from a variety Fanaka. Whereas, next to Holker, almost the lowest equal stem rust severities of 3.40%, 3.76% and 3.82% were recorded from IBON-174/03, Singiten and Bahati varieties, respectively. Similarly, Significant ($P \leq 0.05$) difference between varieties for agronomic parameters were recorded. The highest grain yield of 5524.6 kg/ha was recorded from a variety HB-1963 and two additional varieties; IBON-174/03 and Traveler produced the next higher yields, 5482.5 kg/ha and 5385.7 kg/ha, respectively. Correlation analysis showed that there was significant ($P \leq 0.05$) strong negative correlation between stem rust severity and agronomic parameters. The associations of stem rust severity with TKW and grain yield were ($r= -0.6762$; $P \leq 0.001$) and ($r=$ (-0.8570; $P \leq 0.0001$), respectively. Whereas there was strong positive correlation between TKW and grain yield ($r= 0.6067$; $P \leq 0.001$). Therefore, considering the stem rust resistance and yielding performance of malt barley varieties, HB-1963 variety is recommended in areas where stem rust is a limiting factor in malt barley production. . However, malt barley varieties IBON-174/03 and Traveler can also be used in the absence of HB-1963 or for varietal diversification as the two varieties have a yield potential comparable to HB-1963.*

Key words: Malt barley, stem rust, *Puccinia graminis*, Resistance

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in the world ranking fourth in production after wheat, rice and maize (Zhou, 2010). It is adapted to broad range of agro-ecologies and it is tolerant to soil salinity, draught and frost to a considerable level. It successfully grows in the arid climates of Sahara, the Tibetan plateaus, and the highlands of Himalayas, the mountains of Ethiopia or Andean countries, and the tropical plains of India (Taketa *et al.,* 2004). It is also the major traditional crop in Ethiopia representing about 7.4% of the total national cereal production and ranking fifth after maize, wheat, Teff, and sorghum in volume of production (CSA, 2021). In Ethiopia, barley covers about 8.79% of the total cereal crops cultivated land and its productivity is 25.26 qt/ha (CSA, 2021). This crop is used in different forms like food, feed and making drinks. For food, the barley grain is rich in zinc, iron and soluble fibers and has higher content of Vitamins A and E than other cereals.

Barley productivity is hampered by diseases and insect pests among the yield reducing biotic factors. The major leaf diseases affecting barley growth and development are net blotch (*Pyrenophora teres*), scald (*Rhynchosporium secalis*), leaf blotches (*Helminthosporium* spp.), rusts (*Puccinia* spp.) and powdery mildew (*Erysiphae graminis*). These are among the most widely distributed foliar diseases in the country (Chilot *et al.,* 1998; Bekele *et al.,* 2011). Russian Wheat Aphid and barley shoot fly are the major insect pests that attack barley in Ethiopia. *Delia arambourgi* Seguy and *D. flavibasis* Stein are the two shoot fly species recorded to occur in Ethiopia (Tafa and Muluken, 2007). In recent years, barley stem rust caused by the fungus *P. graminis* f.sp. *tritici and P. graminis* f.sp. *secalis* disease is devastating the crop in most barley growing areas. However, the effort made to identify resistant/tolerant varieties is very minimal. Similarly, development of management options is not yet considered regardless of the devastative nature of the disease. Therefore, this study is initiated to screen and evaluate malt barely varieties for their resistance/tolerance to stem rust.

Materials and Methods

Description of experimental site

The field experiment was conducted in three districts of Bale highlands for two years; 2019/20 and 2020/21 during the main growing season "Bona". These are among the potential districts for malt barley production in Bale zone. The specific sites were Sinana on-station, Dinsho and Goba. Sinana and Goba districts receive rain twice a year; the main season in which this experiment was planted is from August to December and is locally called 'Bona' and the second is from March to June, which is called "Genna"; while Dinsho district receives rain fall once per year. This designation of the seasons as “Genna” and “Bona” was derived from the time of crops harvest (Dagne *et al.,* 2016). Sinana is located at 7°7' N latitude and 40°10' E longitude on and at an elevation of 2400 m.a.s.l. The area receives an average annual rainfall of 750-1000 mm and has an average annual temperature of 9–21 ºC (Nefo *et al.,* 2008). Dinsho has a latitude and longitude of 7°05′N 39°45′E and an elevation of 3207 meters. It has a mean annual temperature of 14°C. And, Gobs, the geographical coordinates are 7° 1' 0'' North, 39° 59' 0'' East and has mean annual temperature range of 5.5 ^{o}C -23.9^{o}C.

Treatments and Design

The experiment was laid out in RCB Design in 3 replications. Fourteen (14) malt barley varieties (Table 1) released from different research centers and registered by brewing companies in Ethiopia were evaluated for resistance to barley stem rust (*Puccinia graminis*).

Table 5: Malt barley varieties, Breeding center and year of their release

No.	Variety name	Year of release	Breeding center
1	HB1964	2016	Holetta Agricultural Research Center
2	HB1963	2016	Holetta Agricultural Research Center
3	IBON 174/03	2012	Holetta Agricultural Research Center
4	EH1847	2011	Holetta Agricultural Research Center
5	Miscal-21	2006	Holetta Agricultural Research Center
6	Holker	1979	Holetta Agricultural Research Center
7	Beka	1976	Holetta Agricultural Research Center
8	Singten	2016	Sinana Agricultural Research Center
9	Moata	2018	Sinana Agricultural Research Center
10	Bahati	2011	Kulumsa Agricultural Research Center
11	Bekoji-1	2010	Kulumsa Agricultural Research Center
12	Fanaka	2015	Holetta Agricultural Research Center/Meta Abo
13	Traveler	2013	Holetta Agricultural Research Center/Heniken
14	Grace	2013	Holetta Agricultural Research Center/Heniken

The plot was 1.2m x 3m that had 6 seeding rows. Spacing between rows, plots and replications were 0.2m, 1m and 1m, respectively. Stem rust disease was scored according to the modified cobb-scale (Peterson *et al.*, 1948). The seed rate was 100kg/ha and all other management practices like land preparation, fertilizer application and weeding were applied as per the agronomic recommendation for barley as non experimental variable across experimental plots.

Collected data

Stem rust severity data were collected on the basis of plots by using the modified cobb-scale scoring method (Peterson *et al.,* 1948). Net-blotch disease severity was scored based on the modified Saari and Prescott's double-digit scale (00-99) scoring method (Saari and Prescott, 1975). Thousand kernel weight (TKW) was weighed from 1000 randomly sampled grains. Grain yield was measured as a weight of the total grains harvested from the four middle rows and adjusted to 12% moisture level.

Data management and statistical analysis

The data on TKW (g), grain yield (kg/ha), net-blotch and stem rust disease severity were analyzed to evaluate the difference between treatment means. ANOVA was performed for net-blotch and stem rust disease severities, TKW, and grain yield by using the statistical analysis system (SAS) Procedure (SAS, 1998). The LSD technique with a probability of 5% was used to detect the smallest possible difference between treatment means. Correlation and regression analyses were used to assess the association between disease severity and agronomic parameters.

Results and Discussions

The over years and locations data were combined after homogeneity test for ANOVA (analysis of variance). The result showed statistically significant ($P \leq 0.05$) difference between varieties for their resistance to stem rust and net-blotch diseases (Table 2). Among the tested varieties, Fanaka was the most susceptible variety affected by the disease where the stem rust severity (19.44 %) was the highest. On the other hand, Holker was the most resistant malt barley variety among the tested varieties, where the lowest stem rust severity (1.96%) was recorded (Table 2). Compared to the other varieties evaluated, IBON-174/03 was found to be better option in line with host resistance to stem rust next to Holker. The second lowest stem rust severity (3.40%) was recorded from IBON-174/03 variety. The recorded variability between malt barley varieties for their resistance to stem rust is enormous. This was further confirmed from field research in Kenya where variability among malt barley varieties for stem rust resistance was made clear through stem rust severity ranges of 6s to 93s (Mwando *et al.,* 2012).

Table 6: Disease resistance and agronomic performance of malt barley varieties

Variety	Net blotch (%)	Stem rust (%)	TKW (g)	Grain yield (kg/ha)
Fanaka	17.70^{cde}	19.44^{a}	56.67^{b}	5073.0^{abcd}
HB-1964	17.56^{cde}	6.26d^{e}	52.00^{bc}	4560.3^{abcd}
Bekoji-1	16.74^{cde}	10.89^{bc}	48.89^{cde}	4417.5^{abcd}
Beka	25.79^{bc}	6.20^{de}	42.22^{fg}	5121.4^{abc}
Traveler	47.19^{a}	6.14^{de}	44.00^{efg}	5385.7^{a}
Holker	11.80^{e}	1.96^{f}	63.11^{a}	3747.6^{cd}
Grace	34.98^{b}	14.00^{b}	45.89^{def}	5031.0^{abcd}
EH1847	17.28^{cde}	7.11^{cde}	44.67^{ef}	3672.2^{d}
IBON-174/03	19.20^{cde}	3.40^{ef}	51.33^{c}	5482.5^{a}
HB-1963	14.54^{de}	7.64^{cd}	50.89^{cd}	5524.6^{a}
Bahati	20.85^{cde}	3.82^{def}	50.89^{cd}	4952.4^{abcd}
Miscal-21	16.19^{cde}	5.12^{def}	51.56^{bc}	3772.2^{bcd}
Moata	17.83^{cde}	4.56^{def}	39.33^{g}	5190.5^{ab}
Singiten	23.32^{cd}	3.76^{def}	50.22^{cd}	4731.0^{abcd}
CV (%)	19.12	16.82	11.46	23.39
$LSD_{(0.05)}$	9.86	4.14	5.29	1440.7

Note: Figures designated with the same letters within the same column are not statistically significant at $P \leq 0.05$

Different races of stem rust have the capability to infect barley varieties. However, one study has shown that race Ug99 (TTKSK) has the potential to infect about 95% of the world's barely varieties (Zhou *et al.*, 2014). Over years and locations combined ANOVA showed that there was highly significant ($P \leq 0.05$) variations between malt barley varieties for grain yield (Table 6). The highest grain yield of 5524.6 kg/ha was recorded from a variety HB-1963. This is a variety known for its high yield in many barely growing areas and preferred by farmers (ICARDA, 2016; Misganaw and Zina, 2020). With productivity of 5482.5 kg/ha and 5385.7 kg/ha, IBON-174/03 and Traveler varieties, respectively were the second and third high yielding varieties recorded in the current trial (Table 6). The lower yields (3672.2 kg/ha, 3747.6 kg/ha and 3772.2 kg/ha) were recorded from EH1847, Holker and Miscal-21 varieties, respectively (Table 6).

Correlation analysis

The pair-wise-pearson's correlation model was used to assess the relationships between agronomic parameters (TKW and grain yield) and stem rust severity. This analysis revealed that stem rust severity has significant ($P \leq 0.05$) relationship with agronomic parameters. Accordingly, stem rust severity has strong negative correlation with TKW (r= -0.6762; $P \leq 0.001$), and grain yield (r= (-0.8570; $P \leq 0.0001$) (Table 3). Whereas, the relationship between TKW and grain yield was found to be strong positive correlation (r= 0.6067; $P \leq 0.001$).

Table 7: Correlation analysis between stem rust severity and agronomic parameters

	Sr	TKW	Yield
Sr	1	-0.6762**	-0.8570***
TKW		1	0.6067**
Yield			1

Conclusion and recommendation

Currently, the demand for malting barley in Ethiopia has been increasing considerably due to the increasing number of malting and beer industries in the country. Plant diseases are the most important biotic factors reducing the productivity of Malt barley. Stem rust is one of the most important plant diseases in barley, but it has started expanding in barley fields recently. However, not much works were conducted as part of the stem rust disease management in barley. Therefore, in an effort to reduce the effect of stem rust disease on malt barley productivity, the current study has identified and recommended some stem rust resistant varieties. Holker is a variety that is most resistant to stem rust infection among the evaluated varieties; however, its productivity is very low for recommendation. On the other hand, HB-1963, IBON-174/03 and Traveler are the top three highly productive varieties identified in the prevailing stem rust pressure. Among which, a variety HB-1963 was the most productive variety. Therefore, based on the result of the current study, it is highly convincing to recommend the high yielder variety HB-1963 and it is recommended for farmers in the Bale highlands and similar agro-ecologies. However, in the absence of this variety, farmers can also produce the other two high yielding malt barley varieties (IBON-174/03 and Traveler).

References

Bekele Hundie, Kiros Meles, Fekede Abebe, Asnakech Tekalign, Melkamu Ayalew, Getaneh Woldeab, Yonas Worku, Eshetu Belete, Birhanu Bekele, 2011. Achievements in Barley Scald research in Ethiopia. In: Mulatu, B. and Grando, S. (Eds), Barley Research and Development in Ethiopia. Proceedings of the 2nd National Barley Research and Development Review Workshop. 28-30 November 2006, HARC, Holetta, Ethiopia. ICARDA, PO Box 5466, Aleppo, Syria. pp xiv + 391.

Central Statistics Agency (CSA), 2021. Agricultural Sample Survey 2020/21: Report on Area and Production of Major Crops (private peasant holdings, meher season). Statistical Bulletin 590 (1): 1-143.

Chilot Y., Fekadu A., Woldeyesus S., 1998. Barley-based farming systems in the highlands of Ethiopia. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.

CSA (Central Statistical Authority), 2013. Crop Production Forecast Sample Survey: Report on area, production and yield of major crops for private peasant holdings in Ethiopia, Meher Season, Dec. 2013, Addis Ababa, Ethiopia.

Dagne K., Temam H. and Seid A., 2016. Epidemiology of chocolate spot (*Botrytis fabae*Sard.) on faba bean (*Viciafaba* L.) in the Highlands of Bale, Sinana district, Southeastern Ethiopia. *Global Journal of Pests, Diseases and Crop Protection.* Vol. 4 (1), pp. 131-138.

ICARDA (International Center for Agricultural Research in the Dry Areas), 2016. Two new malt barley varieties released in game-changing development in Ethiopia. Accessed from https://www.icarda.org/media/news/two-new-malt-barley-varieties-released-game-changing-development-Ethiopia, ON 24/11/2022.

Misganaw Ferede and Zina Demsie, 2020. Participatory evaluation of malt barley (*Hordium disticum* L.) varieties in barley-growing highland areas of Northwestern Ethiopia. *Cogent Food and Agriculture*, Vol. 6(1). DOI: 10.1080/23311932.2020.1756142.

Mwando K.E., Tabu I. M., Otaye O.D. Njau and P. N., 2012. Effect of Stem Rust on the Quality of Selected Barley Genotypes. *ISRN Agronomy*. Vol. 2012, pp. 8. Doi:10.5402/2012/617081.

Nefo, Kedir; Geleto, Tilahun; and Aman, Allo (eds.), 2008. Fifteen years achievements: Oromia Agricultual Research Institute, Sinana Agricultural Research Center, Bale-Robe, Southeast Ethiopia.

Peterson R.F., Campbell A.B., and Hannah A.E., 1948. A Diagrammatic Scale for Estimating Rust Intensity on Leaves and Stems of Cereals. *Canadian Journal of Research*. Vol. 26c (5).

Saari E.E., Prescott J.M., 1975. A scale for appraising the foliar intensity of wheat disease. *Plant Dis Reporter*. Vol. 59, pp. 377–380.

SAS Institute. 1998. SAS/STAT guide for personal computers, version 6.12 edition. Cary, NC:SAS Institute.

Tafa Jobie and Muluken Goftishu, 2007. Effect of sowing date on infestation of barley shoot fly on barley in southeastern Ethiopia. *African Crop Science Conference Proceedings*. Vol. 8. Pp. 6.

Taketa S., Kikuchi S., Awayama T., Yamamoto S., Ichii M., Kawasaki S., 2004. Monophyletic origin of naked barley inferred from molecular analyses of a marker closely linked to the naked caryopsis gene (*nud*). *Theor Appl Genet*. Vol. 108, pp. 1236-1242.

Zhou H., Steffenson B.J., Muehlbauer G., Wanyera R., Njau P., Ndeda S., 2014. Association mapping of stem rust race TTKSK resistance in US barley breeding germplasm. *Theor*. *Appl. Genet*. Vol. 127, pp. 1293-1304. DOI 10.1007/s00122-014-2297-8.

Zhou M.X., 2010. Barley production and consumption. Accessed from: https://www.researchgate.net/publication/226861704 on November 19/2022.

Effect of Chemical and Hand weeding Control Methods on Growth Yield Components and Yield of Field Pea in Bale Highlands, Southeastern Ethiopia

Tamiru Meleta*, Reta Dargei, Dagne Kora and Baharu Dajane
Sinana Agricultural Research Centre
* Corresponding author: Tamiru Meleta E-mail:tamish09@gmail.com

Abstract
The poor competition ability of Field pea opens the door for weed to cause a serious yield loss. The experiment was conducted to evaluate the integrated effects of pre-emergence herbicides and hand-weeding on weed control, yield components, yield, and their economic feasibility for cost effective weed control in field pea. There were 9 treatments. Dual-gold 2 liter per hectare supplemented with hand weeding at 25-30 days after crop emergence resulted in the highest grain yield and economic benefit. However, in case labor is constraint and Pre-emergence herbicide is timely available, pre emergence application of Dual-gold 2 liter per hectare should be the alternative to preclude the yield loss and to ensure maximum benefit. Herbicides application is an integral part of farmer's crop management in modern agricultural systems.

Introduction

Pulses are the cheapest and important source of dietary protein for humans. Field pea (*Pisum sativum* L.) is an important food legume, which is widely cultivated in tropic, sub-tropic and temperate regions of the world. It also plays a vital role in improving soil health, by adding huge amounts of organic matter and fixing of biological nitrogen. It leaves about 30 kg N ha^{-1} into the soil which is useful for succeeding crop (Anonymous, 2006). Weeds are the major threats in field pea which limits the productivity (Tripathi *et al.*, 2011). Weeds Present in the field pea, due to its initial slow growth and short stature, results in huge yield loss (Chaudhary *et al.*, 2009). Weed competition resulted in the yield reduction of up to 65.8% (Mishra, 2006; Veres and Tyr, 2012). For the control of weeds, generally farmers adopted manual weeding (Singh and Wright, 2006). But due to increased labour cost and scarcity of labour, manual weeding become a difficult task in field pea, which force them for alternative, cheaper and easier method of chemical weed control. Hand weeding or hoeing which is very effective but it is not only laborious and insufficient but also expensive *i.e.* most of times due to continuous rains, scarcity of labours during peak period and financial limitations, it make weeding difficult after the initiation of reproductive stages of growth. It also hinders pod development and effective and economic weed control on large scale is not possible through age old practice of manual and mechanical means. Thus, there is need to develop efficient and economically viable system for managing weeds. So, herbicides are the only alternatives left under such circumstances of unavailability of labours, high cost of labours and unfavorable environment. Pre-emergence application of herbicides proved effective in reducing density and dry matter production of weeds resulted in higher yield attributes and seed yield of field pea (Govardhan *et al.*, 2007).Weeds are generally controlled with the conventional methods i.e. cultural manipulation either by Chemical weed control which is easier, time saving and economical as compared to hand weeding alone. Presently a wide variety of old and new generation herbicides are available and being recommended for usage. Efficacy of Dual gold herbicides combined with hand weeding has not yet been evaluated in Field pea growing in mid and highlands of south eastern Ethiopia. Therefore, the objectives of this study was to evaluate the effect of pre-emergence herbicides with or without hand weeding on weed control, yield components and yield of field pea and to assess the economic feasibility of supplementing herbicides with hand weeding for effective and cost effective weed management.

Materials and Methods

Description of Experimental Site

The experiment was conducted on research field of Sinana Agricultural research center and Agarfa sub-site, Highlands of Bale, Southeastern Ethiopia under rain fed conditions during 2020 and 2021 main cropping season. Sinana is located at a distance of about 463 km from Addis Ababa at about 7^0 07' North longitude and $40^0$10' East latitude, at an altitude of about 2400 meters above sea level. On other hand, Agarfa is located at a distance of about 460 km from Addis Ababa situated at $38^0$40' to 46^0 3' East latitude and 40^0 to $80^0$11' North longitude, at an altitude of about 2350 meters above sea level. The areas are characterized by bimodal rainfall pattern which is locally named Bona and Ganna season named based on the time of crop harvest. Soils are characterized as Cambisol and Vertisol at Sinana and Agarfa respectively. The preceding crop planted in experimental sites was bread wheat.

Treatments and experimental design

The treatments were comprised of nine different weed management practices *viz*., pre-emergence application of Dual gold 1 lit on 2 DAS or followed by 2 and 3 lit/ha applied in sequence with or without hand weeding on 21 DAS. The treatments were arranged in randomized complete block design with three replications.

Experimental procedure and management

The experimental field was ploughed and disked by a tractor. Land leveling was done manually prior to planting. The experimental fields were prepared to fine tilth. The gross plot size was 4m × 1.2 m (4.8 m^2) with 20 and 10 cm inter and intra-row spacing, respectively. Spacing of 0.8 and 1.5 m were allocated between plots and blocks, respectively. The Field pea variety "Harana" was used as teste crop. Thus, the net harvestable area was 4m × 0.8m (3.2m^2) and harvesting was done manually at crop maturity.

Table 8. The Treatments and their codes

Treatment code	Detail
T1	Dual-gold 1lit/ha
T2	Dual-gold 2lit/ha
T3	Dual-gold 3lit/ha
T4	Dual-gold 1lit/ha+HW
T5	Dual-gold 2lit/ha+HW
T6	Dual-gold 3lit/ha+HW
T7	one time HW
T8	Two time HW
T9	Weedy check

Data Collection

Weed density was taken twice (at the time of first and second hand weeding) for each individual weed species from each plot using $0.25m^2$ quadrants four times. The weed species found within the sample quadrant were identified, counted and expressed in m^2. Individual and general weed control scores were also taken four weeks after herbicide application, first and second hand weeding and at the time of harvest. At harvest the weeds were cut near the soil surface and placed in an oven at 65^oc temperature till constant weight and their dry weight was measured. The dry weight was expressed in gm-2. The data on weed density and dry matter were subjected to $\sqrt{x+0.5}$ transformations before analysis.

Weed control efficiency: $WCE = \frac{(WDC-WDT)}{WDC} x100$

Where: WCE=Weed Control Efficiency, WDC= Weed Dry mater in weedy check, WDT=Weed Dry Matter in particular treatment

Plant height: was measured from 5 randomly selected plants in each plot.

Thousand seeds Weight: seeds were counted randomly and their weight was measured at 10 % grain moisture content.

Grain yield was also measured after threshing the sun dried plants harvested from each plot and adjusted at 10% grain moisture content.

Partial budget analysis was calculated by taking in to account the additional input cost (the labor cost for hand weeding, harvesting, threshing and winnowing) and gross returns obtained from different weed control treatments.

Statistical analysis

Finally, all data were subjected to analysis of variance following a procedure appropriate to the design of the experiment using SAS statistical software, where ANOVA and mean separation were carried out at 5% level of probability.

Results and Discussion

Weed Control Efficiency Weed control efficiency (%) was affected significantly by different rates of dual –gold herbicide. The maximum weed control efficiency was recorded in twice hand weeded plot (94.13%) followed by Dual-gold at 3 litter per hectare plus one hand weeding (90.28%). While, the lowest weed control efficiency was recorded in weedy check (0). The result is in agreement with the findings of (Jafari,R, *etal*,.2013) who reported that pre-emergent herbicides gave higher weed control efficiency by reducing the weed density and dry weight significantly as compared to weedy check.

The experimental field was found to be infested with different types of grasses and broad leaved weeds (Table 9).The most dominant broad leaved weeds include *Polygonum nepalensis, Plantago lanceolata, Raphanus rephanistrum, Galinsoga parviflora, Oxalis latifolia*, and *Guizotia scabra*. Among the grass weeds *Snowdenia polystachya, Setaria pumlia, Phalaris paradoxa* and *Avena fatua* were dominant.

Table 9. The major problematic weeds in the experimental fields during 2019/20 and 2020/21 cropping seasons.

Botanical name	Family	Life form	Category
Galinsoga parviflora	Composite	Annual	Broad Leaved
Guzotia scabra	Composite	Annual	Broad Leaved
Raphanus raphanistrum	Brassicaceae	Annual	Broad Leaved
Oxalis latifolia	Oxalidaceae	Perennial	Broad Leaved
Plantago lanceolata L.	Plntaginaceae	Annual	Broad Leaved
Setaria pumlia	Poaceae	Annual	Grass Leaved
Snowdenia polystachya,	Poaceae	Annual	Grass Leaved
Phalaris paradoxa	Poaceae	Annual	Grass Leaved
Avena fatua	Poaceae	Annual	Grass Leaved
Polygonum nepalensis	Polygonaceae	Annual	Broad Leaved
Brumuspectinatus Poaceae	Poaceae	Annual	Grass Leaved
Gallium spurium	Cleavereae	Annual	Broad Leaved
CommelinasublataL.	Commelinaeae	Annual	Broad Leaved
Cyperusassimilis L.	Cyperaceae	perennial	Sedge Leaved
Chenopodium album L	Chenopodium album	Annual	Broad Leaved
Amaranthus hybridus L.	Amaranthaceae	Annual	Broad Leaved

Table 10: Effect of different weed management practices on weed density, weed dry weight, weed control efficiency, of field pea at Sinana and Agarfa

Treatments	Weed density ($Nos.m^{-2}$) 45 DAS	Weed dry weight(gm^{-2}) 45 DAS	Weed control efficiency (%)
Dual-gold 1lit/ha	141.2^{c}	24.5^{c}	55.05^{d}
Dual-gold 2lit/ha	135.9^{c}	23.1^{c}	57.61^{d}
Dual-gold 3lit/ha	104.1^{d}	15.4^{d}	71.74^{c}
Dual-gold 1lit/ha+HW	143.6^{c}	24.9^{c}	54.31^{d}
Dual-gold 2lit/ha+HW	36.3^{e}	6.8^{e}	87.52^{b}
Dual-gold 3lit/ha+HW	31.4^{e}	5.3^{f}	90.28^{a}
One time HW	205.6^{b}	31.76^{b}	41.72^{e}
Two time HW	24.3^{ef}	4.2^{f}	92.29^{a}
Weedy check	354.8^{a}	54.5^{a}	0.00
LSD	8.1	1.40	4.61
CV(%)	17.4	4.2	5.33

Mean value within column followed by same latter(s) are not significantly different at 5%; LSD= least significant difference P<0.05: DAS=(Days After Sowing),HW= (Hand weeding)

Crop phenology and growth

Days to 50% flowering and 90% physiological maturity

Both days to 50% flowering and 90% physiological maturity were significantly influenced by weed management practices. Field pea plants attained early average flowering date of 65 days. In weedy check, the shading of crop plants by weeds might have reduced sunlight interception thus prolonged the vegetative growth resulting in delayed days to flowering (Table 10).In line with this result, Sunday and Udensi (2013) identified that the plants in not weeded plots took the longest time to reach 50% flowering in cowpea. The influence of weed management practices on 90% days to physiological maturity was followed similar trend to 50% days to flowering at both sites.

Plant height: The maximum plant height (149.3 cm) was recorded from weedy check which did not significantly vary with plots treated with Dual-gold 2 lit/ha. The two time hand weeding plot had plants with lowest height (125.5 cm) that was due to the impact of weeds on the growth and development of field pea. The height in weed free treatment might be due to abundance of growth promoting factors in both treatments that allowed the plants to attain their maximum height. The increased plant height with the weedy plot might be due to the effect of severe competition among plants which make them elongated in search of light and lack of availability of plentiful of growth encouraging factors in weedy plot that allowed the plants to increase in height. The competition between weeds and crop for sun light and space in unweeded plots resulted in tall height of plants. Similarly, Salahuddin *et al*., (2016) reported that the competition among weeds and wheat plant enforced to grew plant.

Table 11: Effect of weed management practices on Days to flowering, Days to Maturity, Plant height and Productive tiller plant of field pea

Treatments	Days to flowering	Days to Maturity	Plant Height(cm)	Productive tiller plant^{-1}
Dual-gold 1lit/ha	68.42^{bc}	127.00^{bcd}	134.78^{bcd}	2.88^{b}
Dual-gold 2lit/ha	68.25^{bc}	127.00^{bcd}	146.22^{ab}	3.38^{ab}
Dual-gold 3lit/ha	67.17^{bcd}	127.83^{b}	137.04^{abcd}	3.27^{ab}
Dual-gold 1lit/ha+HW	66.58^{bcd}	$125.67d^{e}$	135.75^{bcd}	3.63^{a}
Dual-gold 2lit/ha+HW	65.00^{e}	124.83^{e}	129.81^{cd}	3.58^{a}
Dual-gold 3lit/ha+HW	67.42^{bc}	125.83^{cde}	134.89^{bcd}	3.62^{a}
one time HW	68.83^{ab}	127.83^{b}	142.53^{abc}	3.48^{a}
Two time HW	65.42^{de}	127.42^{bc}	125.58^{d}	3.63^{a}
Weedy check	70.33^{a}	129.92^{a}	149.33a	2.89^{b}
Lsd (5%)	1.91	1.68	13.18	0.57
CV (%)	3.49	1.63	11.84	20.95

Mean value within column followed by same latter(s) are not significantly different at 5%; LSD= least significant difference P<0.05:HW= (Hand weeding)

Yield Components and Yield of field pea

Pod per plant and seed per pod The analysis of variance showed that significant variation was observed on number of pod per plant. Whereas seed per pod showed non significant different among treatments (Table 5)The highest number of pods (13.86) plant^{-1} was recorded from dual-gold 2 liter per hectare plus one time hand weeding. Seed per pod was significantly increased under weed free environment (Munakamwe et al., 2008.). Higher yield attributes under these treatments may be due to lesser crop-weed competition, which gave better environment for crop growth and development of crop. Because, in these treatments weed population and their growth were abstracted during initial as well as latter stages of crop growth by sequential hand weeding. It confirms the conclusion drawn by (Chaudhary et al., 2009) from the results of their experiments on weed control in pulses.

Total above Ground Biomass

Above ground biomass yield ranged from 9204.51 kg ha-1 to 5529.38 kg ha-1(Table 5). The highest biomass yield (9204.51kgha^{-1}) was recorded for weed free treatment followed by two times hand weeding (8513.89 kgha^{-1}). Minimum biomass was recorded at weedy plots with the mean of 5529.38 kgha^{-1} (Table 5). This lowest biomass yield at weedy plot could be due to lower weed control efficiency. Among herbicide treated plots herbicide combination at lower rate had better biomass yield than herbicide combination at recommended rate and single application of recommended rate. Similarly, Hassan et al., (2003) reported that the mixture of herbicides produced a higher biomass yield than weedy check plots.

Table 12. Influence of d Weed Management Practices on Yield and Yield Components of field pea in Southeastern Ethiopia, Sinana and Agarfa 2020 and 2021

Treatments	Pod per plants	Seed per pods	Biomass yield kg/ha^{-1}	Grain Yield kg/ha^{-1}	Thousand Seed weight(gm)	Harvest index
Dual-gold 1lit/ha	10.23bcd	4.11	6751.74de	1816.60cd	167.67	26.74
Dual-gold 2lit/ha	11.66ab	4.61	6392.36def	1813.44cd	166.40	26.95
Dual-gold 3lit/ha	11.51abc	4.18	7362.99bcd	2002.15cd	172.33	27.11
Dual-gold 1lit/ha+HW	10.60bc	4.54	7991.32abc	2187.67bc	166.10	28.19
Dual-gold 2lit/ha+HW	13.86a	4.50	9204.51a	2640.97a	170.78	28.41
Dual-gold 3lit/ha+HW	10.49bcd	4.14	6817.78cde	1842.22cd	170.87	25.94
one time HW	8.64cd	4.27	5911.21ef	1711.15de	166.50	28.91
Two time HW	10.71bc	4.57	8513.89ab	2379.92ab	174.78	27.72
Weedy check	7.64d	4.03	5529.38f	1427.99e	165.38	24.23
Lsd(5%)	2.95	0.7	1217.8	376.85	ns	Ns
CV(%)	34.44	20.18	20.97	23.48	6.04	4.29

Mean value within column followed by same latter(s) are not significantly different at 5%; LSD= least significant difference P<0.05:HW= (Hand weeding)

Grain yield:-All weed management treatments increased grain yield and yield advantage of field pea over weedy check.The analysis of variance indicated that the highest grain yield 2640.97kg ha^{-1}) resulted from Dual –gold 2 liter per hectares plus one time hand weeding and significantly vary from the weedy check plot but not statistically differ with two times hand weeding. Comparable result obtained in plant height, pods per plant and biomass yield between treatments according to Daba, N.A. etal, 2018.

Thousand seed weight the highest and lowest hundred seed weight were attained in two hand weeding and weedy check treatments respectively which were statistically insignificant among treatments.

Partial Budget Analysis

Marginal analysis is an important step in assessing the results of on farm experiments before making recommendations. For this trial variable cost of dual gold and hand weeding frequencies were considered since both locations are similar. Cost and Benefit Analysis Getting higher profitability lies not only in using appropriate agronomic management but also in lowering costs per unit crop production through higher yields. Therefore, economic analysis is required for making recommendation for farmers from such agronomic experiments. In practice, not all farmers, however, can aim for the largest net benefits because of the generally larger costs involved to other risks associated with farming. The cost and benefit analysis result indicated that the highest marginal ret of return (3466.77 ETB ha^{-1}) was obtained from the treatments two time hand weeding followed by application of Dual-gold 2lit/ha plus two time hand weeding (1350.56 ETB $ha^{-1)}$. But, in the study area since field pea production is in large scale labor competition is high. So, application of Dual-gold 2lit/ha plus two time hand weeding. Therefore, application of Dual-gold 2lit/ha plus two time hand weeding was produced better grain yield and economic feasible and recommended for improved field pea production in sinana and Agarafa and similar agro ecologies in south eastern Oromia.

Table 13. Marginal analysis of Dual-gold and Hand weeding frequency on field pea production at Agarafa and Sinana.

Treatment	Yield	Total Cost	Marginal Cost	Net Benefit	Marginal Benefit	Marginal ret of Return
Weedy check	1427.99	0	0	57119.6	100	0
one time HW	1711.15	1125	1125	67321	10201.4	906.79
Two time HW	2379.92	1875	750	93321.8	26000.8	3466.77
Dual-gold 1lit/ha	1816.6	1375	500	71289	-22032.8	-4406.56
Dual-gold 2lit/ha	1813.44	2050	675	70487.6	-801.4	-118.73
Dual-gold 3lit/ha	2002.15	3975	1925	76111	5623.4	292.12
Dual-gold 1lit/ha+HW	2187.67	2100	1875	85406.8	9295.8	495.78
Dual-gold 2lit/ha+HW	2640.97	3350	1250	102288.8	16882	1350.56
Dual-gold 3lit/ha+HW	1842.22	4425	1075	69263.8	-33025	-3072.09

CONCLUSION AND RECOMMENDATIONS

Weed is the major production constraints, particularly for field pea production in Bale Highlands, and hence its management is quite paramount important to increase the production and productivity.

Results of these study revealed that two hand weeding can be recommended for field pea farms where labor is not a problem. But, in the study area the use of chemical herbicide is the choice with no options since field pea production is in large scale. So, in areas where labor competition is very high during critical period, pre-emergence application of Dual-gold 2.0 L ha^{-1} supplemented with one hand weeding at the later stage could be used as an alternative weed management. However, further research is required to find out another pre or post-emergency herbicide which can control weed problems without supplemental hand weeding practices.

Reference

Anonymous. Handbook of agriculture. Indian Council of agricultural Research, New Delhi, 2006, 911-918.

Chaudhary S, Rathi JPS, Chaudhary DK, Singh OP. Weed management in field pea (Pisum sativum L) through agronomic manipulations. International Journal of Plant Science. 2009; 4(2):524-526.

Daba, N.A. and Sharma, J., 2018. Assessment of Integrated Weed Management Practices on Weed Dynamics, Yield Components and Yield of Faba bean (Vicia faba L.) in Eastern Ethiopia. Turkish Journal of Agriculture-Food Science and Technology, 6(5), pp.570-580

Govardhan JD, Dar S, Rajeev, Bharat KA. Effect of different weed management practices on growth and yield of field pea (Pisum sativum L.). Agricultural Science Digest. 2007; 27(4):311-312.

Jafari, R., Rezai, S. and Shakarami, J., 2013. Evaluating effects of some herbicides on weeds in field bean (Phaseolus vulgaris). International Research Journal of Applied and BasicSciences, 6(8), pp.1150-1152.

Mishra JS. Efficacy of post emergence herbicides against wild oat in field pea. Indian Journal of Weed Science. 2006; 38:140-142.

Singh G, Wright D. Effect of weed management on weeds and on the nodulation, nitrogenase activity, growth and yield of pea (Pisum Sativum L) Acta Agronomica Hungarica. 2006; 54(4):469-485.

Tripathi AK, Meena HN. Competitive ability of field pea (Pisum ativum L) cultivars with weeds at varying row spacing. Current Advances in Agricultural Science. 2011; 3(2):112- 114

Veres T, Tyr S. Temporal dynamics of weed infestation in the pea for grain canopies in the years 2000-2010. Research Journal of Agricultural Science. 2012; 44(2):123-126

Assessment of irrigated snap Bean Pests (Disease and Insect) in East Shewa, Ethiopia

Feyisa Begna[1] and Tarikua Shumi

Adami Tullu Agricultural Research Center

[1]E-mail::fbos2009@gmail.com, Batu/Ziway, Ethiopia

Abstract

Snap bean (Phaseolus vulgaris L.) is one of the most important vegetable crops in Ethiopia.The report shows that area of production increases from year to year eventhouth the productivity is declining. The main reasons for low productivity of snap bean in Ethiopia include luck of certified seed and disease, insect pest and weeds.The objective of this work is to assess major insects and disease dynamics, occurrence, distribution and status of damage. Field surveys was conducted between 2020 and 2021/2022 on common bean crop in the main snap bean growing areas of East Shewa (Adami Tulu and Dugda districts) that are located in the mid rift valley of Ethiopia.The survey revealed that Snap bean production in East Shewa is affected by diseases caused by fungi, bacteria and virus. Fungal diseases (such as Angular Leaf spot, Anthracnose, Rust, and powdery mildew); one of it is bacterial (Common bacterial blight) and one of them is viral disease (i.e. Common mosaic virus). The major and most important insect pests observed were leaf minor, spider mite (Tetranychusurticae), white fly and aphid, having pest damage record of about 65, 40, 45, 25% for leaf minor, white fly, spider mite and aphids. In order to manage insect pests and diseases of snap bean, some functional action plan including awareness creation training on insect pest and diseases identification and their managements has to be designed.

Key words: snap bean, disease, insects, survey, East shewa

Introduction

Snap bean (Phaseolus vulgaris L.) is belongs to the family Fabaceae, tribe Phaseoleae, subfamily Papilionoideae (Mahajan, A. and Gupta, R.D. 2009). It was assumed to have originated in North America and Europe (Silbernagel, M.J *et al*., 1991). It is a strain of common bean which is developed for succulent pods having little fiber through breeding and selection (CIAT 2006). It is usually called garden, green, wax or string bean and all are grown for their immature pods. It is used as vegetable and serve as an important source of protein (Beshir*et al.,* 2015), fiber, micronutrients such as Fe and Zn and vitamin A.

Snap bean (*Phaseolus vulgaris* L.) is one of the most important pulse crops in Ethiopia. The main production areas include eastern Ethiopia, the south and the south west, the west and the Rift Valley. The Rift Valley area accounts for more than half of the country's bean production, mainly of the green bean type that is grown for export (FAO, 2020). Currently, Ethiopia is one of the most important beans producing country in the world. The report by central statistical agency, (CSA, 2019) indicates that the country produces 3,878,023.01 Qts in 2011/12 main cropping season and the estimate production for 2012/13 is 4,127,345.88 Qts. The report reveals that although the area under production increase from year to year the productivity is declining. The main reasons for low productivity of snap bean in Ethiopia include luck of certified seed (Nagash*et al.,* 2011) and disease, insect pest and weeds.

Among the many diseases affecting bean plants, common bacterial blight is the most destructive bean diseases. Common bacterial blight may be highly destructive during extended periods of warm and humid weather, resulting in yield and seed quality losses. These conditions commonly occur in Central Rift Valley during flowering to seed setting growth period and the disease is highly distributed and most severe during this period and farmers considered as it is a major production constraint which limits the productivity and market value of their bean (Allen *et al.* 1989).

A yield loss that reached up to 80% had been reported on susceptible snap bean genotypes under severe conditions of infection (Stenglein*et al*., 2003; Mwangombe*et al*., 2007. Yield losses of up to 61% have been reported in southern Tanzania (Mongi, 2016). Recently, it has become a major production-limiting problem in Ethiopia. Recent reports also confirmed the existing challenges of the disease to both subsistence farmers and commercial producers in the country.

It is essential that the concerned body have to come up with alternative measures such as establishing effective and sustainable solutions by undertaking a periodic survey on the occurrence and distribution of the pests. Such measures will also help in strengthening internal quarantine to limit the geographic expansion of the pests to new areas. Information on the association of cultural and environmental factors with pest occurrence are still lacking in the areas. Therefore, collecting concrete information about snap bean pests is very important to develop and apply pest management measure.

Objective

- To assess major insects and disease dynamics, occurrence, distribution and status of damage

Material and Methods

Description of Study Area

Field surveys was conducted between 2020 and 2021/2022 on common bean crop in the main snap bean growing areas of East Shewa (Adami Tulu and Dugda districts) that are located in the mid rift valley of Ethiopia.

Assessment of snap bean field

During the surveys, detailed questionnaire was used to collect general information about each snap bean farm from the farmers, development workers, horticulture experts, and other stake holders. The questionnaires were deals with geographical and climatic aspects of the major snap bean production areas, snap bean field, including farm size, rootstock and seed source, cultivars planted and application of fertilizer. The field survey comprises the major diseases and insect pests, and the management practices used in each common bean field. Information collected from the different snap bean field were combined for each question and summarized for the main parameters to give an overview of snap bean production and field management practices in the mid rift valley of Ethiopia.

Survey and sampling techniques

The survey was conducted by on-spot inspection of bean farms and by interviewing growers involved in bean based on the availability of suitable field for the survey, it was conducted along the main road at 5 to 10 km interval in the right and left of the main road. Five sampling points per field were selected in a "W" fashion. At each sampling point five randomly selected plants were selected for assessing and estimating the severity of the diseases in percentage.

Incidence and Severity of major snap bean pests

The prevalence, incidence and severity of the pests were assessed based on the characteristic pests' symptoms that were visually determined in the field on randomly selected plant parts.

Diseases prevalence: proportion or percentage infected areas/ fields from the total assessed areas. Diseases prevalence tells us the geographic distribution of the diseases. The percent diseases prevalence is calculated as follows:

Disease prevalence (DP %) = $\frac{\text{Total infected areas}}{\text{Total assessed areas (field)}} X100$

Diseases incidence: is the proportion or percentage of diseased leaves in a plant, diseased stalks or tillers or diseased seedlings in afield. It is the diseased percentage of parts or pants in the sample or population. Disease incidence generally tells about the prevalence of the disease in a given areas or host population. The percent of diseases incidence is calculated as follows

Diseases incidence (DI %) = $\frac{\text{number of infected plants}}{total\ number\ of\ assessed\ plants}$ x100

Disease severity (DS) is the percentage of relevant host tissues or organ covered by symptom or lesion or damaged by the disease. Severity results from the number and size of the lesions. Disease severity tells about the extent of damage caused by diseases. Diseases severity calculated using the following formula (Wheeler, 1969).

$$\text{Disease severity or Infection index} = \frac{\text{Sum of all disease rating}}{total\ number\ of\ rating\ maximum\ disease\ grade} \text{X100}$$

Insect pest leaf damage

All plants and plant parts were examined for leaf damage. The score on each leaf of a plant was taken based on a scale of 0 to 5 (0= no leaf damage; 1= up to 20 % of the total leaf area damaged; 2= 21-40% of the total leaf area damaged; 3= 41-60% of the total leaf area damaged; 4= 61-80 % of the total leaf area damaged; and 5= more than 80 % leaf area damaged) (Iman*et al*, 1990).

Data Analysis:

The collected data on incidence and severity were subjected to statistical analysis using the R software and LSD were used for mean separation at 0.05% significance level. Responses of the questionnaire were subjected to statistical analysis by descriptive statistics using SPSS computer software.

Results and Discussion

General information of surveyed fields

Districts differed in altitude ranges in which 100% of the assessed farms were located at 1612-1668 m.a.s.l., respectively. Field sizes ranged from 2500 m^2 to 75000 m^2 in both districts.

Snap beans grown in the areas were Vodca and Contender cultivars (which are introduced). Farmers obtained those genotypes from local market and/or farm saved (recycled from previous cropping season). Farmers observed to practice sole cropping (systems. Maize, papaya) were associated with bean intercropping systems. But papaya-bean intercropping was the most common system across districts. During the survey, pre- flowering, flowering, pod forming and pod filling growth stages were noted.

The majority of the farmers used to plough three or four times before planting. Most of the farmers used to rotate fields with cabbage, onion and tomato. Most of farmers were using NPS and urea blended fertilizer at a recommended rate (100-200 kg ha^{-1}), in bean fields. Hoeing for three to four time was very common.

Table 14. General information of surveyed fields

Districts	Pa	Alt.(m asl)	Latit	Long	No. of assessed farm	Variety	Crop gwoth stage	Cropping system	Ploughing	Hoeing	NPS or Urea(Qu /ha)	Fungicide/insecticide
Adami Tulu JidoKombolcha	Boches	1649	$7^{0}51'.32$	$38^{0}43'.80$	10	Vodka and contender	Flowering	Maize and papaya intercrop	3	3	2,2	Mancozeb, sulphore,farrate
	Dodicha	1653	$7^{0}51'.16$	$38^{0}43'.62$	10	Vodka	Vegetative	Maize intercrop	3	3	1.5,2	Matco, Diamethote
	Haleku	1612	$7^{0}50'.55$	$38^{0}42'63$	10	Vodka		Mono	3	2	2,2	
Dugda	WaldaKalina	1658	$8^{0}08'.89$	$38^{0}50'.35$	8	Vodka, contender	Flowering	papaya intercrop	3,4	3	1,1	Omaxim, farrate
	WaldaMekdela	1665	$8^{0}08'.33$	$38^{0}50'.15$	10	Vodka and contender	Vegetative	papaya intercrop	4	3	1,2	
	Sh.Gamo	1668	$8^{0}08'.31$	$38^{0}50'.20$	7	Vodka	Flowering	papaya intercrop	4	3	1,1	

Pest status

The survey revealed that Snap bean production in East Shewais affected by diseases caused by fungi, bacteria and virus (Table2). Fungal diseases (such as Angular Leaf spot, Anthracnose, Rust, and powdery mildew); one of it is bacterial (Common bacterial blight) and one of them is viral disease (i.e. Common mosaic virus). Based on the disease severity, incidence and prevalence scores, the diseases can be categorized into three i.e. Major, intermediate and minor diseases. Rust and powdery mildew can be grouped as Major. Common bacterial blight, Angular Leaf Spot and Anthracnose can be categorized as Intermediate and the remaining categorized as minor (Table2) .Disease prevalence, incidence and severity varied among the surveyed districts. The distribution, incidence, severity and prevalence of all observed diseases are indicated inTable2 and 3 below.

Angular leaf spot (*Pseudocercospora griseola)*

The Angular Leaf spot disease was having mean prevalence of 36.6%, incidence of 41.6% and severity of 23.3% in the zone. The highest disease incidence score of 50%was obtained in Dugda District, followed by Adamitulu Jido Kombolcha District with 30%. ALS disease severity was highest at Dugda (30%) followed by Adami tulu Jido Kombolcha District at (20%) (Table2). Similarly, Getachew and Habtamu(2019) reported the disease with variable severities in different districts (41% at Konso, 29% at Demba Gofa and 14% at Mihirab Abaya Districts). Getachew and Habtamu(2019), associated the high disease severity with altitude range of below 2000 m.a.s.l., poorly prepared farms, farm saved and local market seed sources, intercropping, early planting, low **level of fertilizer application and with high weed. Rezene *et al.* (2018) reported high pathogenic diversity of ALS with 21 races (Pathotypes) (Pseudo *Cercospora griseola*) was reported widely distributed.**

Anthracnose (*Colletotrichum lindemuthianum)*

Anthracnose is one of important diseases of snap bean in Ethiopia. It occurred with prevalence of 40%, incidence of 60% and severity 40% in surveyed districts. The survey revealed the variability of the disease from 15 to 60 % in prevalence. The disease (anthracnose) heavily attached the crop in Dugda District with 40% prevalence, with 60% incidence and with 40% severity scores, followed by Adami Tullu Jido Kombolcha with 30% prevalence, 40% incidence and 40% severity scores. So, anthracnose is an important disease in the both districts. Fernandez *et al.,* 2000 reported bean anthracnose is transmitted from one season to another through infected seed and when infection occurs early in growth cycle of susceptible cultivars, disease severity can be up to 100%. Similarly, Tesfaye (2003), obtained anthracnose in all surveyed areas with high incidence at Bako, Didessa, Ambo, Arsi-Negele, Meki and Areka. He also reported high severity of bean anthracnose in the humid zone (H2) and high incidence to be associated to semi- arid (SA) zones.

Common bacterial blight (*Xanthomonas axonopodispvphaseoli)*

The mean CBB disease occurrence in the surveyed area was significant (table 2). The mean prevalence was 39.3%, the incidence was 36.6% and severity was 26.6%. However, the high exchange of seeds among the farmers within the zone and absence of quarantine among the districts will make it easy for the disease to be introduced and established in the other districts. Tesfaye (2003), reported, CBB distribution to be high in cooler areas where rainfall is erratic. he obtained, high level of the disease in central rift valley with semi-arid agro ecology, and intermediate level of the disease in eastern Ethiopia with sub\ moisture agro ecology and low levels of the disease in semi humid and moist areas (Jimma, Metu, Hararghe, and Melkassa) Tesfaye (2003).

When snap bean is exposed to extended period of warm and humid weather, CBB can be highly destructive and causes losses Opio et al. (1992), reported, estimated losses due to CBB to be 10-40% on susceptible cultivars in Uganda. The disease has been reported in many parts of Ethiopia.

Powdery mildew *(Erysiphe cucurbitarum*)

Powdery mildew is reported to be caused by Erysiphe cucurbitarum, is one of the major diseases in East Shewa zone. It was obtained with prevalence of 80%, incidence of 50% and severity of 35% in Adami Tulu Jido Kombolcha district also prevalence of 80%, incidence of 45% and severity of 30 in Dugda district. (Getachw and Habtu, 2019) reported Powdery mildew (caused by Podosphaera xnathii or Erysiphe cichoracearum) is a common and serious disease of snap beans. Since no resistant cultivars are available for this disease, fungicides are the primary means for management. Powdery mildew has always been one of the major yield limiting factors in some common bean production regions in the world, such as Brazil, Mexico, Spain, and the United States, and can cause up to 69% of yield loss (Felix GR., 2011)

Leaf Rust (*Uromyces appendiculatus*)

Snap bean rust, is caused by Uromyces appendiculatus (Pers.) Unger, was obtained in Dugda and Adami Tulu Jido Kombolcha District. It was occurred with higher than 80% prevalence, 60% incidence and 40% severity in the zone. The survey revealed the variability of the disease from 10 to 80% in prevalence. The disease (rust) heavily attached the crop in both Adami Tulu Jido Kombolcha district with 80% prevalence, with 60% incidence and with 35% severity scores, followed by Dugda, with 70%prevalence, 45% incidence and 40%severity scores. Its distribution expressed in prevalence was 89.3% in the metekel zone and 73.3% in Dibate district reported by Degu T, Yaregal W, Gudisa T (2020). The disease severity and incidence score was 8.5 and 60.8, in the zone. The high disease incidence was scored at Mandura (85.2%) and Bullen (57.4%) District (Degu T, Yaregal W, Gudisa T., 2020).

The intensity of snap bean disease in 2022

The Rust heavily attached the crop in both Adami Tulu Jido Kombolcha District with 45% prevalence, with 65% incidence and with 65% severity scores, followed by Dugda, with 40% prevalence, 55% incidence and 50%severity scores. The powdery mildew heavily attached the crop in both Adami Tulu Jido Kombolcha District with 65% prevalence, with 55% incidence and with 50%severity scores, followed by Dugda, with 35 % prevalence, 40% incidence and 50%severity scores. The highest common bacterial blight, anthracnose and angular leaf spot were incidence score of 20, 15 and 20% were obtained in Dugda District and Adamitulu Jido Kombolcha District. The highest common bacterial blight, anthracnose is and angular leaf spot were severity score of 15, 20 and 10 % were obtained in Dugda District and Adamitulu Jido Kombolcha District. The disease intensity of 2022 was comparatively very low when compared to 2021. This is duo to cool temperature of the season and crop growth stage which is at vegetative stage. Mersha and Hau (2008) reported the disease to be favored by cool to moderate temperatures, high moisture, late planting, excess nitrogen or hail damage. Repeated disease cycles may occur at 10 to 14-day intervals under favorable conditions.

Fusarium Wilt

During the 2021 and 2022 year fusarium wilts were one of the constraints for beans production. In 2021, virus incidence varied from 10% around Adami Tulu to 10 % Dugda in area. During the next year fusarium wilt, caused by ranged from 15% in Adamitulu to 18% in Dugda.

Disease intensity at early in the assessed areas was above 10% (Table 1). Roberts and Kucharek, 2005 also reported fusarium wilt as an important disease of beans during the nursery stage which causes about 15 to 40% damage to the crop. The observed high infestation might be due to prevailing high soil moisture. As a result of the existing high rainfall and moderate temperature along with high humidity at seedling stage, rainy season leads to the development of the damping off diseases (Kucharek et al. 1992). In the present survey, more fungal diseases were encountered as compared with the other disease causing agents.

Table15: **Disease severity, incidence and prevalence of snap bean diseases in 2021 and 2022 cropping season.**

Districts	Ganda s	Common bacterial blight			Anthracnose			Rust			Powdery mildew			FusariumWilt	Angular leaf spot		
		Prev	Inc	Sev	Prev	Inc	Sev	pre	Inc	Sev	prev	inc	sev	Inc	pre	inc	sev
Adami Tulu JidoKombolcha	Bochesa	30	20	20	15	20	15	60	45	15	70	40	20	5	20	20	10
	Dodicha	60	35	15	20	25	30	80	60	35	80	50	30	10	0	0	0
	Haleku	30	20	10	30	40	40	30	25	10	70	40	35	10	20	30	20
	Mean	40	24	18	22	28.3	28.6	56.6	20	20	73	43.3	26.6	8.3	16.6	16.6	10
	WaldaKalina	45	40	35	20	25	20	70	45	30	40	40	20	10	40	50	30
	WaldaMkidela	40	50	35	40	60	40	70	30	40	50	30	30	0	40	50	30
Dugda	ShubiGamo	30	20	10	30	30	20	80	40	30	80	45	20	10	30	25	10
	Mean	39.3	36.6	26.6	30	38.6	26.6	73	38.6	33.6	56.3	35	26.6	6.6	36.6	41.6	23.3
	2022																
Adami Tulu JidoKombolcha	Bochesa	10	5	5	15	10	5	45	65	65	60	55	45	15	15	15	5
	Dodicha	20	15	15	10	10	15	40	45	45	55	50	40	20	20	10	10
	Haleku	15	20	15	10	15	20	25	55	45	65	40	50	10	5	20	5
	Mean	15	13	11.5	11.6	11.6	13	38	55	52	60	48	45	15	13	15	6.6
	WaldaKalina	15	5	3	15	5	5	40	55	50	30	40	50	18	0	0	0
	WaldaMkidela	5	10	5	0	0	0	30	30	45	30	25	30	15	15	20	25
Dugda	ShubiGamo	0	0	0	20	15	10	25	40	40	35	20	40	10	15	25	25
	Mean	6.6	5	2.6	13	6.6	5	31	41	45	31.6	35	40	14.6	10	8.3	16.6

The distribution of insect and spider mite pest observed

The survey results indicated that the production of snap bean in East Shewa is subjected to various insect pests. Data recorded in Table 3 showed that the major and most important insect pests observed were leaf minor, spider mite (*Tetranychusurticae*), white fly and aphid, having pest damage record of about 65, 40, 45, 25% for leaf minor, white fly, spider mite and aphid's.

In African fields, numerous insect pests attack all parts of snap bean during all stages of growth, from seedling to stored product (Abate T. and Ampofo J., 1996). Only a few of these are recognized as major pests. Their economic importance varies from one environment to another, but bean researchers generally agree that bean aphids, flower thrips, pod borers, and spider mite (Mwanauta, R., Mtei K. and Ndakidemi P., 2015). Spider mite is a cosmopolitan species considered a snap bean pest in several countries (Hernández *et al.*, 1995). Bean aphids are found in colonies around the stem, leaves and growing point. Crop damage due to Aphid is estimated to 37%.Besides causing direct damage to the host by sucking the sap from various plant parts, they also indirectly transmit common mosaic viruses which result in early plant death (Munyasa A.J., 2013).

Table 16.the level of Insect pest damage (%) in study areas

Districts	Ganda	Leafminer (*Liriomyza spp*.)	White fly (*Trialeuroides variabilis)*	Spider mite (*Tetranychus urticae*)	Aphid (*Myzuspersicae*)
Adami Tulu JidoKombolcha	Bochesa	50	10	30	0
	Dodicha	65	0	52	20
	Haleku	30	15	45	8
	Mean	45	8	42	8
Dugda	W.Kalina	30	40	15	15
	WaldaMekdela	50	0	40	20
	ShubiGamo	0	40	40	25
	Mean	27	30	35	20
		2022			
Dugda	WaldaKalina	30	30	45	20
	WaldaMekdela	35	15	25	22
	ShubiGamo	55	30	35	20
	Mean	40	26.5	32	21
Adami Tulu JidoKombolcha	Abinegarmama	45	30	15	20
	Dodicha	60	20	35	15
	Haleku	45	15	40	18
	Kamogarbi	65	18	36	25
	Mean	55	22	32	21

Conclusion and Recommendation

The survey revealed that snap bean production in East Shewa Zone is affected many diseases caused by fungi. Based on the disease severity, incidence and prevalence scores, the diseases Rust and powdery mildew were grouped as major. Angular Leaf Spot, Anthracnose and common bacterial blight are categorized as Intermediate and the remaining diseases: fusarium wilt was grouped under minor diseases.

Insect and spider mite pests such as leaf minor, aphids and white fly were the major pests of some surveyed location and recorded as major insect pests.

Despite the appearance of several major diseases during the survey periods most farmers do practically chemical control these diseases. In order to manage insect pests and diseases of snap bean, some functional action plan including awareness creation training on insect pest and diseases identification and their managements has to be designed.

Moreover, an integrated pest management approach should be introduced in the study area. For identified major insect pests and diseases regular inspection of fields, monitoring of some known pests and fast control measure is advised. Furthermore, since there were not enough information as regards the biology, ecology and economic thresholds for pests it is necessary to carry out more research in this regard and proper attention be given towards designing control strategies for this pest.

Reference

Abate, T. and Ampofo, J. K. O., 1996. Insect Pests of Beans in Africa: Their Ecology and Management. Annual Review of Entomology, 41, pp 45-73

Allen DJ, Dessert M, Trutmann P, Voss J., 1989. Snap bean in Africa and their constraints. pp. 1-32. In: Schwartz HF, Pastor-Corrales MA (eds.), Bean production constraints in the tropics (2nd ed.). Centro Internacional de Agricultura Tropical CIAT, Cali, Colombia.

Beshir, M.H., Tesfaye, B., Bueckert, R. and Tar'an, B., 2015.Pod quality of snap bean as affected by N fixation, cultivar and climate zone under dry land agriculture. African Journal of Agricultural Research, 10(32): 3157-3169

Broughton, W. J., Hernandez, G., Blair, M., Beebe, S., Gepts, P. and VanderleydenJ., 2003.Beans (Phaseolus spp.)-model food legumes.Plant and Soil.Pp 252: 55 - 67.

CIAT. 2006. Highlights CIAT in Africa: Snap bean for income generation by small farmers in East Africa. No.31. http://ciat library.ciat.cgiar.org/articulos_ciat/highlight31.pdf 27.

Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon WT, Laprise R, Magaña-Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, SarrA,Whetton P. 2007. Regional climate projections.P.850-925.)

CSA (Central Statistics Agency of Ethiopia) (2019). Report on area and crop production of major crops for 2016 Meher season, 1: 125.

FAO (Food and Agricultural Organization) (2020).Phaseolusbean post-harvest operations.Post-harvest compendium.

Felix-Gastelum, R.; Maldonado-Mendoza, I.E.; Herrera-Rodríguez, G.; Martinez-Valenzuela, C.; Espinosa-Matías, S.; Cordero-Ramírez, J.D.; Martínez-Álvarez, J.C., 2011.Powdery mildew on common bean (Phaseolus vulgaris L.) in Northern Sinaloa, Mexico.Pp 169–182. [Google Scholar]

Degu T, Yaregal W, Gudisa T., 2020.Status of Common Bean (Phaseolus vulgaris L.)Diseases in Metekel Zone, North West Ethiopia. J PlantPatholMicrobiol 11:494. doi: 10.35248/2157-7471.20.11.494

Gudero G, Terefe H., 2019 Distribution and relative importance of snap bean angular leaf spot in subsistence farming systems in Southern Ethiopia. Pest Management Journal of Ethiopia (21).Pp 35–55.

Habtu A, Sachet I, ZadoksJC., 1996. A survey of cropping practices and foliar diseases of snap beans in Ethiopia.Crop Protection. 15(2):pp179-186.

Hernández, E., Luna, C., and Hernández, A., 1995.Análisis de la disposiciónespacio-temporal y ácaros-día de *Tetranychuscinnabarinus*Boisd. (Acari: Tetranychidae) en hojas de papayo, en Iguala, Gro., durante 1993. *Paper read at Memoria XXX CongresoNacional de Entomología, Mayo 28 a 31 de 1995, Chapingo, Estado de México*.

Iman, M., S. Dani, S., Jestmandt, I., Adiputra, M. and Ishak, M. 1990. Effect of Insecticides on Various Field Strains of Diamondback Moth and its Parasitoid in Indonesia. P 315 In: N.S Talekar(Ed.). Diamondback Moth and Other Crucifer Pests: Proceeding of the Second International Workshop, Tainan, Taiwan, 10- 14 December 1992, Asian Vegetable Research and Development Center, Shanhua, Taiwan.

Kucharek, T., J. P. Jones, D. Hopkins, and J. Strandberg., 1992.Some Diseases of Vegetable and Agronomic Crops Caused by Fusarium in Florida.Circular 1025. Gainesville: University of Florida Institute of Food and Agricultural Sciences.

Mahajan, A. and Gupta, R.D. 2009. Integrated Nutrient Management (INM) in a Sustainable Rice-Wheat Cropping System, Springer Science Business Media B.V

Mersha Z, Hau B., 2008. Effects of bean rust (Uromycesappendiculatus) epidemics on host dynamics of snap bean (Phaseolus vulgaris). Plant Pathology (57). Pp674-686

MongiRJ., 2016. Breeding for resistance against angular leaf spot disease of common bean in the Southern Highlands of Tanzania.Ph.D. Dissertation, College of Agriculture and Science, University of KwaZulu Natal, Pietermaritzburg Campus, Republic of South Africa.Pp223.

Munyasa, A.J., 2013.Evaluation of Drought Tolerance Mechanisms in Mesoamerican Dry Bean Genotypes.

Mwanauta, R. ,Mtei, K. and Ndakidemi, P., 2015. Potential of Controlling Common Bean Insect Pests (Bean Stem Maggot (Ophiomyiaphaseoli), Ootheca (Oothecabennigseni) and Aphids (Aphis fabae)) Using Agronomic, Biological and Botanical Practices in Field. Agricultural Sciences, 6, 489-497. doi: 10.4236/as.2015.65048.University of Nairobi, Nairobi.

Mwang'ombe AW, Wagara IN, Kimenju JW, Buruchara RA. 2007. Occurrence and severity of angular leaf spot of snap bean in Kenya as influenced by geographical location, altitude and agroecological zones. Plant Pathology Journal 6(3):235-24.

Negash K, Genbeyehu S, Tumsa K, Habte E., 2011. Enhancing progress and prospects with research and development of TLII in Ethiopia, 3rd ESA Annual Review & Planning Meeting, Lilongwe, Malawi.

Opio AF, Teri JM, Allen DJ., 1992. Assessment of yield losses caused by common bacterial blight of beans in Uganda.African Crop Science Journal.pp59-67.

Rezene Y, Tesfaye K, Clare M, Gepts P.,2018. Pathotypes characterization and virulence diversity of Pseudocercosporagriseola the causal agent of angular leaf spot disease collected from major snap bean (Phaseolus vulgaris L.) growing areas of Ethiopia. Journal of Plant Pathology Microbiology.(9):pp 445.

Roberts, P., and T. Kucharek. 2005. Florida Plant Disease Management Guide: University of Florida Institute of Food and Agricultural Sciences. http://gcrec.ifas.ufl.edu/snap beans/ diseases/diseases.htm

Silbernagel, M.J., Janssen, W., Davis J.H.C. and de Oca, G.M. 1991. Snap bean production in the tropics: Implementations for genetic improvement. In: van Schoonhoven, A. and Voysest, O.(ed.) Common beans: Research for crop improvement. CABI, 848p.

Stenglein SL, Ploper D, Vizgarra OP, Balatti P. 2003. Angular leaf spot: A disease caused by the fungus Phaeoisariopsisgriseola (Sacc.) FerrarisonPhaseolus vulgaris L. Advances responses of Australian native in Applied Microbiology 52:209-243.

Tesfaye B., 2003. Biology and Control of Bean Anthracnose in Ethiopia. A PhD thesis submitted in fulfillment of requirements for the degree of Doctor of Philosophy in the Faculty of Natural and Agricultural Sciences, (Plant Pathology), University of the Free State Bloemfontein, South Africa. Pp144.

Wheeler BJ. 1969. An Introduction to Plant Diseases. John Wiley and Sons, Ltd., London. 374pp.

Assessment of Watermelon (Citrulluslanatus (Thunb) Pests (disease and insects) in East shewa, Ethiopia

Feyisa Begna[1], Adisu Longale[2] and Gobana Tesfaye[2]

* E-mail::fbos2009@gmail.com, Batu/Ziway, Ethiopia

Abstract

Watermelon (Citrulluslanatus (Thunb.) is an important horticultural crop, which is mostly cultivated for its sweet and juicy fruit. According to farmers in east Shewa (near Koka Lake) the crop was introduced by Italians in 1950's. Currently, its major production is limited to lake shore areas of East Shewa zone. Watermelons are affected by a number of disorders that may limit their marketability and thereby restrict economic returns to growers. The objective of the study is assess major insect and disease occurrence, distribution and status of damages. Field surveys were conducted between 2020 and 2021/2022 EC on watermelon field in the main watermelon growing areas of East shewa (Lume and Bora districts) that are located in the mid rift valley of Ethiopia. The survey revealed that watermelon production in East Shewa Zone is affected by diseases caused by fungi. Fungal diseases (such as Anthracnose, Altarnaria leaf blight, Downy and Powdery mildew) were observed in the survey area. The major and most important insect pests observed were leaf minor, spider mite (Tetranychusurticae), white fly and aphid, having pest damage record of about 20-70% for spider mite, 10-25 % for white fly, 10-40% for spider mite and 15-40% aphid's. In order to manage insect pests and diseases of watermelon, some functional action plan including awareness creation training on insect pest and diseases identification and their managements has to be designed.

Key words: water melon, disease, insects, pest, lume, bora

Introductions

Watermelon (*Citrulluslanatus* (Thunb.) is an important horticultural crop, which is mostly cultivated for its sweet and juicy fruit (Duduyemi *et al*., 2013). In Africa, watermelon accounts for

5.4% of the harvested area devoted to vegetable production in 2008, and this contributed 4.6% (99,194,223 tonnes) of world watermelon production (Gichimu *et al*.,2008). Many research reports showed that, watermelon is very rich in micro nutrients and also serves as a good source of phyto chemicals including lycopene, a red carotenoid pigment which acts as antioxidant during normal metabolism (Koocheki *et al*., 2007). A cup of watermelon provides 24.3% vitamin C, and 11.1% vitamin A of the daily requirement (Nagal *et al.*, 2012). Due to its antioxidant properties; lycopene helps cells and other structures in the body to protect from oxygen damage and prevent heart disease (Erukainure *et al*., 2010, Erifeta *et al.*, 2011). The exact time for introduction of watermelon fruit to Ethiopia is not known. According to farmers in east Shewa (near Koka Lake) the crop was introduced by Italians in 1950's. Currently, its major production is limited to lake shore areas of East Shewa zone where it was introduced with little expansion to other parts of the country (Fanos and Belew2015). Nowadays, watermelon has good demand especially by foreigners and some of the society in central parts of Ethiopia. Regardless of its current demand, various factors affected improvement in watermelon production in the country. Among the factors, disease, insect and others are the major ones. The quality of watermelon that has been produced by Ethiopian farmers is very low compared to the world average (Zhang *et al*., 2011). Watermelons are affected by a number of disorders that may limit their marketability and thereby restrict economic returns to growers. Pathogenic diseases discussed include bacterial rind necrosis (Erwinia sp.), bacterial fruit blotch and Acidovoraxavenae subsp. citrulli (Schaad*et al*., 1998). One insect-mediated disorder, rind worm damage is discussed Physiological disorders considered are blossom-end rot, bottleneck, and sunburn.

Additionally, cross stitch, greasy spot, and target cluster, disorders of unknown origin are discussed. Each defect is shown in color for easy identification. Growers and advisory personnel are often confronted with field problems that are difficult to diagnose. Although watermelon fields are frequently scouted for pest management purposes, fruit are not examined carefully until harvest begins. Accordingly, rapid diagnosis with accurate prediction of consumer acceptability is essential for marketing purposes (Wall *et al*., 1988). Occurrence, epidemic development and severity of a disease is influenced by cropping systems and production practices, topographical features, crop genotypes, altitudinal ranges and cropping season and field management practices under a given environment (Zhu *et al*. 2000). Assessing of different factors associated with pests development are important to obtain relevant data for gaining insight into the occurrence, distribution and relative importance of different crop diseases (Rusuka *et al*. 1997). Moreover, disease management requires a thorough understanding of all such factors which contribute to disease epidemics (Fininsa and Yuen 2001; Mwang'ombe *et al.* 2007; Ddamulira *et al*. 2014; Kijana *et al.* 2017). However, detail information on the distribution, relative importance and how the different cropping practices and environmental factors affect pest's epidemics is lacking in the study areas.

Objective

To assess major insect and disease occurrence, distribution and status of damages

Material and Methods

Description of Study Area

Field surveys were conducted between 2020 and 2021/2022 EC on watermelon field in the main watermelon growing areas of East shewa (Lume and Bora districts) that are located in the mid rift valley of Ethiopia.

Assessment of watermelon field

During the surveys, detailed questionnaire was used to collect general information about each watermelon farm from the farmers, development workers, horticulture experts, and other stake holders. The questionnaire was deals with geographical and climatic aspects of the major watermelon production areas, watermelon field, including farm size, rootstock and scion source, cultivars planted, orchard and/or tree age, ownership, flora composition around the orchard, soil type and application of fertilizer. Information collected from the different watermelon orchards were combined for each question and summarized for the main parameters to give an overview of watermelon production and field management practices in the mid rift valley of Ethiopia.

Survey and sampling techniques

Systematic sampling technique was employed to determine sampling fields. Hence, 10 fields were assessed from each location. Then after, the diseased and insect-infested was assessed from the leaf, fruit and shoot part of the standing plant. Most insect pests were determined visually during the execution of the survey.

Incidence and Severity of major watermelon pests

Most of watermelon fields were assessed randomly in the three locations. The prevalence, incidence and severity of the pests were assessed based on the characteristic pests' symptoms that was visually determined in the field on randomly selected plant parts.

Diseases prevalence: proportion or percentage infected areas/ fields from the total assessed areas. Diseases prevalence tells us the geographic distribution of the diseases. The percent diseases prevalence is calculated as follows:

Disease prevalence (DP %) = $\frac{\textbf{Total infected areas}}{\textbf{Total assessed areas (field)}} \boldsymbol{x100}$

Diseases incidence: is the proportion or percentage of diseased leaves in a plant, diseased stalks or tillers or diseased seedlings in afield. It is the diseased percentage of parts or pants in the sample or population. Disease incidence generally tells about the prevalence of the disease in a given areas or host population. The percent of diseases incidence is calculated as follows

Diseases incidence (DI %) = $\frac{\textbf{number of infected plants}}{\boldsymbol{total\ number\ of\ assessed\ plants}}$ x100

Disease severity (DS) is the percentage of relevant host tissues or organ covered by symptom or lesion or damaged by the disease. Severity results from the number and size of the lesions. Disease severity tells about the extent of damage caused by diseases. Diseases severity calculated using the following formula (Wheeler, 1969).

Disease severity or Infection index= $\frac{\textbf{Sum of all disease rating}}{\textit{total number of rating maximum disease grade}}$ X100

Insect pest leaf damage

All plants and plant parts were examined for leaf damage. The score on each leaf of a plant was taken based on a scale of 0 to 5 (0= no leaf damage; 1= up to 20 % of the total leaf area damaged; 2= 21-40% of the total leaf area damaged; 3= 41-60% of the total leaf area damaged; 4= 61-80 % of the total leaf area damaged; and 5= more than 80 % leaf area damaged) (Iman*et al*, 1990).

Data Analysis:

The collected data on incidence and severity was subjected to statistical analysis using the R software and LSD was used for mean separation at 0.05% significance level. Responses of the questionnaires were subjected to statistical analysis by descriptive statistics using SPSS computer software.

Results and Discussions

General information of surveyed fields

Different agro-ecologies, cropping systems, field management practices (nutrient management), land uses, gentle slope to and pest management systems were major characteristics of surveyed areas. Districts differed in altitude ranges of the assessed farms were located at <1570 to 1665 m.a.s.l., respectively.

Watermelon cultivars grown in the areas are cripson and other cultivars (which are introduced). Farmers obtained those cultivars from local market and/or farm saved (recycled from previous cropping season). Farmers observed to practice sole cropping systems. During the survey, pre-flowering, flowering, fruit forming and pod filling growth stages were noted.

The majority of the farmers plough their fields three or four times before planting. Farmers produce watermelon along the lake shore when the water left the land.

Table 17: description of the survey areas

Districts	Ganda	Altitude	Latitude	Longitude	Number Of Farm	Variety/	Cropping System	Ploughing	Hoeing
Lume	Koka Nagawo	1570	$08^{0}25'.22$	$039^{0}04'.34$	10	Cripson	Mono	3	3
	Dhungugi Bekele	1650	$08^{0}25'.50$	$039^{0}06'.72$	10	Unkwon	Mono	3	3
	Danbela	1665	$08^{0}28'.47$	$039^{0}06'.82$	8	Cripson	Mono	3	2
	2022								
Bora	Gora Laman	1589	$08^{0}24'.21$	$38^{0}58'.39$	10	Unkwon		2	2
	Malima Bari	1602	$08^{0}19'.65$	$39^{0}00'.09$	10	Cripson	Mono	2	3

Pest status

The survey revealed that watermelon production in East Shewa Zone is affected by diseases caused by fungi (Table2).Fungal diseases such as Anthracnose, Altarnaria leaf blight, Downy and Powdery mildew) were observed in the survey area. Based on the disease severity, incidence and prevalence scores, the diseases can be categorized into three i.e. Major, intermediate and minor diseases. Downy and powdery mildew can be grouped as Major. Anthracnose and Altarnaria leaf blight can be categorized as Intermediate and the remaining categorized as minor (Table18). Disease prevalence, incidence and severity varied among the surveyed Districts. The distribution, incidence, severity and prevalence of all observed diseases are indicatedinTable2. Fungal, bacterial, and viral diseases were the most commonly reported diseases affecting cucurbits, as has also been reported in other sub-Saharan African countries like Sudan, Kenya, and Tanzania Desbiez et al., (2016).

Downy mildew (Pseudoperonospora cubensis)

The disease was having a mean prevalence of 90%, incidence of 57 and severity of 61% in the zone.The highest disease incidence score of 90% was obtained in Bora District, followed by Lume District with 70%.Downy mildew disease severity was highest at Bora(90%)followed by Lume at (80%) (Table18). Masika et al. (2022) reported the disease with variable severities (24%) in different districts of Tanzania. Similarly, Getachew and Habtamu (2019) reported the disease with variable severities associated the high disease severity with altitude range below 2000m.a.s.l., poorly prepared farms. In the presence of moisture, spores that land on a leaf germinate and enter the leaf tissue. New lesions are produced in 4–7 days, and downy mildew spreads rapidly if not controlled (Roberts and Kucharek 2005).

Powdery mildew (Erysiphe cichoracearum)

The disease was having a mean prevalence 45%, incidence 33% and severity 33% in the zone. The highest disease incidence score of 70% was obtained in Lume District, followed by Bora District with 70%. In 2022 powdery mildew disease severity was highest at Bora(40.5%)followed by Lume at (40%) (Table 18).

Powdery mildew (caused by *Erysiphe cichoracearum*) is a common and serious disease of watermelons. In severe cases, the fungus will colonize the whole leaf, leading to death. Among these diseases, powdery mildew, caused by the fungus *Podosphaera xanthii* (Castagne) in the field for susceptibility to variety can be severity (43%) (Keinath and Hassell, 2000). In 2013, 2014, powdery mildew severity reached 55% and 57.5%, respectively, in the untreated plots. Dry conditions, usually followed by periods of free moisture at night, tend to promote the reproduction and spread of this pathogen can be affect the leaf (37%) Masika*et al.* (2022)

Alternaria leaf blight (*Alternaria cucumerina*)

The Alternaria leaf blight (Alternaria cucumerina) disease showed average prevalence 25%, incidence 30 and severity 15% in the zone. The highest disease incidence score (50%) was obtained in Dugda District, followed by Adamitulu jido kombolcha District with 40%. ALS disease severity was highest at Dugda (30%) followed by Adamitulu jido kombolcha District at (20%) (Table 18). Similarly, Roberts and Kucharek 2005 reported that the alternarial blight (Erwinia cucumerina) intensity (33.3%) Mbega and Mabagala (2012) indicated that, watermelon crop were infected by Alternaria blight (96.7%) as in other fungal diseases. Spores require moisture to germinate and enter the leaf tissue, while spore release from the plant is best achieved under dry conditions

Anthracnose (Colletotrichum lindemuthianum)

Anthracnose is one of the most important diseases of watermelon in Ethiopia. It occurred with 40% prevalence, 60% incidence and 40% severity in the surveyed districts. The survey revealed the variability of the disease from 15to60% in prevalence. The disease (Anthracnose) heavily attached the crop in Dugda district with 40% prevalence, with 60% incidence and with 40% severity scores, followed by Adami Tulu Jido Kombolcha, with 30% prevalence, 40% incidence and 40%severity scores. So, anthracnose is an important disease in both districts. Then it does occur, anthracnose can destroy the entire field if not controlled, particularly after several days of warm, rainy weather (Bertelsen et al. 1994).

Similarly in Uganda anthracnose (35%) affects watermelon and pumpkin production and productivity (Dinssa et al., 2016).Anthracnose diseases on the other had cause enormous damage to pumpkin and watermelon and up to 80% losses have been recorded in cucurbits in the United States of America (Rojas et al., 2015). Disease development is greatest during humid, rainy weather. Spores are spread by wind, splashing rain, people, and machinery. The fungus, which can be seedborne, survives between crops on infected plant debris and volunteer plants (Maynard and Hopkins 1999)

Fusarium Wilts

During the 2021 and 2022 year fusarium wilts were one of the constraints for water melon production. In 2021, fusarium incidence varied from 10% around Lume to 15 % Bora in area. During the next year fusarium wilt, caused by ranged from 10% in Bora to 15% in Lume. (Trecate, L.; 2019) also reported fusarium wilt as an important disease of melon during the nursery stage which causes about 15 to 40% damage to the crop. The results of Mbega and Mabagala (2012) in Tanzania indicated that, watermelons were infected by Fusarium oxysporum (40%) and above. The observed high infestation might be due to prevailing high soil moisture. As a result of the existing high rainfall and moderate temperature along with high humidity at seedling stage, rainy season leads to the development of the damping off diseases (Trecate, L.; 2019).

Table18: The distribution, incidence, severity and prevalence of water melon diseases.

Districts	Ganda	Crop growth stage	Anthracnose (*Colletotrichumorbiculare*)			Downy mildew (*Pseudoperonosporacubensis*			Alternaria leaf blight (*Alternariacucumerina*)			Powdery mildew (*Erysiphecucurbitarum*)			Fusarium wilts (*Fusariumoxysporum*)
			Pre	Inc	Sev	Pre	Inc	Seve	pre	Inc	Seve	pre	inc	seve	Incidence
Lume	Koka	Fruit formation	30	20	15	100	70	80	40	15	5	70	40	40	15
	DhungugiBekele	Flowering	20	15	10	100	60	70	25	15	10	50	30	25	10
	Danbela	Fruit maturing	25	25	20	100	80	80	20	25	15	65	50	60	15
Bora	Malima	Flowering	35	30	20	100	75	75	15	10	5	40	45	40	5
	Mean		22.5	18	13	100	57	61	25	13	7	45	33	33	9
		2022													
Lume	DhungugiBekele	Fruit maturing	15	10	5	100	80	60	20	15	10	40	30	40	10
	KokaNagawo	Fruit maturing	25	10	5	80	90	65	10	10	5	45	40	30	15
	DararaDanbela	Fruiting	30	30	20	100	70	80	20	5	5	45	55	45	0
Bora	Gora Laman	Fruit formation	25	20	15	80	90	90	15	5	3	45	30	25	10
	Malima Bari	Fruit maturing	35	20	25	100	80	90	20	10	5	35	35	25	5
	Mean		26	18	16	91	81	70	17	9	5.6	40.5	40	33	6

The distribution of insect and spider mite pest observed

The survey results indicated that the production of watermelon in East Shewa (lume and bora districts) is subjected to various insect pests. The major and most important insect pests observed were leaf minor, spider mite (*Tetranychusurticae*), white fly and aphid, having pest damage record of about 20-70% for spider mite, 10-25 % for white fly, 10-40% for spider mite and 15-40% aphid's. (Table 19)

In both district generally higher insect pest damages were observed in 2021 as compared to the second year (2022) insect damage (Table 19). Also, more or less similar trends were observed other surveyed districts in watermelon damage by pests. The principal insect and mite pests on watermelons are aphids, mite, cowpea looper and whiteflies, leaf miners and (Maynard 2003; Hopkins 2003).Spider mite is a cosmopolitan species considered a watermelon pest in several countries (Hernández *et al.*, 1995). Generally, insects account for 15–25% damage in melon crops (Rathee & Dalal, 2018). Some insects are important vectors for many of the bacterial and viral diseases affecting plants. In pumpkin fields, whiteflies (35.6%), aphids (22.2%) were the most important pest constraints (Dietzgen *et al.*,2016).

Table 19: The level of Insect pest damage (%) in study areas

Districts	Ganda	Crop growth stage	Leaf minor	Aphid	Spider Mite	White Fly
Lume	KokaNegawo	Fruit Formation	50	30	40	25
	Dhungugi Bekele	Flowering	45	25	30	20
	Danbela	Fruit Maturing	70	40	20	20
Bora	Malima Bari	Flowering	40	30	10	10
		2022				
Lume	Dhungugi Bekele	Fruiting	35	15	20	15
	Danbela	Fruit Maturing	40	25	30	15
	Koka Negawo	Fruiting	45	15	20	20
Bora	Gora Laman	Fruit Formation	40	20	10	10
	Malima Bari	Flowering	20	17	25	20
	Mean		36	18.4	21	16

Conclusion and Recommendation

The survey revealed that snap bean production in East Shewa Zone is affected by many diseases caused by fungi. Based on the disease severity, incidence and prevalence scores, alternaria leaf spot, downy mildew, powdery mildew and fusarium wilt were the most frequently and dominantly occurred at most surveyed ganda s and recorded as the most important diseases of the area.

Insect and spider mite pests such as leaf minor, aphids and white fly were the major pests of some surveyed location and recorded as major insect pests. In order to manage insect pests and diseases of watermelon, some functional action plan including awareness creation training on insect pest and diseases identification and their managements has to be designed. Moreover, an integrated pest management approach should be introduced in the study area. For identified insect pests and diseases regular inspection of fields, monitoring of some known pests and fast control measure is advised. Furthermore, since there were not enough information as regards the biology, ecology and economic thresholds for pests it is necessary to carry out more research in this regard and proper attention be given towards designing control strategies for this pest.

REFERANCE

Dietzgen RG., 2016. Plant virus–insect vector interactions, current and potential future research directions. Viruses. 2016;8(11):303. https://doi.org/10.3390/v8110303.

Dinssa FF, Hanson P, Dubois T, Tenkouano A, Stoilova T, Hughes Ju'A, Keatinge JDH., 2016. World Vegetable Center's women-oriented improvement and development strategy for traditional African vegetables in sub-Saharan Africa.Eur J HorticSci.81(2):pp91–105

Duduyemi O, Adebanjo S, and Oluoti K., 2013. Extraction and Determination of Physico-Chemical Properties of Watermelon Seed Oil (Citrulluslanatus L) For Relevant Uses.International Journal of Scientific & Technology Research Volume2(8):2277-8616.

Erifeta O, Omage K, UhumwanghoS,Njoya K, Amegor O, and Okonkwo C., 2011. Comparative Evaluation of Antioxidant Effects of Watermelon and Orange, and Their Effects on Some Serum Lipid profile of Wister Albino Rats.International Journal of Nutrition and Metabolism3(8):97-102.

Erukainure O,L, Oke O, V, Daramola A, O, Adenekan S, O and Umanhonlen E, E., 2010. Improvement of the Biochemical Properties of Watermelon Rinds Subjected to Saccharomyces Cerevisae Solid Media Fermentation.Pakistan Journal of Nutrition 9(8):806-809.

FanosT,andBelew D., 2015. A Review on Production Status and Consumption Pattern of Vegetable in Ethiopia.Journal of Biology Agriculture and Healthcare5(21):82-93.

Gichimu B,M, Owuor B,O, and Dida M,M., 2008. Agronomic Performance of Three Most Popular Commercial Watermelon Cultivars in kenya as Compared to One Newly Introduced Cultivar and

One Local Landrace Grown on DystricNitisolsUnder Sub-humid Tropical Conditions. ARPN Journal of Agricultural and Biological Science3: pp 5&6.

Hernández, E., Luna, C., and Hernández, A., 1995. Análisis de la disposiciónespacio-temporal y ácaros-día de TetranychuscinnabarinusBoisd. (Acari: Tetranychidae) en hojas de papayo, en Iguala, Gro., durante 1993.

Keinathanda Hassel, 2000.Controlling powdery mildew on cucurbit rootstock seedlings in the greenhouse with fungicides and bio fungicides.Crop Protection journal Volume 75, Pages 70-76. USA

Koocheki A, Razavi S,M, Milani E, Moghadam T,M, Abedini M,Alamatiyan S, and Izadkhah S., 2007. Physical Properties of Watermelon Seed as a Function of Moisture Content and Variety.JournalInternational.Agrophysics21:pp349-359.

Hopkins, D., 2003. Plant pathologist, UF/IFAS Central Florida Research and Education Center, in communication with the author.

Maynard, D., 2003. Horticultural scientist, UF/IFAS Gulf Coast Research and Education Center, in communication with the author.

Mbega E.R. and Mabagala R. B., 2012.Fungal diseases of watermelon in Morogoro urban. Journal of Phytology 4(5): pp 61-64. Tanzania.

Maynard, D. N., and D. L. Hopkins, 1999.Watermelon Fruit Disorders."HortTechnology 9 (2): 155–161

Rathee M. and Dalal P., 2018.Emerging insect pests in Indian agriculture.Indian J Entomol. 80(2):267–81. https://doi.org/10.5958/0974-8172.2018.00043.3.

Rojas ES, Batzer JC, Beattie GA, Fleischer SJ, Shapiro LR, Williams MA., 2015. Bacterial wilt of cucurbits: resurrecting a classic pathosystem. Plant Dis.99(5): pp 64–74. https://doi.org/10.1094/PDIS-10-14-1068-FE.

Zhang H, GuoyiG, Shaogui G, Yi R, and Yong X., 2011).Screening the USDA Watermelon Germplasm Collection for Drought Tolerance at the Seedling Stage.National Engineering Research Center for Vegetables Hortscience 46(9):pp1245–1248.

Zhao W, Pin L, Huihui G., 2013. Studies on Carotenoids in Watermelon Flesh.Journal Agricultural Sciences 4(7A):13-20

Wheeler BJ., 1969. An Introduction to Plant Diseases. John Wiley and Sons, Ltd., London. 374pp

Insect Pests on Major Crops in Borana and West Guji Zones, Southern Ethiopia

Kemal Kitaba*, Rameto Nura, Ejigu Ejara and Gutema Edosa

Yaballo Pastoral and Dryland Agriculture Research Centre
*Corresponding author. E-mail: kemalkitaba@gmail.com

Abstract

Major crops insect pest assessment was conducted in two zones of southern Oromia, West Guji and Borana zones from 2020 to 2022 cropping seasons. The districts were selected purposively based on potential of crop they produce.The insects identified on common bean which leads to high yield loss are cutworm and pod borer. Cutworm is recorded only in Teltelle, while pod borer is mostly found in all 432156surveyed districts. The Maximum damages percentage of pod borer was observed at Yaballo (40%) followed by Teltelle (36%) whereas minimum damaged percentage (27.78%) was observed in Bule Hora. Three major insect pest species (fall army warm, aphids (black) and stem borer were observed on maize. Fall army warm was the dominant pest and accounts for about 50%, 73.7%, and 18.5% damage percentage in Teltelle, Yaballo and Abaya districts respectively followed by stem borer. Shoot fly was the major pest on teff with infestation levels 23.39%, 19.7%, 30% and 33.64% in Teltelle, Yaballo, Bule Hora, and Abaya districts respectively.

Keywords: Crops, Insects, Damage, Abundance

Introduction

Plant protection, have an obvious role to play in meeting the growing demand for food quality and quantity (Strange and Scott 2005). One practical means of achieving greater yields is to minimize the insect associated losses (Oerke *et al*. 1994). Crop production is one of the major sources of income diversification available to pastoralists and ironically one of the most important competitors to the pastoralist way of life (Tache, B., 2000). According to Mengistu *et al*. (2020) the major crops grown around Borana and West Guji are teff, maize, common bean and wheat (exceptional for west Guji zone). In Ethiopia during 2020/21 production year major crops such as teff, wheat, maize and red common bean and white common bean were cultivated over the area 2.93mil ha, 1.9mil ha, 2.53mil ha, 0.21mil ha, and 0.1mil ha respectively. The production from those areas were 1.882t/ha, 3.05t/ha, 4.18t/ha, 1.796 t/ha, and 1.76t/ha respectively.

In Borana maize was cultivated on 6,716.82ha and yields about 891.2089t which is 1.33t/ha. Red common bean is cultivated on 5,447.35ha and yielded about 577.16t with average yield 1.10t/ha. Similarly in West Guji maize was cultivated on over 9,180.49ha of land and yields about 37880.01t, with 4.13t/ha yields, Red common bean 932.52t from 5,222.94ha with 0.18t/ha (CSA, 2021). Despite its importance, the productivity of those major crops was very low compared to the national average yield. The yield losses caused by biotic pests are altogether responsible for losses ranging between 20 and 40 % of global agricultural productivity (Oerke *et al*. 1994). Among biotic factors, Insect pests are one of the major limiting factors to crop production and storage.In Ethiopia pre harvest yield loss due to insect pests in cereal and legume crops are estimated around 21-44% and 16-29 respectively (Getaneh *et al.*, 2016). The potential areas of Borana and West Guji zones for crop productions includes Yaballo, Teltelle, Elweye, Dire, Abaya and Bule Hora districts. The above listed districts have alike climatic conditions except Bule Hora district. Bule Hora district has long rainy season over the other districts and also, its elevation very far from those districts in Borana zone, it tends from midland to highland. Nowadays, demands for crop production had already been raised to fill demand for food security. The study by Tache and Sjaastad, (2008) also confirmed that crop cultivation is firmly expanding in the rangelands and tenure. Though crop production is relatively at initial level in pastoral areas, nowadays the urge for crop production knocks the integrity of every household regardless of the production skill and knowledge (Liao, 2014). According to Mengistu *et al*. (2020) about 85%, 65% and 30% of the respondents confirmed that they were producing maize, common bean and Teff respectively. Some internal constraints are lack of agricultural inputs and land competition. According to respondents, the major factors constraining crop production are external and include lack of rainfall (the rainfall pattern is highly erratic and rains often do not occur at the expected time), presence of different harmful agricultural pests, and lack of access to well-functioning markets. The objectives of this survey were to identify the major crops important insect pests and their distribution at Borana and West Guji zones.

Materials and Methods

Description of the study area

West Guji and Borana zones are located at 463km and 570km from Addis Ababa to the southern part respectively. Their climatic condition is hot, but unlike the other districts found in these zones Bule Hora has different agro-climatic conditions which tends to be mid highland and has a long rainy season than the others. Geographically they fall under an elevation of 1356masl to 1874masl for Borana, and 1422-2328masl for West Guji. Specifically, by districts the altitude range of the surveyed area are Yaballo 1490-1800masl, Teltelle 1356-1460masl, Abaya 1422-1460masl and Bule Hora 1860-2328masl. There are two rainy seasons with in year and main rainy season is from March to May while short rainy season is from early September to end of October.

Insect pest Assessment methods

The assessment was conduct at two zones, West Guji and Borana zonesin 2020 to 2022 production seasons. The survey was conducted in four districts. The districts were selected purposively based on potential of crop they produce. Fields were assessed with the distance of about 3-5km apart accordingly i.e., based on crop abundance. The GPS was used during the assessment for the purpose of geographical data such as elevation, latitude and longitude, distance and area of the survey areas. 1m*1m quadrant was used during the survey to take a sample from the fields and the sampling was done in diagonal pattern in each field. Questioner was developed to collect additional data from the farmers. The infestation percentage of the insects on the crop was recorded specifically for each crop as well as infesting insects. The insect species and their infestation level were recorded from all the surveyed districts for each crop. The major crops produced at the study areas include maize, common bean and teff. Percentage infestation level and damage were calculated using the formula adopted from (Singh *et al.*, 1983).

$$\text{Percent Infestation} = \frac{\text{No of Infested Plants}}{\text{Total number of observed plants}} \times 100$$

Data analysis

All collected data were feed into computer and managed by using Excel and lastly the data was analyzed using IBM SPSS Statistics 20.

Result and Discussion

The major Insect Pests

The survey indicates that there are different insect pests for each crop. Their prevalence differs from location to location based on the crop type and cropping history. In majority of assessed areas producers use local varieties which may increase the risk of insect pest damage.Based on the commodity the species of insects observed on each crop were different and even within a crop based on infestation level, they vary from location to location (Table 20).

Table20. Identified insect pests for three major crops Maize, Common bean and Teff with their abundance percentage across four districts

Districts	Crop	Identified insect name	Damage (%)	Average	Abundance %
Teltelle	Common bean	Cutworm	51.67		25
		Pod borers	36		41.67
		Ladybird beetle	37.14		29.17
	Maize	Fall army warm	50		38.33
		Stem borers	27.7		28.89
		Aphids	15.4		33.33
	Teff	Shoofly	23.39		21.45
Yaballo	Common bean	Pod borers	40		79.41
		Ladybird beetle	13.33		17.65
	Maize	Fall army warm	73.7		30.49
		Stem borers	53.8		30.36
		Aphids	50		40
	Teff	Shoofly	25.01		22.93
Bule Hora	Common bean	pod borers	27.78		46.3
	Teff	Shoofly	30		27.51
Abaya	Maize	Fall army warm	18.5		27.5
		Stem borers	10.5		25
	Teff	Shoofly	33.64		30.84

Types and infestation of insects on the crops

The insect pests on common bean which leads to high yield loss are cutworm,ladybird beetle and pod borer. These insects have their own abundance and damage levels on the crop (figure 1). The population/abundance and damage percentage differ from district to district and from field to field. Cutworm is recorded only from Teltelle, while pod borer is found in all districts. Pod borer damages the crops with about 36%, 40% and 27.78% damages at Teltelle, Bule Hora and Yaballodistricts respectively. Sharma *et al.*, (2008) also reported the pod borer as a major pest of cowpea and pigeon pea, but also damages other food legumes.

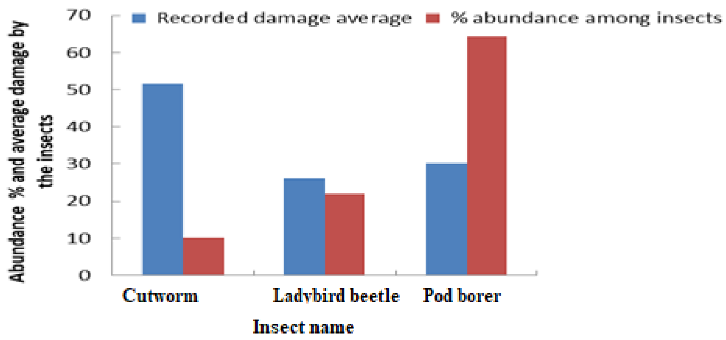


Figure 4. Insects recorded from common bean and their damage level with infestation percentage in districts

About 94 maize fields were assessed across the four districts and three major pests (fall armyworm, stem borer, and aphids (black) were recorded. The damage level and their infestation percentage vary from field to field and district to district. Fall armyworm was the dominant and existed all over the surveyed fields of both Borana and West Guji zones. Where about 65 fields were infested by the pest. It accounts for about 50%, 73.7% and 18.5% of damage percentage in Teltelle, Yaballo and Abaya districts respectively (Table 2). Highest infestation was occurred with maize infested with FAW, over the other insect pests. High percentage of infestation was observed at Yaballo district (73.7%) followed by Teltelle (50%) while low infestation was recorded at Bule Hora district (18.3%). The infestation of stem borer in maize fields ranged from 10.5% to 53.7% in surveyed districts. Rajin *et al*. (2000) also reported the infestation of maize stem borer could extend up to 60%, which is in range with this survey results.Aphids' infestation in maize field was less compared to another insect pest at all surveyed district.

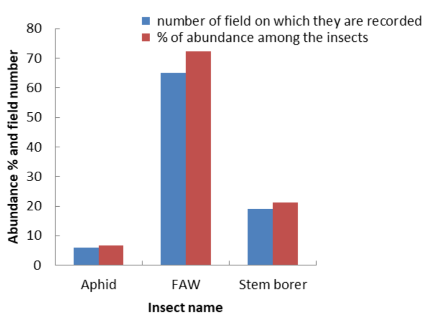


Figure 21. Major insects identified on maize with their abundance percentage

Teff is the third commodity and is one of the most widely cultivated crop in the areas. A total of 89 fields were assessed from both Borana and West Guji zones. On this crop shoofly was theonly major insect from recorded in 76 fields. Infestation level was 23.39%, 25.01%, 30% and 33.64% at Teltelle, Yaballo, Bule Hora and Abaya districts respectively. Similarly,Kalleshwaraswamy *et al.*,(2022) reported the infestation of shoot fly in teff with up to 42.0% infestation level at the age of panicle initiation and infestation could extend up to 100% in severe cases (Ademe and Mehiretu, 2016).

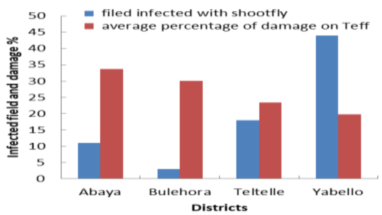


Figure 6. Number of infected Teff fields with Shoofly and damage percentage at four districts of the study area

Conclusion and Recommendation

Most agro-pastoralists are highly increasing production of field crops. They mostly cultivate common bean, maize and teff. Insect pests are affecting crop production and productivity and needs major attention to overcome the destructions occur with it. Pod borer and cut worm on common bean, FAW on maize and shoot fly on teff are the major ones. In the future, efforts should be made towards the integration of multiple control options like development of resistant varieties, development of improved agronomic practices, awareness creation among farmers and experts' right from site selection till post-harvest handling of various insect and their management.

References

Ademe and Mehiretu, (2016). Evaluation of Insecticides for the Management of Teff Shoot Fly. 4(5), 4–6. https://doi.org/10.4172/2329-8863.1000243

Boku T, Sjaastad E (2008). Pastoral conceptions of poverty: An analysis of traditionaland and conventional indicators from Borana, Ethiopia. World Development 38(8):1168-1178.

Central Statistical Agency Agricultural Sample Survey 2020/21 (2013 E.C.). VOLUME I Report on Area and Production of Major Crops. (2021).

Getaneh, G., Ayalew, G., &Derso, E. (2016). Plant Protection Research in Ethiopia: Major Achievements, Challenges and Plant Protection Research in Ethiopia: Major Achievements, Challenges and Future Directions Plant Protection Research in Ethiopia Major Research Achievements Plant Pathology Res. October 2021.

Kalleshwaraswamy, C. M., Ambarish, S., &Sridhara, S. (2022). First record on the incidence of shoot fly, Atherigonapulla (Wiedemann) (Muscidae: Diptera) in newly introduced crop Tef, Eragrostistef from India. Journal of Entomological Research, 46(1), 193–194. https://doi.org/10.5958/0974-4576.2022.00034.2

Liao C (2014). Case Study: Borana, Ethiopia, s.l.: ACSF-Oxfam Rural Resilience Project, Natural Resources, Cornell University.

Mengistu, D., Tefera, S., &Biru, B. (2020). Pastoral farming system and its temporal shift: A case of Borana zone, Oromia National Regional. 16(9), 1233–1238.

Oerke, E. C., Dehne, H. W., Schönbeck, F., & Weber, A. (1994). Crop production and crop protection. Estimated losses in major food and cash crops. Amsterdam: Elsevier.

Rajin, J, C., T Thangaraju, D. and David, P. M. M. 2000. Relative abundance of maize stems borer species in Tamil Nadu. Madras Agril. J. Pub. 2001, 87(4-6):228-234.

Sharma, H. C., Clement, S. L., & Ra, G. V. R. (2008). Insect pest management in food legumes: The future strategies. 1, 522–544.

Strange, R. N., & Scott, P. R. (2005). Plant disease: a threat to global food security. Annual Review of Phytopathology, 43, 83–116.

Major Diseases on major Crops in Borana and West Guji Zones, Southern Ethiopia

Kemal Kitaba*, Rameto Nura, Ejigu Ejara and Dejene Temesgen
Yaballo Pastoral and Dryland Agriculture Research Centre,
*Corresponding author. E-mail: kemalkitaba@gmail.com

Abstract

The disease assessment was conducted in two zones of southern Oromia, West Guji and Borana zones in 2020-2022 cropping rainy seasons. The districts were selected purposively based on potential of crop they produce. The recorded diseases on common bean were Angular leaf spot, *Anthracnose, common bacterial blight and leaf rust. The incidences of the diseases were 34.66 %, 32.57% and 24.93% for Common Bacteria Blight, Angular leaf spot and Anthracnose, respectively. The major diseases recorded on maize with their incidence percentage were Gray leaf spot (75.85%), Turcicum leaf blight (15%), Maize common smut (4.07%), and maize chlorotic mosaic (4.23%). The major disease recorded on teff was leaf rust and its incidence was 26.09%, 83.33%, 31.82%, and 19.23% in Abaya, Bule Hora, Teltelle and Yaballo districts respectively.*

Keywords: Major crops, incidence, severity.

Introduction

Ethiopia is capable with diverse agro-ecologies suitable for different crops such as cereals, pulses, oil crops, vegetables, fruits, and root crops (Dessie, 2018). Crop production is one of the major sources of income diversification available to pastoralists and one of the most important competitors to the pastoralist way of life (Tache, B., 2000). According to Mengistu *et al.* (2020) the major crops grown around Borana and West Guji are teff, maize, common bean and wheat. In Ethiopia during 2020/21 production year major crops (teff, wheat, maize and red common bean and white common bean) were cultivated on the area of 2.93mil ha, 1.9mil ha, 2.53mil ha, 0.21mil ha, and 0.103mil ha respectively and the obtained yields from those areas were 1.882t/ha, 3.05t/ha, 4.18t/ha, 1.796 t/ha, and 1.76t/ha respectively (CSA, 2021). In Borana maize was cultivated on 6,716.82ha of land and its yield was about 891.2089t which is 1.33t/ha, and red common bean was cultivated on 5,447.35ha of land and the yield was about 577.16t with average yield of about 1.10t/ha. Similarly in West Guji maize was cultivated on 9,180.49ha of land and its yield was about 37880.01t, with 4.13t/ha yields, Red common bean 932.52t from 5,222.94ha with 0.18t/ha (CSA, 2021).

Despite its importance, the productivity of those major crops was very low compared to the national average. This low yield is attributed to both biotic and abiotic factors (FAO, 2021). Crop losses due to pests (biotic factor) causes low crop productivity and food insecurity, low volume of export products and raw materials supplied for local industries, losses of major crops due to pests in Ethiopia are mostly estimated between 20 up to 40%. Among biotic factors, disease is the major limiting factors (Eshte *et al* 2015). Nowadays, demands for crop production had already been fueled to fill demand for food security. The past study also confirmed that crop cultivation is firmly expanding in the rangelands and tenure (Tache and Sjaastad, 2008).

The major factors constraining crop production are factors such as, erratic rainfall and presence of agricultural pests (Mengistu *et al* 2020). In Borana and West Guji, there is a need to assess important disease for major crops. Crop disease assessment is necessary to deliver management tools that will benefit societies, environments, consumers and farmers. Therefore, the objective of this study was to identify important disease for major crops in Borana and west Guji zones.

Materials and Methods

Description of the study area

The disease assessment was conducted in two zones, West Guji and Borana in 2020-2022 cropping seasons. West Guji and Borana zones are located at 463km and 570km south of Addis Ababa respectively. Geographically the surveyed area falls under an elevation of 1356masl to 1874masl for Borana, and 1422-2328masl for West Guji. Specifically, by districts the altitude range of the surveyed area were as follows Yaballo 1490-1800masl, Teltelle 1356-1460masl, Abaya 1422-1460masl and Bule Hora 1860-2328masl. The area has two rainy seasons with in a year and main rainy season from March to May while short rainy season is from early September to end of October.

Disease Assessment methods

The survey was conducted in four districts of the zones and the districts were selected purposively based on potential of crop they produce. Fields were assessed with the distance of about 3-5km apart accordingly i.e., based on crop abundance. But, the assessed field for each crop was not equal, it was about 113 fields for common bean, 94 for maize and 89 fields for Teff. The GPS was used during the assessment for the purpose of geographical data such as elevation, latitude and longitude, distance and area of the survey. A 1m*1m quadrant was used during the survey to record disease prevalence from the fields and it was done in diagonal pattern in each field. Questioner was developed to collect additional data from the farmers.

Disease Incidence

Disease incidence refers to a proportion or percentage of diseased plants (entities) within a sample population. The incidence percentage of the diseases on the crop was recorded specifically for each crop as well as diseases.

$$DI\ (\%) = \frac{\text{Number of diseased plants in the quadrant /field}}{\text{Total number of plants in the quadrant /field}} * 100$$

Disease Severity

Disease Severity refers to severity in the quantity of disease affecting plants (entities) within a sample population. Estimate disease severity by observing sizes of lesion and its extent (spread) in the diseased plant parts.

Disease Severity (%) = (nxv/4N) x100;

Where, (n) = Number of plants in each category, (v) = Numerical values of symptoms category. (N)= Total number of plants, (4) = Maximum numerical value of symptom category.

$$\text{Disease Prevalence} = \frac{\text{Number of fields with disease infection in the survey area}}{\text{Total number of fields surveyed}} * 100$$

Data analysis

All collected data were entered into computer and managed by using Excel and lastly the data was analyzed using IBM SPSS Statistics 20.

Result and Discussion

Major Diseases of the Crops

The major crops produced at the study areas are maize, common bean and teff and the survey result shows us, there are different diseases for each crop and their prevalence's differs from location to location based on the crop type (Table 22).

Intensity of the disease on each Crop

Among the major disease recorded from Common bean fields Angular leaf spot and Common bacteria blight observed within 44 and 37 fields respectively out of 113 fields common bean assessed. The total incidence and severity of the recorded diseases on common bean are summarized in the Table 1. Similarly, the overall mean incidence and severity for major diseases observed on common bean across the district is described onFigure 1. As the results indicates Common bean leaf rust has highest mean incidence rate (39%) across the districts over the other observed diseases and followed by Common Bacterial Blight which has 34.66% and Angular Leaf spot (32.57%) of mean incidence rate.

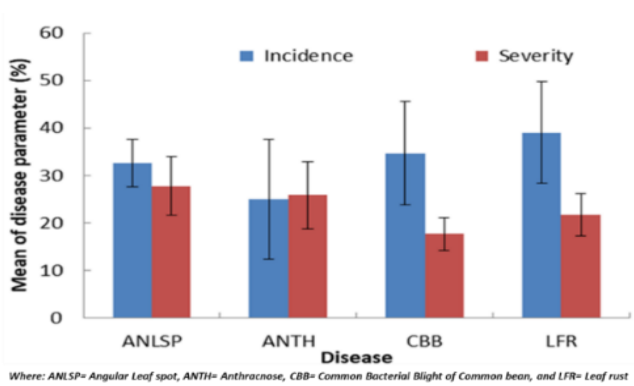
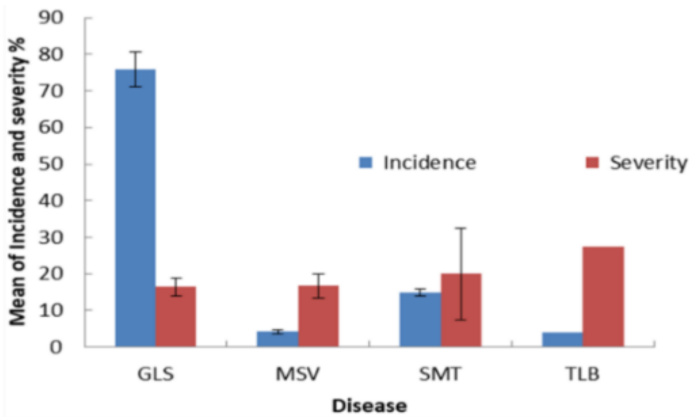


Figure 7. Incidence (%) for total disease recorded on Common bean over the districts

Among the major crops grown around the study area maize is the other commodity which holds large number of fields. For this study about 94 maize fields were assessed across the four districts and the diseases that recorded from maize are listed in the Table 22. Among the major disease observed on maize crops Gray Leaf Spot (GLS) is the most dominant with 76.6% of incidence.

Similarly, the maize GLS mean incidence rate of the assessed districts is higher (75.85%) than the other disease recorded from maize fields and followed by Maize common smut (15% incidence) disease (Figure 2). Minyahil and Assefa (2017), reported that GLS is one of the major diseasesthat affects maize crop in the country.Likewise, GLS incidence and severity is accounts high rank among the diseases (GLS, maize rust, Northern maize blight (TLB)) observed around the study area on maize crop (Tolessa *et al.*, 2015).



Where: GLS=Gray leaf spot of maize, MSV=Mosaic virus like, SMT= Common smut of maize &TLB= Turcicum leaf blight

Figure 8. Incidence rate for total disease recorded on Maize over the districts

Table 22. Disease incidence and severity on each crop and districts

Districts	Crop	Disease	Nº of field assessed	Incidence (%)	Severity (%)
Teltelle	Common bean	Angular leaf spot	41	34.15	21.63
		Anthracnose	41	9.76	40
		Common bacteria Blight	41	53.66	10.91
		Leaf rust	41	2.44	20
	Maize	Gray leaf spot	32	84.38	17.97
		Mosaic viruses	32	3.13	20
		Turcicum leaf blight	32	3.13	15
	Teff	Leaf rust	22	7.87	33.57
Yaballo	Common bean	Angular leaf spot	62	41.94	21.73
		Anthracnose	62	14.52	20
		Common bacteria Blight	62	22.58	22.14
		Leaf rust	62	14.52	15

		Anthracnose	62	6.45	10
	Maize	Gray leaf spot	40	75	19.83
		Mosaic viruses	40	5	20
		Smut	40	15	20
		Turcicum leaf blight	40	5	40
	Teff	Leaf rust	26	5.62	20
Abaya	Common bean	Leaf rust	3	100	30
	Maize	Gray leaf spot	22	68.18	11.67
		Leaf rust	22	27.27	62.5
		Mosaic viruses	22	4.55	10
	Teff	Leaf rust	23	6.74	62.5
Bule Hora	Common bean	Angular leaf spot	7	57.14	40
		Anthracnose	7	28.57	17.5
		Common bacteria blight	7	14.29	20
	Teff	Leaf rust	18	16.85	37

The third most widely and commonly cultivated crops around the study area is Teff and about 89 Teff fields were assessed from both Borana and West Guji zones. On this crop the major identified disease is Leaf rust only and it is found on 33 fields from the total assessed fields across the districts. The incidence and severity of this disease for all districts is described in the Table 22. The fourth commodity assessed for disease during this survey was wheat, which is mainly grown at Bule Hora district. On the assessed wheat fields from this district's three major wheat diseases were observed. The diseases observed on wheat are stem rust, yellow rust and leaf rust. Their incidence percentages are 42.86%, 28.57 % and 28.57 % respectively.

The intensity of each observed disease differences from location to location is may result from inputs used by farmers during crop management or the weather conditions of the area during production and other management practices applied for the crop. Among the agricultural inputs pesticides used for the management of the disease and seeds used are the major one. In majority of assessed areas producers use local variety for Common bean and for Maize and Teff mostly they use crop seeds that are available in local market, which their background information is not well known. These unknown varieties/seeds of the crop are may susceptible to different diseases and increases risk of crop failure and low productivity. Tolessa *et al*.,(2015) reported that as farmers use land races (particularly for maize during the main growing season) which take longer time to mature and that why the crop is exposed to pathogen for a long period of time and this will create opportunity to cause a significant decrease of yield. In general, the result obtained from this survey is supported with the disease incidence and severities were vary from district to district and from year to year ranging from zero to 100%.

Conclusionand Recommendation

There is increasing demand for food and crop production in pastoral and semi pastoral areas. Crop production is seriously challenged by diseases like ALS and CBB on common bean, GLS on maize and leaf rust on teff. Farmers should be advised on use of well-known improved seeds and agronomic practices (cropping pattern, sowing period, use of appropriate inputs such as fertilizers and pesticides, cultivation frequency) etc. In the future, efforts should be made towards the integration of multiple control options like development of resistant varieties, development of improved agronomic practices, awareness creation among farmers and experts' right from site selection till post-harvest handling of various diseases and their management options.

References

Boku T, Sjaastad E (2008). Pastoral conceptions of poverty: An analysis of traditional and conventional indicators from Borana, Ethiopia. World Development 38(8):1168-1178.

Central Statistical Agency Agricultural Sample Survey 2020/21 (2013 E.C.). Volume I Report on Area and Production of Major Crops. (2021).

Dessie, A. (2018) 'Cereal Crops Research Achievements and Challenges in Ethiopia', 5(September), pp. 116–122.

Mengistu, D., Tefera, S., &Biru, B. (2020). Pastoral farming system and its temporal shift: A case of Borana zone, Oromia National Regional. 16(9), 1233–1238.

Minyahil K., Assefa G., (2017). Survey and Identification of Diseases on Major Crops of Assosa and Kamashi Zones, Ethiopia. Galore International Journal of Applied Sciences and Humanities Vol.1; Issue: 1; Jan.-March 2017

Tolessa T., Natol B., Yonas S., and Addis S., (2015). Assessments of Major Cereal Disease in Potential Agro-Ecology of Borana Zone, Southern Oromia. Journal of Biology, Agriculture and Healthcare. Vol.5, No.11, 2015

Major Weeds on Major Crops in Borana and West Guji Zones, Southern Ethiopia

Kemal Kitaba*, Rameto Nura, Ejigu Ejara and Dejene Legesse
Yaballo Pastoral and Dryland Agriculture Research Centre
*Corresponding author. E-mail: kemalkitaba@gmail.com

Abstract

The weed flora assessment was conducted in two zones of southern Oromia, West Guji and Borana zones in 2020-2022 cropping seasons. The districts were selected purposively based on crop production potential. About nineteen weed species under eight families in common bean, twenty-one species of weed under eight families in maize and twenty-one weed species under seven families on teff were identified and recorded. and twelve weed species under five families in wheat fields. Generally, weed families identified from the surveyed areas includes Asteraceae, Commelinaceae, Compositeae, Cyperaceae, Papaveraceae, Poaceace and Solanaceae. Among the *identified weed species Asteraceae and Poaceace are the most dominant weed families compared to the other families of the weeds.*

Keywords: Major crops, weed flora, frequency, Abundance, Similarity index

Introduction

Weeds are plants that interfere with the objectives and requirements of man (Steven, 1984). Weeds are genetically diverse and can readily take advantage of the variety of conditions created by any given crop production system. This is primarily due to their ability to produce a large quantity of viable seeds (if it is an annual) or vegetative tissues such as rhizomes (if it is a perennial) in a single growing season Weed serve as alternate and alternative for pest organisms that adversely affect crop production system (Zimdahl *et al.*,1988).The degree of yield loss due to weeds on crop depends on the species' competitive ability, relative growth height, time of emergence (relative to the crop), leaf area, vegetative mass and density. In Ethiopia during 2020/21 production year major crops (tef, wheat, maize and red common bean and white common bean) were cultivated on the area of 2.93mil ha, 1.9mil ha, 2.53mil ha, 0.21mil ha, and 0.1mil ha respectively. The yields from those areas were 1.882t/ha, 3.05t/ha, 4.18t/ha, 1.796 t/ha and 1.76t/ha respectively. In Borana maize was cultivated on 6,716.82ha of land and its yield was about 891.2089t which is 1.33t/ha, and red common bean was cultivated on 5,447.35ha of land and the yield was about 577.16t with average yield of about 1.10t/ha. Similarly in West Guji maize was cultivated on 9,180.49ha of land and its yield was about 37880.01t, with 4.13t/ha yields, Red common bean 932.52t from 5,222.94ha with 0.18t/ha (CSA, 2021).

Despite of its importance, the productivity was very low in compare to the national average yield. This low yield is attributed to both biotic and abiotic factors (FAO, 2021). Among biotic factors, Weeds are one of the major limiting factors that can affect crop yield based on their species composition and density, Weeds reduce crop yields by competing for light, nutrients, water and carbon dioxide as well as interfering with harvesting and increasing the cost involved in crop production (Amare *et al.*,2015). Weeds are a major challenging factor for crop productions throughout the country. However, the type of weed species could be differ from region to region based on agro-climatic conditions of the crop growing areas and cultivated crops. The potential areas of Borana and West Guji zones for crop productions includes districts such as Yaballo, Teltelle, Elweye, Dire, Abaya and Bule Hora. The above listed districts have alike climatic conditions except Bule Hora district. Bule Hora district had long rainy season over the other districts and also, its elevation very far from those districts in Borana zone, it tends from midland to highland. Nowadays, the demand for food resulted in increased areas of crop production. The study by Tache and Sjaastad, (2008) also confirmed that crop cultivation is firmly expanding in the rangelands and tenure. Though crop production is a relatively in initial stage in pastoral areas, nowadays the urge for crop production knocks the integrity of every household regardless of the production skill and knowledge (Liao, 2014). The objective of this study was to know the major crops important weed pests and their distribution in Borana and West Guji zones.

Materials and Methods

Description of the study area

The weed assessment was conducted in two zones, West Guji and Borana in 2020 to 2022 cropping seasons. West Guji and Borana zones are located at 463km and 570km south of Addis Ababa respectively. Geographically the surveyed area falls under an elevation of 1356masl to 1874masl for Borana, and 1422-2328masl for west Guji. Specifically, by districts the altitude range of the surveyed area were as follows Yaballo 1490-1800masl, Teltelle 1356-1460masl, Abaya 1422-1460masl and Bule Hora 1860-2328masl. The area has two rainy seasons with in a year and main rainy season from March to May while short rainy season is from early September to end of October.

Assessment methods

The survey was conducted in four districts of the zones and the districts were selected purposively based on potential of crop they produce. Fields were assessed with the distance of about 3-5km apart accordingly i.e., based on crop abundance. But, the assessed field for each crop was not equal, it was about 113 fields for common bean, 94 for maize and 89 fields for teff. The GPS was used during the assessment for the purpose of geographical data such as elevation, latitude and longitude, distance and area of the survey. A 1m*1m quadrant was used during the survey to record the weed species and abundance level per field. Questioner was developed to collect additional data from the farmers. Weed species compositions frequency (F), abundance (A), dominance (D) and similarity index (SI) were summarized as follows:

Frequency (constancy): Is the percentage of sampling plots (vegetation registrations) on which a particular weed species is found. It explains as how often a weed species occurs in the survey area. Frequency is calculated for all weed species as follows:

$F=100*X/N$

Where, F= frequency; X = number of occurrences of a weed species; N= sample number

Similarity index/Community index is the similarity of weed communities between different locations or crop types.

Similarity index=SI = 100*Epg/ (Epg + Epa +Epb);

Where; Epg = number of species found in both locations; Epa = number of species found in location I; Epb= number of species found in locations II

Data analysis

All collected data were feed into computer and managed by using Excel and lastly the data was analyzed using IBM SPSS Statistics 20.

Result and Discussion

The outcome of the survey showed that there are number weed species grown in crops and have different abundance percentage over districts ad in each crop.

Major Weed flora in Common bean

Total of 113 common bean fields were assessed. About 19 weed flora species with 8 families were identified (Table 1). According to this result some species have high abundance percentage over the other species. Among weed flora recorded weed family of *Poaceae and Asteraceae* are the most dominant and present in high frequency.

Table 23: Weed families and species in common bean fields

S/N	Weed flora Family	No. of Species
1	Poaceaceae	4
2	Asteraceae	6
3	Leguminosae	2
4	Commelinaceae	1
5	Compositeae	2
6	Solanaceae	2
7	Papaveraceae	1
8	Cyperaceae	1
	Total	19

Broad leaf weeds are highly dominant over the grass and sedge type weed species. Among a total of 19 major weed species recorded from common bean fields, broad leaf weed species comprises about 66.67%, while grass and sedge types were about 27.78% and 5.56% respectively.

Table 24: The major weed species recorded from Common bean fields

The Similarity Index of weed recorded from Common bean fields over the districts

Botanical Name	Family	Category	Life Cycle	Frequency	Abundance	Dominance
Amaranthus hybrids	*Compositeae*	Broad leaf	Annual	13	2.15	9.57
Argemon mexicana	*Papaveraceae*	Grass	Annual	6	1.36	6.05
Bidens pilosa L.	*Asteraceae*	Broad leaf	Annual	9	3.12	13.91

Commelina benghalensis L.	*Commelinaceae*	Broad leaf	Annual	5	1.14	5.08
Cynodondactylon (L.) Pers.	*Poaceaceae*	Grass	Perennial	18	4.56	20.31
Cyprus esculenta L.	*Cyperaceae*	Sedge	Perennial	4	1.36	6.05
Datura stramonium L.	*Solanaceae*	Broad leaf	Annual	4	0.83	3.71
Galinsogaparviflora (Cav.)	*Asteraceae*	Broad leaf	Annual	2	0.7	3.13
Guizotiascabra	*Compositeae*	Broad leaf	Annual	1	0.09	0.39
Nicandraphysalodes (L.) Gaertn.	*Solanaceae*	Broad leaf	Annual	3	0.22	0.98
Parthniumhysterophus	*Asteraceae*	Broad leaf	Annual	2	0.18	0.78

The result showed that weed communities of crops grown in Yaballo and Teltelle districts are related in terms of species composition. As a result, their similarity indices ranged up to 80%. This shows that the weed grown around these areas have more or less the same hence similar weed management methods can be applied. The reasons for high similarity value could be attributed to similar environmental factors such as soil properties, tillage operations and weed management practices adopted by the producers, while in Bule Hora and Abaya, the weed similarity index shows dissimilarity.As described by Kropff and Spitters (1991), if the similarity index is below 60%, it is said to be that the two locations have different weed communities, for the different location were greater than 60%, it can be concluded that the locations exhibited similar weed community.Their similarity index value ranged from 15.38 to 42.61 %. Hence, different management method should be used. The difference could be due to weed growth, population density and distribution vary from place to place, agroecological factors like altitude, soil type and texture, climatic factors that affect the weed flora, and farmers' management practices, different weed management method can be used to control weed species composition for districts that shown the similarity index below 60% (Mekonnen, 2018).

Table 25: Similarity index of weed species composition in common bean fields of the districts

Districts	Abaya	Bule Hora	Teltelle	Yaballo
Abaya	100	28.57	38.46	42,.61
Bule Hora		100	15.38	34.78
Teltelle			100	80
Yaballo				100

Major Weed flora inmaize fields

A total of about twenty-one (21) weed species classified under eight (8) families were identified from maize fields surveyed in the four districts. Among the identified weed families *Poaceace*a and *Asteraceae*contains large number of species i.e., these two families are the most dominant families over the rest families.

Table 26: Weed families and species recorded from maize fields

S/N	Weed flora Family	No. of Species
1	Composite	*2*
2	Papaveraceae	1
3	Asteraceae	6
4	Commelinaceae	1
5	Poaceace	6
6	Cyperaceae	1
7	Solanaceae	3
8	Leguminosae	1
	Total	21

Broad leaf weed species are the most dominant over grass and sedge weed species. Among a total of 21 weed species in maize field's, broad leaf weeds accounts about 52.17% of the total weed species identified, while grass and sedge types account for about 34.78% and 13.04% respectively.

Table 27: The major weed species recorded in Maize fields

Botanical Name	Family	Category	Life Cycle	Frequency	Abundance (%)	Dominance (%)
Amaranths hybrids	*Compositeae*	Broad leaf	Annual	24	2.13	10.67
Argemon Mexicana	*Papaveraceae*	Grass	Annual	3	0.56	2.83
Avenafatua	*Poaceaceae*	Grass	Annual	7	1.17	5.87
Bidens pilosa L.	*Asteraceae*	Broad leaf	Annual	10	1.07	5.38
Commelina benghalensis L.	*Commelinaceae*	Broad leaf	Annual	11	1.50	7.54

Cynodondactylon (L.) Pers.	*Poaceaceae*	Grass	Perennial	9	0.85	4.25
Cyprus esculenta L.	*Cyperaceae*	Sedge	Perennial	3	0.25	1.23
Datura stramonium L.	*Solanaceae*	Broad leaf	Annual	11	1.07	5.35
Galinsogaparviflora (Cav.)	*Asteraceae*	Broad leaf	Annual	7	1.07	5.35
Guizotiascabra	*composite*	Broad leaf	Annual	4	0.08	0.41
Nicandraphysalodes (L.) Gaertn.	*Solanaceae*	Broad leaf	Annual	5	0.73	3.68
Other grass species	*Poaceaceae*	Grass	Annual	8	1.01	5.07
Poeannual	*Poaceaceae*	Grass	Annual	1	0.08	0.41
Parthniumhysterophus	*Asteraceae*	Broad leaf	Annual	26	3.01	15.09
Phalarisparadoxa	*Poaceace*	Grass	Annual	3	0.36	1.78
setaria	*Asteraceae*	Broad leaf	Annual	3	0.14	0.69
Tagetesminatu L.	*Asteraceae*	Broad leaf	Annual	17	1.81	9.11
Sorghum Halipense	*Leguminosae*	Broad leaf	Annual	1	0.14	0.69
Xanthium strumarium L.	*Asteraceae*	Broad leaf	Annual	2.04	10.23	22
Digitariaischaemum (Schreb.)	*Poaceaceae*	Grass	Annual	18	2.3	10.23
SoloniumNigrum	*Solonacea*	Herb	Biennial	4	0.46	2.33

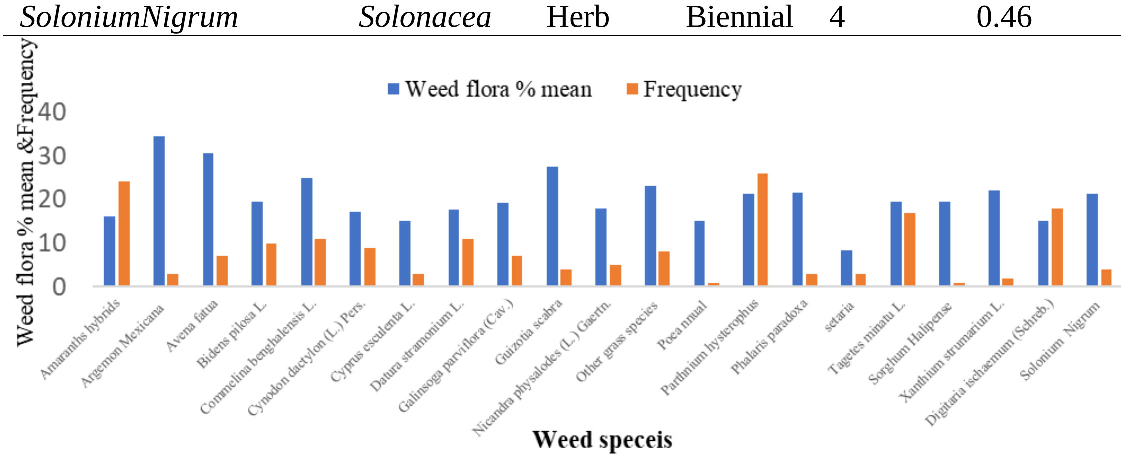


Figure 9: The major weed species identified in maize fields

The Similarity Index of weed recorded from Maize fields over the districts

The Similarity Index result of the weed species recorded from maize field across the districts indicates that Yaballo and Teltelle districts have similar weed species with similarity index that ranged from 72.22%-80. The other reasons could be similar soil properties, tillage operations and weed management practices adopted (Sosnoskie et al 2009). Therefore, for these districts in area where maize is cultivated similar management methods can be designed to overcome the effect of weed on maize production. At mid land agro-climatic condition of Bule Hora, dissimilar with f other districts, their similarity index ranged from 46.66%-57.89.

Table 28: Similarity index of weed species in maize fields among the districts

Districts	Abaya	Bule Hora	Teltelle	Yaballo
Abaya	100	46.66	57.89	72.22
Bule Hora		100	47.36	47.61
Teltelle			100	80
Yaballo				100

Major Weed flora recorded from Teff fields

In Teff fields, about 21 floras of weed species grouped under 7 families were identified in four districts. The result from this assessment showed that, broad leaf weeds are the dominant weed species. From 21 weed species 54.55% are broad leaf, 27.27% grass types and 18.18% are sedge types.

Table 29: Weed families and species recorded in Teff

S/N	Weed flora Family	No. of Species
1	Composite	2
2	Papaveraceae	1
3	Asteraceae	7
4	Poaceaceae	7
5	Cyperaceae	1
6	Solanaceae	2
7	Leguminosae	1
	Total	21

Table 30: The major weed species recorded in Teff fields

Botanical Name	Family	Category	Life Cycle	Frequency	Abundance (%)	Dominance (%)
Amaranths hybrids	*Compositeae*	Broad leaf	Annual	11	0.82	4.89
Ageratum conyzoides	*Asteraceae*	Broad leaf	Annual	3	0.60	3.56

Argemon Mexicana	*Papaveraceae*	Grass	Annual	9	0.34	2.00
Avenafatua	*Poaceaceae*	Grass	Annual	8	1.84	10.98
Biden's pilosa L.	*Asteraceae*	Broad leaf	Annual	6	0.81	4.80
Cynodondactylon (L.) Pers.	*Poaceace*	Grass	Perennial	16	1.12	6.67
Cyprus esculenta L.	*Cyperaceae*	Sedge	Perennial	5	1.04	6.22
Datura stramonium L.	*Solanaceae*	Broad leaf	Annual	6	0.41	2.44
Galinsogaparviflora (Cav.)	*Asteraceae*	Broad leaf	Annual	9	1.83	10.89
Guizotiascabra	*Composite*	Broad leaf	Annual	6	0.97	5.78
Nicandraphysalodes (L.) Gaertn.	*Solanaceae*	Broad leaf	Annual	2	0.11	0.67
Parthniumhysterophus	*Asteraceae*	Broad leaf	Annual	26	1.09	6.49
Phalarisparadoxa	*Poaceace*	Grass	Annual	10	0.34	2.00
Poeannual	*Poaceace*	Grass	Annual	2	0.09	0.53
Setaria	*Poaceaceae*	Grass	Annual	9	0.34	2.00
Sonchus asper (L.) Hill.	*Asteraceae*	Broad leaf	Annual	8	0.30	1.78
sorghumhalipense	*Poaceaceae*	Grass	Perennial	6	0.34	2.00
Tagetesminatu L.	*Asteraceae*	Broad leaf	Perennial	16	1.23	7.33
Trifoliumrueppellianum	*Leguminosae*	Broad leaf	Annual	2	0.11	0.67
Xanthium strumarium L.	*Asteraceae*	Broad leaf	Annual	30	1.92	11.42

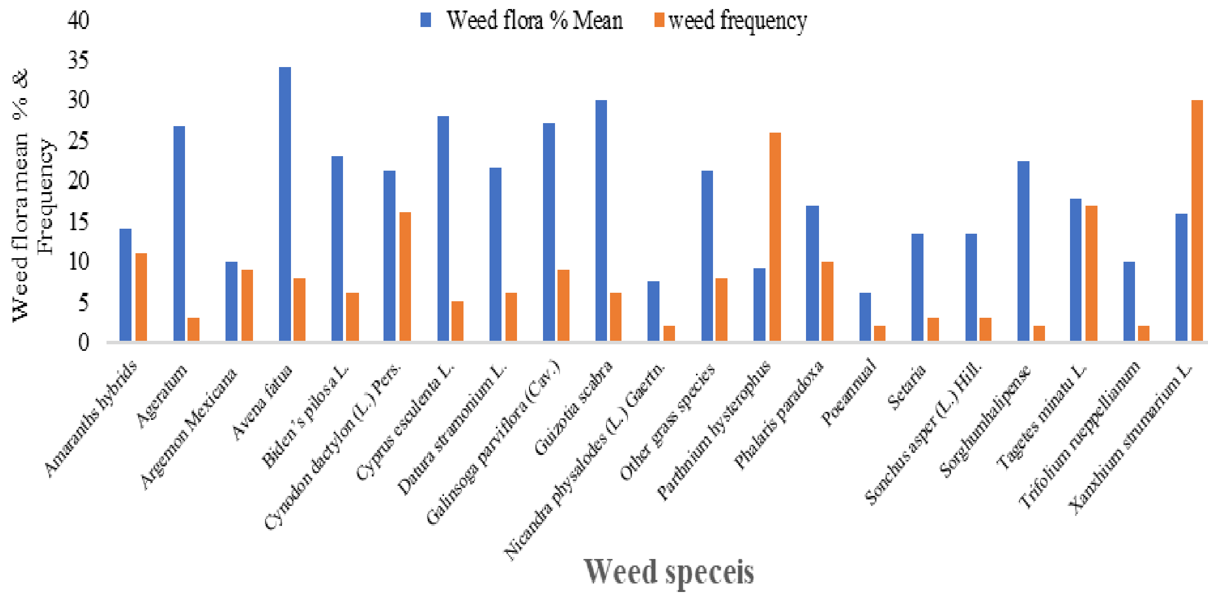


Fig. 10: The major weed species Identified in Teff

The similarity Index of weed recorded from Teff fields over the districts

Similarity index of weed species in Teff fields across the districts showed that weed species composition varied in some districts. But, weed communities in Yaballo and Teltelle districts were similar. Their similarity index was 66.67%. Therefore, similar management methods can be designed to overcome the effect of weed on teff production in these two districts. In Bule Hora and Abaya, the community of weed species are dissimilar with other districts, with similarity index that ranged from 27.27%-50 %. This may due to environmental factors such as rainfall longevity, temperature, humidity, soli type, and other synthetic and natural factors. As described by Kefale*et al.*, (2021), weed flora differ depending upon environmental conditions and weed control practices. The same weed management practices could be advised for districts that show the similarity index greater than 60%.

Table 31: Similarity index of weed species composition in Teff

Districts	Bule Hora	Teltelle	Yaballo
Abaya	27.27	41.17	50
Bule Hora	100	38.46	29.16
Teltelle		100	66.67

Major Weed flora in Wheat field at Bule Hora

Unlike the other crops, weed assessment was conducted only in Bule Hora district for wheat crop. In this district about 12 weed species in 5 families was identified from the district Grass weeds dominate over Broad leaf and sedge weed species. Among a total of 12 weed species 36.36% were broad leaf, 54.55% were grass types and 9.09 % were sedge types.

Table 32: Number of weed families identified and number of species they comprise in wheat fields

S/N	Weed flora Family	No. of Species
1	*Papaveraceae*	1
2	*Asteraceae*	3
3	*Poaceace*	5
4	*polygonacea*	1
5	*Commelinaceae*	1
	Total	12

Table 33: Major weed species Identified from Wheat fields in Bule Hora

Botanical Name	Family	Category	Life Cycle	Frequency	Abundance (%)	Dominance (%)
Argemon Mexicana	*Papaveraceae*	Grass	Annual	1	0.73	5.11
Avenafatua	*Poaceace*	Grass	Annual	2	0.63	4.11
Bidens pilosa L.	*Asteraceae*	Broad leaf	Annual	9	1.56	10.29
Rumexabsinicus	*polygonacea*	Narrow leaf	Perennial	2	0.94	6.17
Cynodondactylon (L.) Pers.	*Poaceacae*	Grass	Perennial	1	0.63	4.11
Commelina benghalensis L.	*Commelinaceae*	Broad leaf	Annual	4	1.13	7.46
Digitariaischaemum (Schreb.)	*Poaceacae*	Grass	Annual	2	0.94	6.17
Galinsogaparviflora (Cav.)	*Asteraceae*	Broad leaf	Annual	1	0.78	5.14
Loliumtemulantum L	*Poaceacae*	Grass	Annual	1	0.94	6.17
Other grass species	*Poaceacae*	Grass	Annual	8	0.45	2.67
Parthniumhysterophus	*Asteraceae*	Broad leaf	Annual	26	2.50	16.46

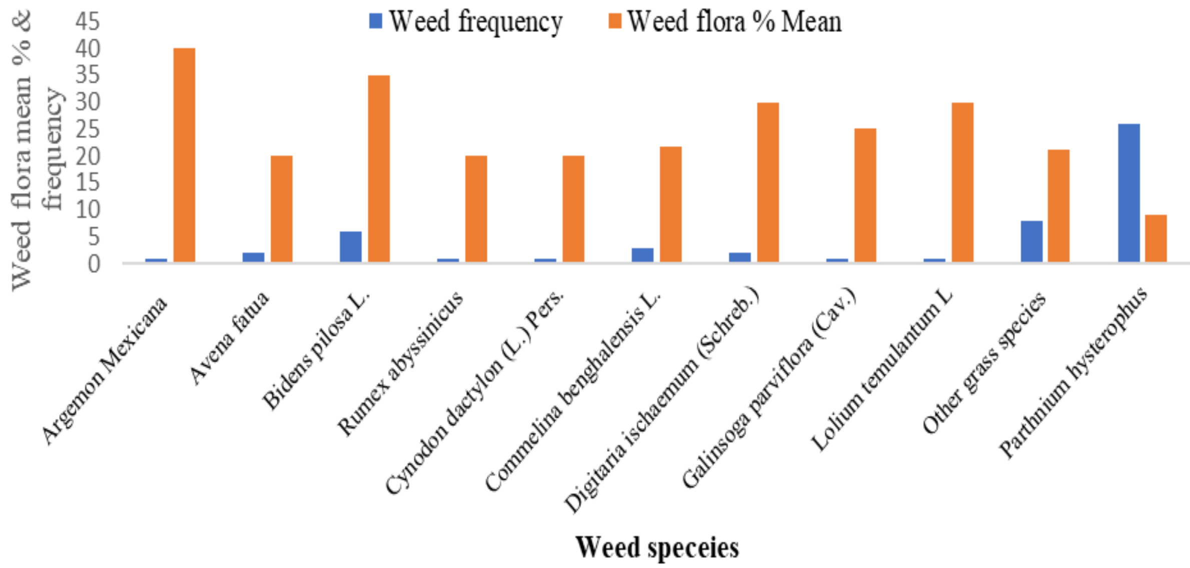


Fig. 11: Major weed species identified from Wheat fields in Bule hora

Conclusion and Recommendation

The *Poaceacae*and *Asteraceae*ffamilies are the most dominant weed families across the districts. But their abundance percentage vary across the districts based on the crop cultivated. Weed species composition varied between four selective districts in both Zones. Therefore, when developing weed control strategy, different weed management options would be required for the districts differing in weed flora composition. In those districts with the same similarity index, similar management method should be used. Most of the major weed species were broadleaf and grass species. Any weed control strategy should focus on these major weeds. Different stakeholders like agricultural offices, research centers and NGO's must cooperate and delivers information's about the risk coming with weed infestation. Future research should focus on development of ecofriendly, economical and efficient weed management options including integrated weed management.

References

Amare, T., Mohammed, A., Negeri, M., & Sileshi, F. (2015). Effect of weed control methods on weed density and maize (*Zea mays* L.) yield in west Shewa Orimia, Ethiopia. 9(January), 8–12.

Boku T, Sjaastad E (2008). Pastoral conceptions of poverty: An analysis of traditionaland conventional indicators from Borana, Ethiopia. World Development 38(8):1168-1178.

Central Statistical Agency Agricultural Sample Survey 2020/21 (2013 E.C.). Volume I Report on Area and Production of Major Crops. (2021).

Kefale, Y. et al. (2021) 'Assessment of pests of tef (Eragrostistef) in central gondar, ethiopia', Indian Journal of Entomology, 83(1), pp. 1–7. doi:10.5958/0974-8172.2020.00218.7.

Kropff et al 1992 'Weed flora survey in field crops of Northwestern', 14(16), pp. 749–758. doi:10.5897/AJAR2019.13947

Liao C (2014). Case Study: Borana, Ethiopia, s.l.: ACSF-Oxfam Rural Resilience Project, Natural Resources, Cornell University. www.acsf.cornell.edu.

Mekonnen, G. (2018). Assessment of Weed Flora Composition in Arable Fields of Bench Maji, Keffa and Sheka Zones, South West Ethiopia. Agricultural Research & Technology: Open Access Journal, 14(1), 23–30.

Sosnoskie, L.M., Webster, T.M., Dales, D., Rains, G.C., Grey, T.L. and Culpepper, A.S., 2009. Pollen grain size, density, and settling velocity for Palmer amaranth (Amaranthuspalmeri). *Weed Science*, *57*(4), pp.404-409.

Steven, R., Rados, E. and J. Holt. 1984. Weed Ecology. Implications for Vegetation Management, pp. 20-24.

Zimdahl et al 1988'Quantitative Estimate of Weeds of Sugarcane (Saccharum Officinarum L.) Crop in Ilorin, Southern Guinea Savanna of Nigeria', Ethiopian Journal of Environmental Studies and Management, 6(6). doi:10.4314/ejesm. v6i6.4. 147.1

Assessment of the major diseases affecting Groundnut (Arachis hypogaea L.) production in East Hararghe Zone

Abebe Getachew*, Motuma Delesa
Fedis Agricultural Research center,
Corresponding author: Email:abebegetachew04@gmail.com

Abstract

The assessment was conducted in four major productive districts in East Hararghe zone of Oromia Regional state during 2021 cropping season with an aim to identify and priorities the major diseases of groundnut crop in the study area. The assessment was done at vegetative and maturity *stage of the crop by using 1m x 1m quadrate laid along diagonal of the fields. In groundnut crop field's five points were chosen along diagonal of the field for inspection. Moreover, plants with in the quadrants were thoroughly examined from base to the apex for diseases incidence and severity. A total of 129 farmers field were enclosed by this assessment. It was founded that about 9 major diseases of groundnut crops were recorded from study areas. The result of this assessment showed, major diseases of groundnut in East Hararghe zone in order of their importance were: 1) Early leaf blight,2) Irregular leaf spot,3) Leaf scorch-a v-shaped parts of the leaf dies,4), Fusarium wilting, 5) Eye spot, 6) Foot and root collar 7) Phosphoria leaf spot , 8) Late leaf blight and 9)late leaf spot respectively each with a magnitude of percentage disease severity index of 50.33,10.56,15,24.45,10.6,12.5,10.64 , 27.015 and 15.4. Therefore, any intervention including direct research toward creating new or adopting an integrated disease management options must focus on those prioritized major diseases of the areas; to have higher, good and quality agricultural produces. In addition, regular disease survey and/or surveillance must be conducted to identify possible challenging diseases of groundnut crops in the study area.*

Keywords: Diseases, major disease, disease severity, disease incidence and severity index

Introduction

Groundnut or peanut (*Arachis hypogaea* L.; 2n = 4x = 40) is one of the major food and oilseed crops in the world. It is an annual legume crop that is predominantly self-pollinated. It is a rich source of oil (45–56%), protein (25–30%), carbohydrates (9.5–19.0%), minerals (P, Ca, Mg, and K), and vitamins (E, K, and B) (Gulluoglu et al. 2016).It is used in intercropping or crop rotation systems because of its ability to improve soil fertility through atmospheric nitrogen fixation (Ajeigbe et al. 2014). Globally, groundnut is cultivated on 27.66 million ha, with an annual total production of 43.98 million tons (FAOSTAT 2018). The leading groundnut producing countries in the world are India (20.97%), China (16.35%), Nigeria (9.68%), and Sudan (8.37%) (FAOSTAT 2018).In Ethiopia, groundnut is one of the five widely cultivated oilseed crops (Wijnands *et al*., 2009). It is commonly produced for food, cash income, and animal feed. It is solely grown by smallholder farmers under dryland conditions in the lowland and drought-prone areas of the country. The national mean yield is 1.796 tons/ha, and the total area under groundnut production is 80,841.57 ha (CSA 2018).

It is largely produced in the Oromia Region, constituting 59.2% of the total national production, followed by Benishangul-Gumuz (24.83%), Amhara (7.43%), Harari (3.29%), and Southern Nation and Nationalities People (1.29%) regions (CSA 2018). The eastern parts of Ethiopia, encompassing Babile, Fedis, and Gursum, are the leading groundnut-producing zones (Chala *et al*. 2013; Guchi *et al.* 2014). Babile and Fedis districts are characterized by low and erratic, poorly distributed rainfall. Further, fungal diseases, such as early leaf spot (Cercospora arachidicola), late leaf spot (Phaeoisariopsis personata), and rust (Puccinia arachidis) are the major factors limiting groundnut production in these agro ecological systems.

It is very low due to biotic factors like diseases affecting both above and underground parts of the plant (Alemeyehu C. *et al*., 2014). A limited number of introduced groundnut varieties were released for cultivation in the country (MoANRs, 2016).For instance, Babile-1 and Babile-2, with a relatively high pod yield and moderate resistance to leaf spot disease, were released in 2016.

However, these varieties are late maturing, low yielding and were not bred for diseases and drought tolerance. Therefore, there is a need to develop groundnut varieties with tolerance to biotic stresses that are adapted for cultivation under these agro-ecologies. Banla *et al*. (2018) identified, through participatory assessment, leaf spot diseases, rosette, and groundnut bud necrosis as key production constraints to groundnut in Togo. However, in the major groundnut-production belts of eastern Ethiopia, there is no recent study documenting farmers' perceived production constraints, and market and farmer-preferred traits. Up-to-date and well-described production constraints and prioritized traits of groundnut are key drivers for developing new cultivars. This should enable release of high-performing cultivars possessing suitable product profiles relevant to farmers and their value chains.The assessment was initiated with the aim to identify and prioritize the major diseases of groundnut in East Hararghe and provide baseline information on the diseases.

MATERIALS AND METHODS

Description of study area

The study was undertaken in East Hararghe zone of Oromia regional state in Ethiopia. It is located in Eastern part of the country at Latitude 8 ^{0} 30'N and longitude 40^{0} 40'E with a land area of about 17,935.40 square kilometers. It is about 525 km far apart from the capital city of Ethiopia Addis Ababa.It was carried out in 2021/2022main cropping season in four selected districts in to rounds at vegetative since September and maturity stage in November and districts were selected according to their potential production and each districts involvedfour main productive PA's. The lists of selected districts where Babile, Gursum, Fadis and Midega Tola respectively. Babile (9° 13′ 09′′ N latitude and 42° 19′ 25′′ E longitude; 1642 m above sea level),and is situated some 35 km away from Harar and about 555 km east of Addis Ababa.

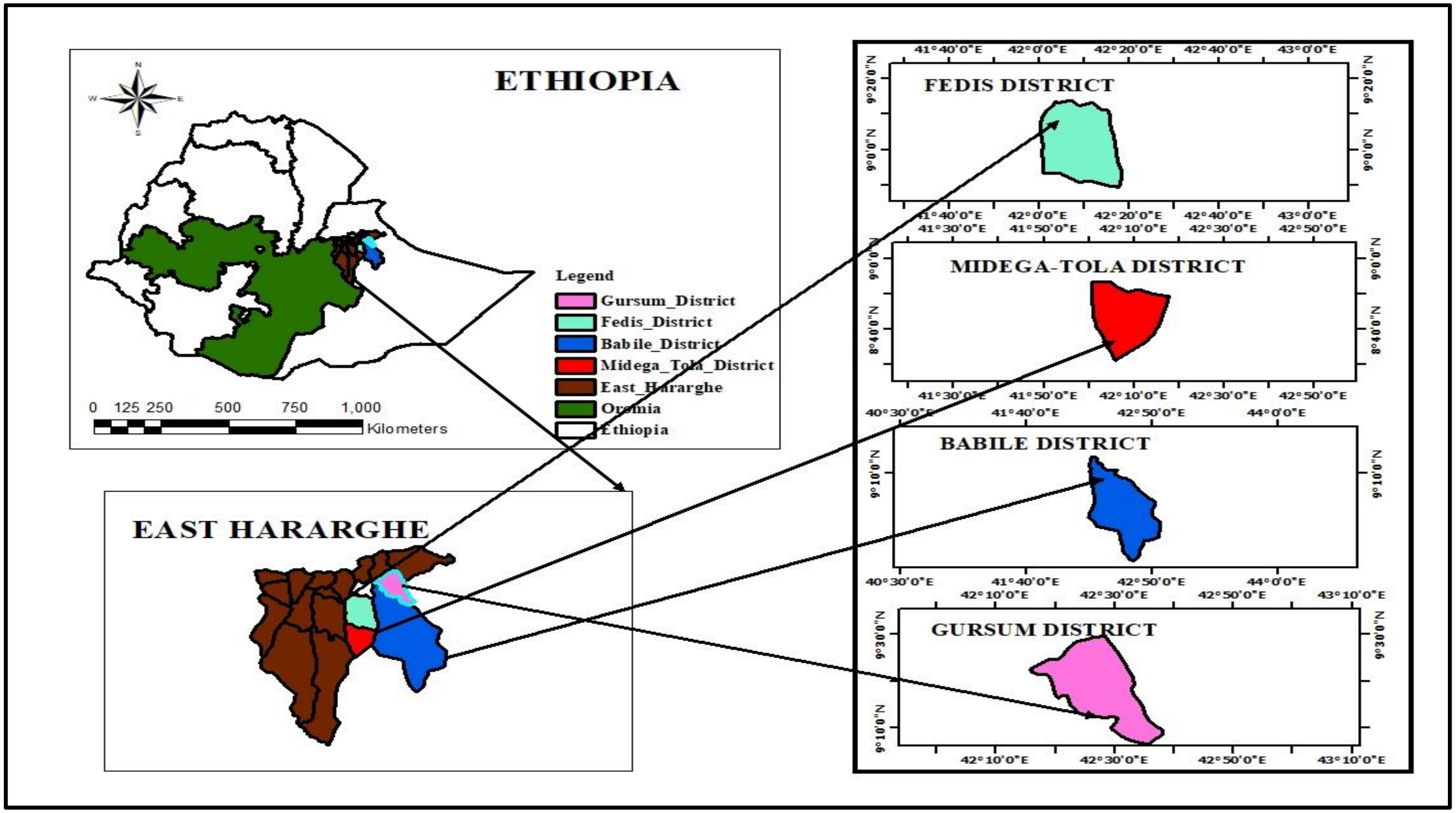


Fig.12. Map of the districts where survey was conducted.

The district has a total area of 3,169.06 km2 (Musa et al. 2016) and a population of 115,229 (CSA 2013). It has a predominantly well drained sandy loam soil that is ideal for groundnut production, the rainfall distribution of the area is bimodal, with the main rain (locally referred to as Meher rain) received during July to October and short rain (locally known as Belg rain) during March to May (Anteneh 2017).

The mean annual maximum and minimum temperatures are 28.1°C and 15.5°C, respectively, with the total annual rainfall ranging from 507 to 984 mm. Fedis (9°07′N Latitude and 42°4′E Longitude; 1702 meters above sea level).Rainfall distribution at Fedis is also bimodal and has a total area of 1,105.02 km2 (Musa et al. 2016) and a population of 135,532 (CSA, 2013).The mean annual maximum and minimum temperatures in Fedis are 27.8°C and 8.8°C, respectively, with a total annual rainfall of 659.2 mm (Anteneh 2017).

Gursum district is located at latitude of 9.35306° or 9° 21' 11" N and Longitude of 42.39694° or 42° 23' 49" east Elevation1,953 metres (6,407 feet). Midega Tola Woreda located in East Hararge Zone 50 km rough road or two-hour drive from Harar town.It is located at 8°52′08″N 42°07′24″E/ 8.8688°N East and the mean annual rainfall is 703 mm a yearElevation: 1392 meters / 4566.93 feet. In which each districts involved four main productive PA’s and each selected PA’s contains five to seven farmers field to gain the expected sample size.

This survey was assessed thoroughly in a total of 129 farmers’ fields in 2021 main cropping season.Within selected fields a five quadrant of 1m x 1m was thrown and disease incidence and severity were taken for every quadrant by crossing the fields diagonally. All plants within the quadrant were exactly observed starting from the ground up to the tip shoots of the crop

Disease Severity was assessed based on a rating scale of 1-9 according to (Subrahmanyam *et al* 1996): Where disease score 1 means no visible infection on foliage,2(1-5%);3(6-10);4(11-20%),5(21-30%),6(31-40%),7(41-60%),8(61-80%),9(81-100%). During assessment altitude and GPS for the location of the field were recorded for more history of the field. It was conducted to identify the major groundnut disease based on theirPrevalence, incidence and severity

Table 34. Description of study areas

Zone	Districts	PA's	Soil type	Altitude	A. R. Fall (mm)	Min-Max (TO)	No. field Assd
East Hararghe zone	Gursum	Odaa Santalla	Sandy loam	1680-1704	800ml	$18c^{o}$-$34c^{o}$	34
		Abadir	Sandy loam	1511-1604	600ml	$16c^{0}$-$28c^{0}$	
		Haro-Bate	Sandy loam	1633-1674	550ml	$13c^{0}$-$22c^{0}$	
		Nur-salaam	Sandy lam	1560-1618	720ml	$19c^{0}$-$27c^{0}$	
	Babbilee	Bishan Babile	Sandy loan	1563-1580	710ml	$24c^{0}$-$28c^{0}$	33
		Ramata-Salam	Silt soil	1372-1470	450ml	$25c^{o}$-$29c^{o}$	
		Abdul-Qadir	Sandy loam	1391-1707	903m	$24c^{0}$-$28c^{0}$	
		Shek-Husen	Sandy lam	1559-1600	500ml	$25c^{0}$-$29c^{0}$	
	Midega Tola	Roobaa	Sandy loam	1490-1519	380ml	$26c^{o}$-$33c^{o}$	27
		Tarkanfata	Clay soil	1490-1655	550ml	$22c^{0}$-$33c^{0}$	
		Urjii	Clay soil	1562-1608	400ml	$18c^{0}$-$26c^{0}$	
	Fedis	Mul'ata	Sandy loan	1641-1723	380ml	$17c^{0}$-$27c^{0}$	35
		Qarree	Sandy loam	1697-1705	750ml	$20c^{o}$-$30c^{o}$	
		Risqii	Silt soil	1638-1656	600ml	$16c^{0}$-$29c^{0}$	
		Bid-booraa	Sandy loam	1638-1664	400ml	$15c^{0}$-$36c^{0}$	
	Total	15		1391-1707	350-850	$18c^{o}$ -$34c^{o}$	129

Sampling Procedures

A multi-stage sampling technique was implemented to ensure good representativeness of groundnut grower households in the study areas. In the first and secondround assessment the districts of Babile (Bishan Babile, Ramata Salama,Abdul-qadir and Shek-Husen), Fedis (Mul'ata,Qarre,Risqi and Bid-Bora),Gursum (Oda Santalla,Haro-Bate,Nur-Salam and Abadir) and Midega-Tola(Roba,Tarkanfata and Urji) were selected and assessed from the Oromia region eastern Hararghe zone on the basis of their current high levels of groundnut production. During the assessment five to seven farmers' fields were selectedpurposively from fifteen PA's and totally one hundred twenty nine (129) fieldswere inspected.

Data and sample collection

The farmers' fields were selected for assessment according to road assessable to the vehicle and the fields of groundnut assessed with the design of ''X'' pattern/fashion using 1m x 1m quadrate and data of average quadrates of five point sample were used as one field. In the fields data were collected by throwing quadrats and counted each plants in the quadrats.

Therefore inspecting types of diseases either it is viral, fungal and bacterial crop and plant parties (leaf, stem, rootand pods). Each inspected disease Incidence and severity were recorded by using (1-9 scoring scale) and also GPS data for field history was recorded.

The sample of new introduced diseases to the area were collected and taken to laboratoryfor further inspection at Haramaya University.

Disease identification techniques.

During field assessments the diseases were identified through visual observation, disease identification of mobile application technology (plantix), laboratory examination at Haramaya University and crop disease books as a reference. The few diseases identified through laboratory at Haramaya University were root and foot collar and v shaped leaf scorch.Naming of the identified diseases were given by all combination of identification technics in the fields and laboratory.

Data Analysis

After the completion of disease data the incidence and severity were done with statistical analysis using SAS software and LSD were be used for mean separation at 0.05% significance level.

Disease Severity was assessed based on a rating scale of 1-9 (Subrahmanyam *et al* 1996):

$$\text{Disease Incidence} = \frac{\text{number diseased plants}}{\text{Total number of plants examined}} \text{ X } 100$$

$$\text{DSI (\%)} = \frac{\sum individual\ numerical\ rating}{Total\ numbers\ of\ assessed\ X\ mumimum\ score\ in\ the\ scale} \text{ X100}$$

$$\text{Disease Severity (DS)} = \frac{\text{Area of plant tissue affected by disease}}{\text{Total area}} \text{ X } 100$$

Results and Discussions

The occurrence and types of diseases recorded as a major during field assessment vary according to the agro-ecology, Altitude range, soil type, crop variety(improved or local), cropping system (intercropping, sole and mixed cropping) and Field management (weedy, drainage system) of the study area. In both first and second round assessment, Seven to eight major groundnut diseases where identified in all districts

Those major diseases where early leaf blight, late leaf blight, irregular leaf spot, leaf scorch-a v shaped parts of the leaf dies, fusarium wilting/wilting root rot, eye spot, foot and root collar and phosphoria leaf spot. The local variety was highly affected by those diseases year round.

Collar root/*Aspergillus niger* disease were caused by fungal pathogen which affects groundnuts at stage of seed and seedlings in loam and medium black soil. Early leaf spot/*cercospora arachidicola* disease were caused by fungus which affects foliar parts of the crop at a temperature of 25c^{0}and 30c^{0}to prolonged leaf wetness hours and RH9>80% disseminated through wind. Root and foot collar diseases were usually caused by any one of various fungal and oomycete plant pathogens which is called *Phytophthora cryptogea*, primarily attacks the stems,although other plant parts may be affected under suitable soil and temperatures is above 60^{o}F and high soil.

Irregular leaf spot is bacterial disease Pseudomonas or Xanthomonas spp which cause leaves to drop prematurely, resulting in the tree or shrub losing most or all of its leaves and occurs in environments of warm humid conditions

Table 35: Percentage of disease Prevalence, Incidence and Severity of first phase assessment

Zone	Districts	Types of dis. observed	Dis. prevalence %	Dis. incidence %	Dis. severity %
EAST HARARGHE ZONE	Gursum	Early leaf spot	75	45	20
		Irregular leaf spot	40	20	10.56
		Leaf scorch	60	10	15
		Wilting	40	30	22
		Early leaf blight	100	50	32. 89
		Wilting	30	86.6	36.6
	Babile	Eye spot	20	12	10.6
		Early leaf blight	100	30	18.33
		Phosphoria leaf spot	100	56.6	10.64
		Foot and root collar	40	26.5	12.5
		Early leaf blight	100	22	24
	Midega-Tola	Early leaf spot	50	72	45
		Wilting	35	22	14.2
	Fedis	Early leaf blight	100	84.66	42.6
		Early leaf spot	80	44.33	32.33
		wilting	50	35	25

Table36: Percentage of disease Prevalence, Incidence and Severity of Second phase assessment.

Zone	Districts	Types of dis. Observed	Disease prevalence (%)	Disease incidence (%)	Disease Severity (%)
EAST HARARGHE ZONE	Gursum	Early leaf blight	80	28.84	20
		Late leaf blight	100	35.4	20.62
		Early leaf spot	40	24	22
		Wilting	20	26	12. 89
		Early leaf blight	66	22.2	36.6
		Late leaf blight	80	30.95	24.5
	Babile	Early leaf spot	32	40.54	15.4
		Wilting	15	10	8.65
	Midega-tola	Early leaf blight	40	34	18.33
		Late leaf blight	80	37.77	32.8
		Early leaf spot	80	32	27
		Wilting	36	24	24
	Fedis	Early leaf blight	65	36	12.5
		Late leaf blight	72	34	30.12
		Early leaf spot	33	26	12.8
		Wilting	24	20	23

Table 37. Detail description of all identified diseases.

Disease name	Pathogen	Scientific name	Plant part affected	Favorable condition
Collar root		Asphergillus Niger	Seed and seedlings	Sandy loam soil and medium black soil
Early leaf spot	Foliar fungal disease	Cercospora arachidicola	Pod, kernel yield, fodder quality	Occurs 30 days after sowing,25c^{o} and 30c^{o} to prolonged leaf wetness hours and RH9>80% disseminated through wind
Early leaf blight	Fungal disease	Alternaria solani	Stem lesions and fruit rot on tomato and tuber blight on potato.	cool, wet weather (70 – 80°F)
Late leaf blight	an oomycete or water mold, a fungus-like microorganism	Phytophthora infestans (Montagne) Bary (ITIS)	the serious potato and tomato disease known as late blight or ...	cool (60°F to 70°F), damp conditions

Wilting/root rot	Corynebacterium, Erwinia, Pseudomonas, and Xanthomonas,	Pseudomonas solanacearum,	Roots are also attacked, especially the apical portions	High soil moisture favors aphanomyces root rot and others to some extent. Soils with good external and internal drainage should be selected
Eye spot	Eyespot is an important fungal disease	Bipolaris sacchari	Eyespot only affects stems	mediated light perception helps the cells in finding an environment with optimal light conditions for photosynthesis
Leaf scorch	scorch is a non-infectious	caused by the bacterium Xylella fastidiosa	Invades the xylem (water and nutrient conducting tissues) of susceptible trees.	Prolonged high temperatures, hot, drying winds, and low rainfall are the most common reasons for leaf scorch
Root and foot collar	Usually caused by any one of various fungal and oomycete plant pathogens.	Phytophthora cryptogea	The fungus primarily attacks the stems, although other plant parts may be affected under favorable conditions	Disease development is favored by soil temperatures is above 60°F and high soil.
Irregular leaf spot	Bacterial disease Pseudomonas spp. or Xanthomonas spp	Xanthomonas vesicatoria	Some leaf spot pathogens cause leaves to drop prematurely, resulting in the tree or shrub losing most or all of its leaves.	warm humid conditions

Conclusion and Recommendation

In the present study, farmers raised challenges of pre-harvest diseases (early and late leaf blight, root rot and leaf spot), low yielding due to lack of disease tolerant varieties, lack of awareness on the management of the diseases.

Among the identified production constraints, pre-harvest diseases/in the field was reported by the majority of the respondents to significantly reduce unshelled groundnut yield across study areas. The results identified very important and major diseases of the crop which is a critical problem in the production of the crop. So there is a need to strengthen formal, semi-formal, and private diseases management to sustain the supply pesticides in the region and immediate awareness on disease presence and its control measures.

The study result indicates the need for an intervention including direct research toward creating new or adopting an integrated disease management options on those prioritized major diseases of the area.

Reference.

Gulluoglu, Leyla, et al. "Characterization of peanut (Arachis hypogaea L.) Seed oil and fatty acids composition under different growing season under Mediterranean environment." *Journal of Experimental Biology and Agricultural Sciences* 4.5S (2016): 564-571.

Samireddypalle, Anandan, et al. "Cowpea and groundnut haulms fodder trading and its lessons for multidimensional cowpea improvement for mixed crop livestock systems in West Africa." *Frontiers in plant science* 8 (2017): 30.

Abady, Seltene, Hussein Shimelis, and Pasupuleti Janila. "Farmers' perceived constraints to groundnut production, their variety choice and preferred traits in eastern Ethiopia: implications for drought-tolerance breeding." *Journal of Crop Improvement* 33.4 (2019): 505-521.

Evaluation of different Postharvest storage mechanisms of Yam tuber seed for disease free and quality planting materials at Bako

Abraham Negera*and Abbay Guta
Bako Agriculture Research Center, P. O. Box: 03, Bako, Ethiopia
*Corresponding author: abrahamgdr@gmail.com

Abstract

The study aimed to conduct a comparative study of three yam tuber storage mechanisms with two yam varieties and to find the most suitable storage mechanisms for farmers in randomized complete block design in factorial arrangement in three replications. The experiment was conducted for two years in Western Ethiopia, Bako; to assess yam tuber loss during storage. No tuber rot was observed on Bulcha variety stored with the mechanism of heaping and hanging at both years and also it was low for Lalo variety. However, both Lalo and Bulcha varieties stored under pit showed large percentage of rotted tubers in both years. More than 21% in 2020 and 13% in 2021 seed tubers were rotted from Lalo variety. Therefore, heaping and hanging storage mechanisms are recommended for better seed tuber storage with diseases free planting materials.

Key words: Hanging, Heaping, Pit, Postharvest, Storage, Yam, Varieties

Introduction

Yams (*Dioscorea* spp.) are annual or perennial vines and climbers with annual or perennial underground tubers. They belong to the *Dioscoreaceae* family. This tuber-producing plant is popular in the humid and sub humid tropics, particularly in Africa, the West Indies and parts of Asia and South and Central America. Knuth (1924) estimated that there are about 600 species in the genus *Dioscorea* L. The most important edible yams belong to only a few species, such as *D. rotundata* Poir. (widely known as white Guinean yam), *D. alata* L. (known as water yam, winged yam or greater yam), *D. cayenensis*Lam. (yellow yam or yellow Guinea yam; may be composed of a complex set of different species), *D. esculenta* (Lour.) Burkill (lesser yam, potato yam or Chinese yam), *D. dumetorum* (Kunth) Pax (bitter yam or trifoliate yam), *D. bulbifera*L. (aerial potato yam), *D. trifda* L.f. (cush-cush yam), *D. opposita*auct. (cinnamon yam) and *D. japonica* Thunb.

Globally, approximately 8.8 million hectares of land were cultivated for yam, with an annual production of 74.8 million tons in 2020 (FAO, 2021). The highest yam production (97%) comes from West and Central Africa, where approximately 60 million people depend on them. Nigeria produced over 74% (50.05 million metric tons) of the global yam production followed by Ghana 12.7% (8.53 million metric tons) and Benin 4.69 (3.15 million metric tons) in 2020 (FAO, 2021).

Nigeria, Ghana, Ivory Coast, Benin, and Togo are the top five world yam producers. In Ethiopia, yam is widely distributed and grown by subsistence farmers in the southern, southwestern, and western parts of the country (Bekele and Bekele, 2020). The total production of yam in Ethiopia in 2020 was approximately 45,730 tons on 4874 hectares (CSA, 2021).

Yam is a major source of energy in the daily diet of many people in Nigeria. Yam contributes more than 200 calories per person per day for more than 150 million people in West Africa (FAO, 2005). According to Bekele and Bekele (2014), the fresh tubers of yam have a high nutritional content of protein, fiber and important minerals, including calcium and iron, but a relatively low fat content. Yam has high starch content and is used as animal feed, a source of medicine, and an industrial raw material (Andres *et al*., 2017). Some cultivars of yam tuber have been found to contain protein levels of 3.2 – 13.9% of dry weight. A yam meal could supply 100% of the energy and protein, 13% of the calcium and 80% of the iron requirement of an adult male (Knoth, 1993). Some food yams have been shown to contain phosphorous and vitamins such as thiamine, riboflavin, niacin and ascorbic acid.

People consume yams, sweet in flavor, as a cooked vegetable fried or roasted. In West Africa yam is often pounded into a thick paste after boiling and is eaten with soup. Presently, whole roasted yam has become a popular street or fast food in urban areas throughout the West African yam belt (Orkwor*et al*. 1998).Yams are also processed into yam chips and flour that is used in the preparation of a paste (Sahore *et al.)*.

Harvested tubers of yam can be stored for six to eight months without sprouting. The possibility to store fresh yam tubers is their dormancy which occurs shortly after their physiological maturity (Wilting point). During the dormancy, metabolic functions of the tubers are reduced to a minimum. It allows the tubers as an organ of vegetative propagation to overcome an unfavorable climatic condition. The duration of natural dormancy fluctuates according to the variety of yam from four to eight weeks (Knoth, 1993). In the storage period, substantial amount of yam is lost. Some of these losses are endogenous i.e. physiological which include; transpiration, respiration and germination. Other losses are caused by exogenous factors (mechanical or biological) such as insects, pest, nematode, rodents and rot bacteria on the stored product (Wilson, 1980). Good management can easily control the exogenous loss factors while the environment controls other sources of loss.

Rot is a major factor limiting the postharvest life of yams and losses can be very high. Losses due to post-harvest rot significantly affect farmers' and traders' income, food security and seed yams stored for planting. The quality of yam tubers are affected by rots, which makes them unappealing to consumers. Most rots of yam tubers are caused by pathogenic fungi such as *Aspergillus flavus, Aspergillus niger, Botryodiplodi atheobromae, Fusarium oxysporum, Fusarium solani, Penicillium chrysogenum, Rhizoctonia* spp*., Penicillium oxalicum, Trichoderma viride* and *Rhizopusnodosus* (Okigbo and Ikediugwu, 2002; Aidoo, 2007). Fungal pathogens causing rots in yam often gain entry into tubers through wounds caused by insects, nematodes or poor handling before, during and after harvest (Amusa *et al.*, 2003).

In Nigeria, over 60% of white yam varieties get rotten when stored for less than six months (Adesiyan and Odihirin, 1975). Report from Ghana indicated that from farmers' fields' observation and with farmers discussions reveal that some farmers lose as high as 70% of their stored yam to rot organisms. Ikotun (1989) reported that 25% of post-harvest losses of yam in storage are due to diseases.

Losses due to rots affect availability and food security of farmers. To reduce post-harvest losses and increase yam availability between harvests and avoid large fluctuations in supply and seed price, good storage is required. Good storage should maintain tubers in their most edible and marketable conditions by preventing large moisture losses and spoilage by pathogens (Amusa *et al.*, 2003, Akangbe, 2012).

In western Oromia yam tuber for seed are stored underground in dug pit. However the stored tubers in this manner rot because of reduced dormancy period and become deteriorate before planting time, different pathogens infected the tuber and destroyed by rodents. Additionally pit construction is costly. And also different varieties have different storage abilities.

Therefore, selection of storage mechanism for healthy planting materials and cost effectiveness that reduces postharvest losses is very pertinent. The main objectives of this study were to evaluate and select effective postharvest storage mechanisms for healthy tuber seed and quality planting materials

Materials and methods

The experiment was conducted at Bako Agricultural Research Center (BARC) in 2020 and 2021 cropping seasons. The experimental site is located in sub-humid areas of central Western Ethiopia, and it lays at latitude of 9°6′ N, longitude of 37°9′ E and 1650 m above sea level. It is a warm sub-humid climate with annual mean minimum and maximum air temperatures of 13.8 °C and 28.9 °C, respectively. The area received average annual rainfall of 1598 mm (2017), 1161.7 mm (2018), 1332.3 mm (2019) mm, 1605 mm (2020) and 1271 mm (2021) with maximum precipitation recorded in the months of May–August. The soil of the experimental site is reddish-brown, nitosol. It is an acidic soil with a pH range of 4.5–5.6 (Zerihun and Haile, 2017).

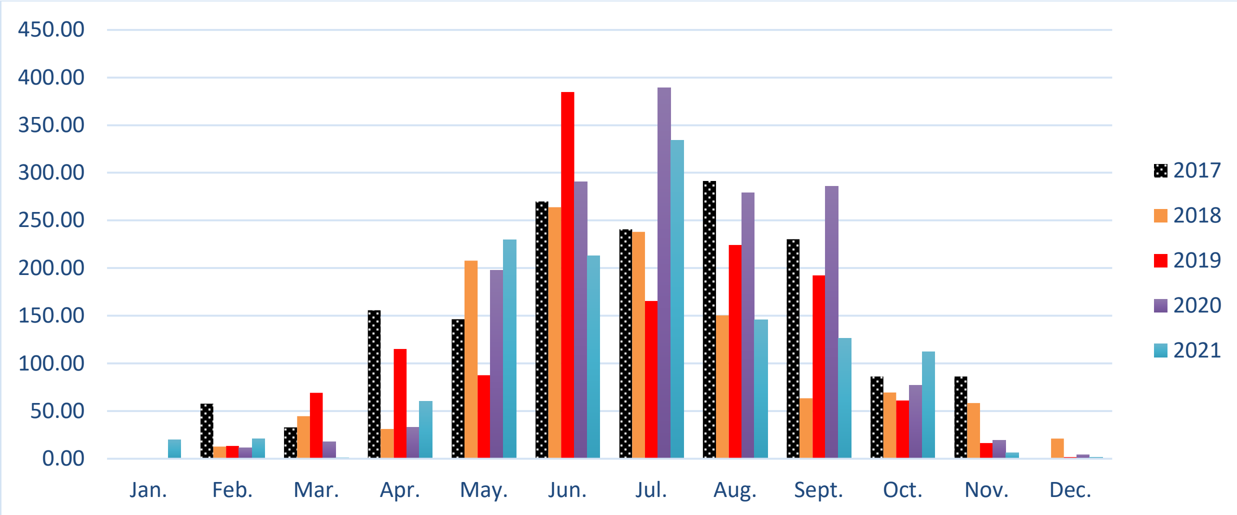


Figure 13. Mean monthly rainfall at of the Bako Agricultural Research Center, Ethiopia, 2017–2021

Two released varieties of yam (Lalo and Bulcha) and three storage mechanisms (Heaping, Hanging and under-ground pit) were evaluated under this experiment. Equal number and almost similar weights of tubers were used for the experiments for both varieties. Initial weight was recorded during harvesting before the tubers were stored in different storage mechanisms from twenty tubers. Stored tubers were evaluated for deterioration or weight loss and rotting after four months storage when yam planting season started. Mean weight of the tubers from all storage mechanisms were recorded during planting for the next experimental period. Also rotted tubers were separated and recorded during planting.

The storage mechanisms and varieties tested under this experiment were arranged in CRD and replicated three times. Tubers stored under different storage mechanisms were planted in the field at BARC to evaluate the effect of the storages on plant sprouting. The tubers in different storage mechanisms were planted on a gross plot size of 2.80m x 3m in RCB design and replicated three times with the net plot size of 1.4m x 3m (4.20 m^2) from which yield and yield related data were recorded.

Statistical Analysis

The data recorded were analyzed statistically using Analysis of Variance (ANOVA) through the procedure of General Linear Model (PROC GLM) on the SAS system software version 9.0. In addition SAS macro PDGLM 800 was used to create group between means for interacting parameters at $p < 0.05$ probability level.

Result and Dissections

Analysis of variance indicates varieties were significantly different on initial weight and percentage tuber weight loss. Storage mechanism of the tubers significantly affect percent tuber weight loss and percentage tuber rot. The initial weight differences between the varieties were because of genetical variation of the varieties. Lalo variety showed significantly higher percentage of tuber rot (36.05%) than Bulcha after four months of storage time. Even though the two varieties are at par with percent tuber rot, higher tuber rot record was shown from Lalo variety (Table 38). Nyadanu *et al* (2014) indicated that different yam genotypes have different acceptability level for tuber rot.

Yam tuber seeds stored with hanging and heaping mechanism showed significantly lower (27.55 and 27.28% respectively) mean tuber weight loss. Percent tuber weight loss showed significantly higher (36.05%) on Lalo variety as compared to Bulch variety. Similar to this study Girardin *et al* (1998) indicated that different yam cultivars showed significant weight loss at end of storage period. Tubers stored with the stated mechanisms recorded minimum (0.83-2.5% tuber rots; while tubers stored under pit showed more than 15% tuber rot (Table 38). Nyadanu *et al* (2014) indicated that storage mechanisms have significantly affected yam tuber rot. Okigbo and Ikediugwu (2000) reported that between 20 and 39.5% of stored tubers may be lost to rot; while Bonire (1985) estimated microbial postharvest losses in yam at 40% when stored for more than six months in Nigeria. Nyadanu *et al* (2014) also reported higher amount of rotten tissues observed in the pit followed by heap methods of storage could be due to lack of ventilation and direct contact of the tubers with one another.

The interaction of yam varieties with the methods of storage was not significant (P>0.05). The non-significant variety and storage mechanisms interaction means that similar trends of rot manifest in both varieties for the various storages. Similar to this study Nyadanu et al (2014) showed there was no variation observed between yam genotypes in tuber rotting.

Table 38: Effect of treatments on final weight, % weight loss and tuber rot of yam tuber at Bako for two years

Treatments	Initial wt	Final wt.	% weight loss	% tuber rot
Variety				
Bulcha	848.61a	553.62a	28.61b	(1.62) 4.44a
Lalo	577.67b	505.73a	36.05a	(2.14) 8.06a
Lsd	114.25		4.89	3.75
StorageMechanism				
Heaping	730.98a	730.98a	27.28b	(1.11) 2.50b
Hanging	712.73a	712.73a	27.55b	(0.92) 0.83b
Pit	695.71a	695.71a	42.16a	(3.62) 15.42a
Lsd	139.93	139.93	5.99	(0.77) 4.59
Mean	713.14	713.14	32.33	(1.88) 6.25
Cv	34.03	34.03	32.15	(70.83) 127.44

Number of tubers per plot was significantly affected by variety. Bulcha variety showed significantly higher (28.78 tubers) tuber number per plot than Lalo variety. However, tubers number per plot was not significantly affected by storage mechanisms in 2021 (Table 39).

Table 39: effect of treatments on number of tuber per plant and plot and unmarketable tuber yield in 2021

Treatments	Tuber per plot (no)	Tuber per plant (no)	Unmarketable tuber per plot (no)
Variety			
Bulcha	28.78a	3.05a	0.09a
Lalo	16.72b	2.98a	0.06a
Lsd	4.22	0.55	0.098
Storage Mechanism			
Heaping	24.75a	2.85b	0.11a
Hanging	19.83a	3.65a	0.04a
Pit	23.67a	2.55b	0.08a
Lsd	5.16	0.67	0.12
Mean	22.75	3.02	0.078
CV	27.15	26.56	184.9

Interaction of variety and storage mechanisms significantly affect yam tuber field sprout and tuber number per plot and plant and tuber yield in 2020 (Table 40). The highest tuber field sprout was recorded from Bulcha variety stored with heaping mechanism followed with Lalo variety stored with the same mechanism. Bulcha variety stored with hanging and heaping mechanism produced high number of tubers per plot than the other interactions.

In 2021 tuber seed sprout showed significant differences by variety and storage mechanism interaction. Bulcha variety nevertheless of storage mechanism it showed high sprouting ability than Lalo variety. Lalo variety stored with heaping mechanism showed high field sprout than other storage mechanisms (Table 41).

Table 40: Interaction effect of variety and storage mechanism on final tuber weights field sprouting, tuber number per plot, tuber number per plant and total yield at Bako in 2020

Variety	Storage	Mean Final weight (g)	Field Sprouting (No.)	Tuber number per plot	Tuber number per plant	Marketable yield (qt/ha)
	Hanging	611.92	9.33c	56.00a	3.16a	982.14a
Bulcha	Heap	667.85	18.83a	45.67ab	1.63b	813.57a
	Pit	381.75	8.67c	35.83bc	3.11a	1288.09a
	Hanging	561.63	6.83c	12.33e	1.63b	257.62a
Lalo	Heap	653.32	12.50b	17.50de	1.57b	376.67a
	Pit	302.23	8.67c	26.50cd	2.43a	442.86a
Mean		529.78	10.80	32.30	2.25	693.49
CV		27.58	23.78	33.95	28.56	34.24

In a column means followed by same letter are not significantly different at 5% level

Table 41: Interaction effect of variety and storage practice on yield and yield related parameters yam at Bako in 2021

Variety	Storage	Mean Final weight (g)	Field Sprouting(No.)	Marketable Yield(qt/ha)	Total Yield (qt/ha)
	Hanging	744.56	15.83a*	670.24a	671.90a
Bulcha	Heap	565.43	14.50a	618.57a	621.90a
	Pit	661.16	15.17a	544.76a	546.90a
	Hanging	198.66	3.33c	47.62c	48.09c
Lalo	Heap	274.47	6.50bc	112.38bc	101.19bc
	Pit	267.24	9.83b	232.62b	234.52b
Mean		529.67	10.86	371.03	370.71
CV		27.56	30.06	34.24	33.87

*In a column means followed by same letter are not significantly different at 5% level

Summary and Recommendation

Quality of yam tuber seed was influenced by storage mechanisms after harvesting. From this experiment higher tuber weight loss observed on tubers stored under pit for both varieties. After the tubers were planted in the field, high sprouting ability of the tubers were observed on tubers stored by hanging and heaping. Generally both variety stored under pit showed high seed tuber rot percentage, while those stored by heaping and hanging showed lower percentage of seed tuber rot within four month storage time. Therefore, heaping and hanging are recommended for better yam seed tuber storage for the producers.

References

Adesiyan, S.O. and Odihirin, R. A. 1975. Histopathology studies of the yam tuber (*Dioscorearotundata*Roir) infected with *Scutellonenabradys*(Steiner and Hettew). *International Biodeterioration Bulletin* 11:48-55

Akangbe, J.A., Oloruntoba, O.O., Ayanda, I.F. and Komolafe, S.E. (2012) An Analysis of Yam Storage Strategy to Promote Food Security in Asa Local Government Area of Kwara State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 5, 550-558

Amusa, N.A. (2001) Fungi Associated with Yam Chips in Storage and the Effect on Its Food Value. *Journal of Agricultural Research*, 2, 35-39

Andres, C., AdeOluwa, O.O. and Bhullar, G.S. (2017). Yam (Dioscorea spp.)-A rich staple crop neglected by research. In Encyclopedia of Applied Plant Sciences. Academic Press. 2: 435-441

Bekele, A. and Bekele, E. (2014). Studies on Molecular Genetic Diversity and Useful Genomic Traits of Yam (Dioscoreaspp) Germplasm Collections from Ethiopia. Doctoral dissertation, Addis Ababa University.

Bekele, A. and Bekele, E. (2020). Identi¦cation of Ethiopian Yam (Dioscorea spp.) Collections and Their Phenotypic Diversity Study. *Agricultural Sciences*. 11(11):1116-1132

Bonire, J.J. 1985. Preventing yam rot with organotin compounds. *Nigeria Journal of Sciences* 19:145-152

CSA (Central Statistical Agency) (2021) Agricultural Sample Survey report on Area and Production of Major Crops (Private Peasant Holdings ‘Meher’ Season): Statistical Bulletin 585. Addis Ababa, Ethiopia.

FAO, 2005. Food and Agriculture Organization of the United Nations Crops and livestock products https://www.fao.org/faostat/en/#data/QCL

FAO, 2021. Food and Agriculture Organization of the United Nations Crops and livestock products https://www.fao.org/faostat/en/#data/QCL

Girardin, O. C. Nindjin,. Z. Farah, F. Escher, P. Stamp and D. Otokore. 1998. Effect of storage system and sprout removal on post-harvest yam (*Dioscorea*spp.) fresh weight losses. *Journal of Agricultural Science, Cambridge*, 130, 329–336

Ikotun T (1989). Diseases of yam tubers. Int. J. Trops. Plant Dis. 7:1-21. Mantell SH (1980) Apical meristem-tip culture for eradication of flexuous rod viruses in yam (*Dioscoreaalata*). Trop. Pest Manage. 26:170- 179.

Knoth J. (1993). Traditional storage of yams and cassava and its improvement. Deutsche GesellschaftfürTechnischeZusammenarbit (GTZ) post- harvest project. Hamburg, Germany, pp. 9-43

Knuth, R. (1924). The International Plant Names Index Collaborators (2019). International Plant Names Index. Checklist dataset https://doi.org/10.15468/uhllmw accessed via GBIF.org on 2022-11-11.

Nyadanu, D., H. Dapaah and A.D. Agyekum. 2014. Resistance to post-harvest microbial rot in yam: integration of genotype and storage methods. *African Crop Science Journal*, 22(2), pp. 89 - 95

Okigbo, R.N., and Ikediugwu, F.E.O. 2000. Studies on biological control of postharvest rot in yams (*Dioscorea*spp.) using *Trichodermaviride*. *Journal of Phytopathology* 148:351-355.

Okigbo, R. N., and Ogbonnaya, U. O. (2006): Antifungal effects of two tropical plant extracts(Ocimumgratissimum and Aframomummelegueta) on post-harvest yam rot. *AfricanJournal of Biotechnology*. 5 (9): 727-731

Orkwor G. C., R. Asiedu and I. J. Ekanayake (1998). Food yams, Advances in Research: International Institute Tropical Agriculture (IITA) Ibadan and National Root Crops Research Institute, (NRCRI) Umudike, pp. 187 – 215

Sahore G. J. and N. A. Kamenan (2007). Changes in nutritional properties of yam (Dioscoreaspp), green plantain (Musa spp) and cassava (Manihotesculenta) during storage. Food Science and Technology 47, 81-88

Wilson J. E. (1980). Careful Storage of Yam. Commonwealth Secretariat, London, England, pp.2-8

Zerihun A, and D. Haile. 2017. The effect of organic and inorganic fertilizers on the yield of two contrasting soybean varieties and residual nutrient effects on a subsequent finger millet crop. *Agronomy.7*, 42; doi: 10.3390/agronomy7020042

Sorghum Germplasm Resistance to Major Sorghum Diseases in Western Oromia, Ethiopia

Abraham Negera* Megersa Debela and Dejene Haile
Bako Agriculture Research Center, P. O. Box: 03, Bako, Ethiopia
*Corresponding author: abrahamgdr@gmail.com

Abstract

191 sorghum genotypes were screened for resistance to three major diseases, viz. anthracnose, Sooty stripe and grain mold including four released sorghum varieties as checks. The experiment was conducted at two locations; Bako and Gute experimental sites. The result showed wide variability between genotype in disease severity in each location. Anthracnose disease severity at last assessment was varied from 11.11 to 100 % at Bako and 10 to 95.56 % at Gute. Sooty stripe severity was as high as 97.78 % at Bako and 100 % at Gute. Rated diseases response of sorghum genotypes to anthracnose in the last assessment showed 47 genotypes were highly resistant, 10 genotypes were resistant at Gute and 39 genotypes were highly resistant and the rest were categorized from susceptible to highly susceptible. Most of the genotypes tested were resistant for sooty strip disease. 145 genotypes showed high resistance to resistance rating at both locations while the rest tested genotypes showed susceptible for sooty stripe. The highest grain mold severity rate 9 was recorded at Gute experimental site. In an average severity of grain mold at both locations, 38 genotypes were highly resistant, 45 genotypes were resistant, 42 genotypes susceptible and the rest genotypes were categorized to highly susceptible. Therefore, it was recommended that genotypes having resistant reaction for different diseases should be used for crossing programs by breeder to transfer gene for resistance.

Key words: Anthracnose, genotypes, sorghum, sooty stripe

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crops globally and in Ethiopia as well (Sleper and Poehlmen, 2006). It is an important food grain crop of Ethiopia which contributes 15.93% of the total cereal production (CSA, 2020/21). It has a high yield potential, comparable to those of rice, wheat, and maize and adapted to wide range of environments (House, 1985). Sorghum is used not only for human food, but also for fodder and feed for animals, building material, fencing, or for brooms (House, 1985; Rooney and Waniska, 2000). In 2019, 70.6% of the harvested area of sorghum was within Africa, where average yields were 1,463 kg ha-1, respectively (FAO, 2019).

In spite of the ample genetic resources, the productivity of sorghum is affected by several biotic and abiotic constraints (Berenji and Dahlberg, 2004) and the current national average (2.76t ha^{-1}) CSA 2017/18 is far below the potential grain yield (above 3-5 t ha^{-1}) (FAO, 2017). Limited availability of adaptable and farmers preferred varieties, birds, lodging, fungal pathogens and other environmental factors are some of the major sorghum production problems. Among fungal pathogens, grain mold and anthracnose are the major pathogen hindering sorghum production and productivity. The diseases can be successfully managed using resistant varieties; however, the pathogens populations are highly variable which reduces the longevity of resistant sources (Thakur, 1995; Valerio *et al*., 2005).

Sorghum serves as a host for over 100 pathogens, including fungi, bacteria, viruses and nematodes (Thakur *et al.,* 1997) and these pathogens, individually or in combination lead to considerable losses in yield and grain quality. Sorghum foliar and panicle disease are the most principal constraints to sorghum (*Sorghum bicolor* (L.) Moench) production and quality in Western and South Western of the country where moist condition occurs later in growing season (EIAR, 2014).

Currently, former minor Sorghum disease such as sooty leaf blight, Turcicum leaf blight, Sorghum leaf rust and Ergot were observed predominantly on farmers' field. Formerly and recently released sorghum varieties via our center were tolerant to major disease like anthracnose and mold although those varieties had demerits (such as long maturity period, long height, and bird damage). Hence, different genotype were brought from different source (from collection, National coordinating center, SMILL and Austrian government) and tested based its own objectives. Therefore it's very important to select from those materials and discern for their reaction to known major and currently become major sorghum diseases in line with the breeding approach of our center. Therefore this study was conducted with the objective to identify resistant/tolerant sorghum genotypes against known sorghum diseases at Bako.

Materials and Methods

Description of the Study Area

The experiment was conducted at Bako Agricultural Research Center (BARC) in 2020 and 2021 cropping seasons. The Bako experimental site is located in sub-humid areas of central Western Ethiopia, and it lays at latitude of 9°6′ N, longitude of 37°9′ E and 1650 m above sea level. The area received average annual rainfall of 1598 mm (2017), 1161.7 mm (2018), 1332.3 mm (2019) mm, 1605 mm (2020) and 1271 mm (2021) with maximum precipitation recorded in the months of May–August. The soil of the experimental site is reddish-brown, nitosol. It is an acidic soil with a pH range of 4.5–5.6(Zerihun and Haile, 2017). It is a warm sub-humid climate with annual mean minimum and maximum air temperatures of 13.8 °C and 28.9 °C, respectively. The Gute experimental site is also located in sub-humid areas of central Western Ethiopia, and it lays at latitude of 9°01′ N, longitude of 36°38′ E and 1880 m above sea level. The area received average annual rainfall of 1586 mm with maximum precipitation recorded in the months of May–August. The soil of the experimental site contains 60% silt, 35% sand and 5% clay wit 1.98% organic carbon, 6.2 ppm available P, 0.17% total N. It is an acidic soil with a pH of 4.43 (Abuye *et al.*, 2021).

Material source

This experiment was conducted at Bako and Gute sub-sites for one year. Sorghum genotypes were brought from National sorghum coordination center, SMILL and from different source of collaborative breeding experiments that was tested on our experimental sites. Totally 191 genotypes including checks were evaluated for their resistance to major sorghum diseases.

Treatment arrangement and disease assessment

The experiment was laid out by Augment design with respective checks. The experimental plots were selected based on the history of the land for continued sorghum production to facilitate disease development. All germplasms were planted with two rows on plot size of 1m x 0.40m.

Six plants per plot were tagged randomly and used subsequently for leaf diseases assessment. Disease severity on leaves, peduncle and rachis was assessed using a 1–9 visual rating scale (Thakur *et al*. 1998). In this scale, 1 no symptoms of disease on plant part; 2 1–5% damaged by disease; 3 6–10% damaged by disease; 4 11– 20% damaged by disease; 5 21–30% damaged by disease; 6 31–40% damaged by disease; 7 41–50% damaged by disease; 8 51–75% damaged by disease and 9 > 75% damaged by disease.

Accordingly genotypes were classified into the following based on disease reaction following Chala and Tronsmo (2012): R = resistant (disease severity of 1%–15%); MR = moderately resistant (16%–30%); MS = moderately susceptible (31%–45%); S = susceptible (46%–60%) and HS = highly susceptible (>60%).

Data collected

Disease data collection commenced starting from the initial disease appearance and collected three times. All necessary agronomic data were collected to evaluate the genotypes.

Data Analysis

The analysis of variance (ANOVA) was performed for the disease parameters (incidence, severity) and yields parameters using SAS version 9.0. Least significant difference (LSD) values were used to separate treatment means ($P<0.05$).

Results and Discussions

The genotypes reacted differently to the diseases. The severity of anthracnose disease significantly varied between the two locations (Bako and Gute). Therefore the ANOVA was done separately for both locations for anthracnose disease.

Different accessions/genotypes showed different resistance level for different diseases. (Table 2-5) At Gute sub site, about 47 genotypes showed resistance to anthracnose; which was almost similar resistance level with standard checks Bonsa and Marara (Table 42). Nine genotypes were completely resistant to the disease than the standard checks, Bonsa and Marara.

Table 42. Anthracnose diseases severity index of some resistant sorghum genotypes at Gute and Bako locations

plot	Genotypes	Gute Severity index of Anthracnose	Bako Severity index of Anthracnose	Mean
1	1351	10.65	86.67	48.66
2	1362	10.65	100	55.325
3	184	10.65	11.11	10.88
4	F4_R16003_206_2	10.65	95.56	53.105
5	F4_R16008_48_1	10.65	48.89	29.77
6	F4_R16008_65_2	10.65	11.11	10.88
7	F4_R16013_10_2	10.65	80	45.325
8	F6_R16016_46_2	10.65	66.67	38.66
9	F4_R16013_8_1	10.65	11.11	10.88
10	Bonsa	10.67	30.22	20.445
11	1035	11.11	11.11	11.11
12	1144	11.11	11.11	11.11
13	1323	11.11	11.11	11.11
14	138	11.11	11.11	11.11
15	304	11.11	11.11	11.11
16	562	11.11	11.11	11.11
17	787	11.11	11.11	11.11
18	F4_R15183_138_1	11.11	11.11	11.11
19	F4_R15183_24_1	11.11	11.11	11.11
20	F4_R15183_24_2	11.11	11.11	11.11
21	F4_R15185_19_1	11.11	11.11	11.11
22	F4_R15190_119_1	11.11	31.11	21.11
23	F4_R16003_146_1	11.11	97.78	54.445
24	F4_R16004_74_1	11.11	100	55.555
25	F4_R16007_88_2	11.11	11.11	11.11
26	F4_R16011_7_2	11.11	11.11	11.11
27	F4_R16013_10_1	11.11	11.11	11.11
28	F4_R16013_3_2	11.11	11.11	11.11
29	F4_R16013_5_1	11.11	11.11	11.11
30	F4_R16013_6_2	11.11	11.11	11.11
31	F4_R16015_1_2	11.11	11.11	11.11
32	F4_R16015_3_1	11.11	11.11	11.11
33	F4_R16015_3_2	11.11	11.11	11.11
34	F4_R16016_19_2	11.11	11.11	11.11

35	F4_R16016_35_1	11.11	11.11	11.11
36	F4_R16016_35_2	11.11	11.11	11.11
37	F4_R16016_38_1	11.11	11.11	11.11
38	F4_R16022_22_1	11.11	11.11	11.11
39	F4_R16022_6_1	11.11	11.11	11.11
40	F6_R16013_1_1	11.11	82.22	46.665
41	F6_R16013_2_2	11.11	11.11	11.11
42	F6_R16016_8_2	11.11	11.11	11.11
43	F7_R15183_110_1	11.11	11.11	11.11
44	F7_R15183_23_2	11.11	33.33	22.22
45	F7_R15183_60_1	11.11	11.11	11.11
46	Macia	11.11	11.11	11.11
47	Marara	11.11	27.56	19.335
48	mm1	11.11	11.11	11.11
49	646	13.33	11.11	12.22
50	Dagim	15.11	31.56	23.335
51	F4_R16004_98_1	17.78	93.33	55.555
52	F6_R16016_21_2	17.78	11.11	14.445
53	294	20	80	50
54	F4_R16019_14_1	20	62.22	41.11
55	KT67	20.89	36.44	28.665
56	F4_R16011_3_2	22.22	44.44	33.33
57	F4_R16016_21_1	22.22	11.11	16.665
58	F4_R16007_159_1	24.44	40	32.22
59	F4_R16011_56_1	26.67	46.67	36.67
60	F6_R16022_10_1	28.89	46.67	37.78
61	F4_R16005_103_1	31.11	93.33	62.22
62	F4_R16008_135_1	33.33	64.44	48.885
63	F6_R16008_135_2	33.33	75.56	54.445
64	F4_R15180_20_2	35.56	66.67	51.115
65	F7_R15180_11_2	35.56	91.11	63.335
66	F6_R16004_14_1	37.78	84.44	61.11
67	F4_R15180_27_2	40	86.67	63.335
68	F4_R16008_20_1	40	53.33	46.665
69	F6_R16004_171_1	40	68.89	54.445
70	F7_R15180_3_1	40	48.89	44.445
71	297	42.22	53.33	47.775
72	F4_R15185_9_1	42.22	95.56	68.89
73	F6_R16022_5_2	42.22	91.11	66.665
74	F4_R16003_29_2	44.44	73.33	58.885
75	F4_R16008_66_1	44.44	80	62.22
76	F4_R16011_38_1	44.44	53.33	48.885
77	F4_R16013_4_1	44.44	51.11	47.775
78	F5_R16004_170_1	44.44	62.22	53.33
79	F4_R16019_30_2	46.67	37.78	42.225
80	F4_R16008_120_2	48.89	60	54.445

81	F6_R16002_49_1	48.89	44.44	46.665
82	F6_R16004_10_1	48.89	64.44	56.665
83	F6_R16011_38_1	48.89	46.67	47.78
84	F4_R16008_106_2	51.11	82.22	66.665
85	F4_R16008_170_2	51.11	73.33	62.22
86	F4_R16008_215_1	51.11	57.78	54.445
87	F4_R16008_35_1	51.11	73.33	62.22
88	F4_R16005_100_1	53.33	11.11	32.22
89	KT148	53.33	56.44	54.885
90	1030	55.56	66.67	61.115
91	270	55.56	84.44	70
92	F4_R15184_9_1	55.56	48.89	52.225
93	F4_R16008_116_2	55.56	60	57.78
94	F4_R16008_69_1	55.56	68.89	62.225
95	F4_R16013_9_2	55.56	62.22	58.89
96	F6_R16004_195_2	55.56	73.33	64.445
97	682	57.78	75.56	66.67
98	F4_R15180_57_1	57.78	88.89	73.335
99	F4_R16008_57_2	57.78	64.44	61.11
100	F4_R16008_95_1	57.78	73.33	65.555
101	F4_R16011_62_2	57.78	91.11	74.445
102	F4_R16013_9_1	57.78	71.11	64.445
103	F6_R16007_112_1	57.78	46.67	52.225
104	F6_R16008_129_1	57.78	77.78	67.78
105	F6_R16008_179_2	57.78	60	58.89
106	F4_R16008_26_2	60	71.11	65.555
107	F4_R16008_58_2	60	86.67	73.335
108	F4_R16004_32_1	62.22	80	71.11
109	F4_R16008_140_2	62.22	95.56	78.89
110	F4_R16004_174_1	64.44	82.22	73.33
111	F4_R16008_174_2	64.44	86.67	75.555
112	F4_R16008_20_2	64.44	71.11	67.775
113	F4_R16008_87_2	64.44	66.67	65.555
114	F4_R16002_8_1	68.89	66.67	67.78
115	F4_R16008_87_1	68.89	86.67	77.78
116	F6_R16004_176_1	68.89	71.11	70
117	F4_R16007_141_1	71.11	91.11	81.11
118	F4_R16008_144_1	71.11	66.67	68.89
119	F4_R16008_64_2	71.11	91.11	81.11
120	QL36	71.11	86.67	78.89
121	1058	73.33	91.11	82.22
122	879	73.33	62.22	67.775
123	F4_R16003_174_1	73.33	64.44	68.885
124	F4_R16004_68_1	73.33	86.67	80
125	F4_R16008_113_2	73.33	86.67	80
126	F4_R16008_82_1	73.33	82.22	77.775

127	F4_R16008_96_1	73.33	77.78	75.555
128	F7_R15184_19_1	73.33	88.89	81.11
129	1029	75.56	80	77.78
130	888	75.56	68.89	72.225
131	F4_R16004_14_2	75.56	71.11	73.335
132	F6_R16016_36_1	75.56	62.22	68.89
133	F4_R15180_6_1	77.78	86.67	82.225
134	F4_R16007_140_2	77.78	88.89	83.335
135	F4_R16008_110_1	77.78	80	78.89
136	F4_R16008_185_2	77.78	97.78	87.78
137	F4_R16022_1_1	77.78	51.11	64.445
138	F4_R16003_193_2	82.22	100	91.11
139	F4_R16004_119_1	82.22	75.56	78.89
140	F4_R16016_23_1	82.22	62.22	72.22
141	F6_R16004_9_1	82.22	100	91.11
142	F7_R15184_13_2	82.22	91.11	86.665
143	F7_R15184_19_2	82.22	82.22	82.22
144	F4_R16004_179_2	84.44	93.33	88.885
145	F4_R16004_25_1	84.44	75.56	80
146	F4_R16011_55_1	84.44	100	92.22
147	F6_R16005_180_2	84.44	77.78	81.11
148	F4_R16008_115_1	86.67	88.89	87.78
149	F6_R16004_108_1	86.67	93.33	90
150	F6_R16008_32_1	86.67	84.44	85.555
151	F4_R15184_11_1	88.89	82.22	85.555
152	F4_R16004_118_1	88.89	86.67	87.78
153	F4_R16008_27_1	88.89	71.11	80
154	F5_R16008_95_2	88.89	68.89	78.89
155	F6_R16008_65_1	88.89	73.33	81.11
156	242	91.11	82.22	86.665
157	779	91.11	100	95.555
158	F4_R16007_134_2	91.11	71.11	81.11
159	F4_R16008_131_1	91.11	93.33	92.22
160	F6_R16003_110_1	91.11	68.89	80
161	F4_R16008_210_1	93.33	88.89	91.11
162	F4_R16016_33_1	93.33	20	56.665
163	F4_R16016_4_1	93.33	73.33	83.33
164	F4_R16008_122_1	95.56	95.56	95.56
165	F4_R16008_66_2	95.56	100	97.78
166	F6_R16007_35_1	95.56	100	97.78
167	F4_R16008_161_2	97.78	91.11	94.445
168	F4_R16008_171_1	97.78	82.22	90
169	F4_R16011_3_1	100	62.22	81.11
170	F6_R16001_175_1	100	88.89	94.445
171	F6_R16016_31_2	100	88.89	94.445
Mean		45.19	36.44	

CV	39.91	18.62	
LSD	11.89	9.098	

At Bako experimental site, anthracnose severity was significantly different between the genotypes. About 39 genotypes showed resistant to the diseases than the most resistant standard check Marara at the location (Table 42). The test genotype F4_R16016-33-1, Marara and Bonsa showed moderately resistant for anthracnose disease. In contrary to this, about 104 genotypes showed susceptible reaction to anthracnose.

Sorghum sooty stripe final disease severity index did not significantly differ by location. Therefore combined mean analysis was performed for genotypes to evaluate their resistance level at field condition. About 92 genotypes were completely resistant at both locations (Table 43). These genotypes showed greater resistance than the resistant standard check KT148. Additionally 15 genotypes showed more sooty stripe disease severity index than TK148 variety, statistically at par with each other (Table 43).

Table 43. Some genotypes of final severity index for resistance for Sooty stripe at mean both locations Bako and Gute

No	Genotype	Sooty Stripe	No	Genotype	Sooty Stripe
1	F4_R16008-82-1	11.11	87	F4_R16008-66-2	11.11
2	F5_R16008-95-2	11.11	88	F4_R16008-96-1	11.11
3	F4_R16008-171-1	11.11	89	F4_R16013-4-1	11.11
4	F6_R16016-36-1	11.11	90	F4_R16011-3-2	11.11
5	F4_R16007-134-2	11.11	91	1351	11.11
6	F4_R16008-26-2	11.11	92	1362	11.11
7	F6_R16016-31-2	11.11	93	KT148	11.33
8	F7_R15184-19-2	11.11	94	270	12.22
9	F6_R16016-46-2	11.11	95	F6_R16011-38-1	12.22
10	F4_R16016-23-1	11.11	96	F6_R16008-129-1	12.22
11	F4_R16004-119-1	11.11	97	F4_R16008-87-1	12.22
12	F4_R16008-95-1	11.11	98	F6_R16004-10-1	13.33
13	F7_R15184-13-2	11.11	99	F4_R16008-215-1	13.33
14	F4_R16008-140-2	11.11	100	F4_R16008-57-2	13.33
15	F4_R16008-87-2	11.11	101	F4_R16003-193-2	13.33
16	F6_R16008-32-1	11.11	102	F4_R16008-116-2	13.33
17	F6_R16008-135-2	11.11	103	F6_R16004-171-1	13.33
18	F4_R15184-9-1	11.11	104	F4_R15185-9-1	13.33
19	F5_R16004-170-1	11.11	105	F4_R16008-20-1	13.33
20	F4_R16008-66-1	11.11	106	F4_R16008-58-2	13.33
21	F4_R16003-174-1	11.11	107	F4_R16004-174-1	13.33
22	F4_R16008-110-1	11.11	108	879	13.33

23	F4_R15180-20-2	11.11	109	F4_R16008-113-2	13.33
24	F4_R16004-32-1	11.11	110	F6_R16022-10-1	14.44
25	F4_R16008-106-2	11.11	111	F4_R16013-9-2	14.44
26	F6_R16004-195-2	11.11	112	F4_R16019-30-2	14.44
27	F4_R16013-9-1	11.11	113	F4_R16002-8-1	15.56
28	F4_R15180-57-1	11.11	114	F6_R16004-14-1	15.56
29	F7_R15180-3-1	11.11	115	F4_R16008-120-2	15.56
30	F6_R16007-112-1	11.11	116	KT67	16.67
31	QL36	11.11	117	F7_R15183-23-2	16.67
32	297	11.11	118	Dagim	18.67
33	F4_R16004-68-1	11.11	119	F4_R16011-62-2	17.78
34	F4_R15180-6-1	11.11	120	Marara	18.00
35	F6_R16005-180-2	11.11	121	Bonsa	21.78
36	F4_R16011-56-1	11.11	122	F4_R16008-135-1	18.89
37	F4_R16016-4-1	11.11	123	F6_R16001-175-1	20.00
38	F6_R16003-110-1	11.11	124	F4_R16008-170-2	20.00
39	F4_R16003-206-2	11.11	125	F4_R16004-98-1	20.00
40	F4_R16008-115-1	11.11	126	F4_R16019-14-1	21.11
41	242	11.11	127	F7_R15180-11-2	21.11
42	F6_R16002-49-1	11.11	128	F4_R16008-65-2	26.67
43	F6_R16008-65-1	11.11	129	F4_R16005-100-1	26.67
44	F4_R16008-131-1	11.11	130	F4_R15190-119-1	27.78
45	F4_R16004-179-2	11.11	131	F4_R16003-146-1	30.00
46	F4_R16008-122-1	11.11	132	F4_R16013-6-2	30.00
47	F6_R16008-179-2	11.11	133	F4_R16016-21-1	34.44
48	F6_R16004-176-1	11.11	134	F4_R16004-74-1	34.44
49	F4_R16007-141-1	11.11	135	294	36.67
50	F4_R16008-69-1	11.11	136	F4_R16016-19-2	36.67
51	F7_R15184-19-1	11.11	137	F4_R16013-8-1	36.67
52	F4_R16008-64-2	11.11	138	1035	36.67
53	F4_R16011-55-1	11.11	139	F4_R16007-88-2	37.78
54	F6_R16004-9-1	11.11	140	646	37.78
55	F4_R16003-29-2	11.11	141	138	38.89
56	F4_R15180-27-2	11.11	142	F6_R16016-21-2	38.89
57	F6_R16022-5-2	11.11	143	F7_R15183-110-1	41.11
58	F4_R16005-103-1	11.11	144	mm1	42.22
59	F4_R16008-48-1	11.11	145	184	43.33
60	F4_R16013-10-2	11.11	146	Macia	44.44
61	682	11.11	147	F4_R15183-24-1	47.78
62	F4_R16008-185-2	11.11	148	1144	47.78
63	F4_R16016-33-1	11.11	149	F4_R16016-35-1	48.89
64	F6_R16007-35-1	11.11	150	F4_R15183-138-1	48.89
65	F6_R16004-108-1	11.11	151	F4_R15183-24-2	48.89

66	779	11.11	152	F4_R16022-6-1	48.89
67	F4_R16008-35-1	11.11	153	304	51.11
68	F4_R16008-20-2	11.11	154	F4_R16011-7-2	52.22
69	F4_R16008-174-2	11.11	155	F4_R16015-3-2	53.33
70	888	11.11	156	F6_R16013-1-1	55.56
71	F4_R16004-25-1	11.11	157	F6_R16013-2-2	55.56
72	F4_R16007-140-2	11.11	158	F4_R16016-35-2	55.56
73	F4_R15184-11-1	11.11	159	F6_R16016-8-2	57.78
74	F4_R16008-27-1	11.11	160	F4_R16015-3-1	60.00
75	F4_R16022-1-1	11.11	161	F7_R15183-60-1	61.11
76	F4_R16008-210-1	11.11	162	562	62.22
77	F4_R16007-159-1	11.11	163	F4_R16013-5-1	66.67
78	F4_R16004-118-1	11.11	164	F4_R16016-38-1	66.67
79	F4_R16011-3-1	11.11	165	F4_R16013-3-2	68.89
80	1029	11.11	166	1323	71.11
81	1030	11.11	167	F4_R16022-22-1	76.67
82	F4_R16008-144-1	11.11	168	F4_R16015-1-2	80.00
83	F4_R16004-14-2	11.11	169	F4_R15185-19-1	81.11
84	1058	11.11	170	F4_R16013-10-1	90.00
85	F4_R16008-161-2	11.11	171	787	97.78
86	F4_R16011-38-1	11.11			
	Mean				17.29
	CV				11.57
	Lsd				2.68

Similarly, grain mold final disease severity was not significantly differed by location. Therefore, two locations combined mean analysis were performed for genotypes to evaluate their resistance level. Standard checks KT67 and Marara were late maturing hence not possible to score grain mold with the other genotypes at the same time. Therefore only three checks (Dagim, Bonsa and KT 184) were used to compare the resistance of the genotypes (Table 44).

Table 44. Some genotypes mean of final severity for resistance to Grain Mold at both locations Bako and Gute

Genotypes	Severity at Bako	Severity at Gute	Mean Severity	Genotypes	Severity at Bako	Severity at Gute	Mean Severity
F6_R16008_135_2	1.00	1	1	F6_R16004_195_2	1.00	2.2	1.6
				F6_R16016_8_2	1.00	2.2	1.6
F4_R16016_23_1	1.00	1	1	F4_R16016_21_1	1.00	2.2	1.6

F6_R16022_10_1	1.00	1	1	1035	1.60	1.6	1.6
F4_R16007_88_2	1.00	1	1	1323	2.20	1	1.6
297	1.00	1	1	F4_R16015_3_2	1.00	2.4	1.7
F4_R15180_6_1	1.00	1	1	F4_R15184_9_1	1.00	2.6	1.8
A646	1.00	1	1	F4_R15180_57_1	1.20	2.6	1.9
F4_R16013_8_1	1.00	1	1	F4_R16008_174_2	1.00	2.8	1.9
F4_R16008_35_1	1.00	1	1	F4_R16011_38_1	2.40	1.4	1.9
F4_R16007_159_1	1.00	1	1	mm1	1.00	2.8	1.9
F4_R16011_3_2	1.00	1	1	F5_R16004_170_1	1.00	3	2
Dagim	1.00	1.04	1.02	F4_R16013_9_1	1.40	2.6	2
KT148	1.00	1.04	1.02	879	2.60	1.4	2
Bonsa	1.00	1.08	1.04	888	2.40	1.6	2
F6_R16004_14_1	1.00	1.2	1.1	1144	2.00	2	2
F6_R16007_112_1	1.00	1.2	1.1	F4_R16008_95_1	1.00	3.2	2.1
F4_R16008_116_2	1.00	1.2	1.1	F6_R16004_171_1	1.20	3	2.1
F4_R16008_20_2	1.20	1	1.1	F6_R16007_35_1	1.00	3.2	2.1
1030	1.20	1	1.1	F4_R16007_134_2	2.40	2	2.2
F4_R16008_48_1	1.00	1.4	1.2	F4_R16019_14_1	1.00	3.4	2.2
F4_R16008_171_1	1.20	1.2	1.2	F4_R16016_35_1	1.40	3	2.2
138	1.00	1.4	1.2	F6_R16022_5_2	1.00	3.4	2.2
F6_R16008_179_2	1.40	1	1.2	F4_R16008_120_2	1.80	2.6	2.2
F4_R16003_29_2	1.00	1.4	1.2	F4_R16004_14_2	3.00	1.4	2.2
F4_R16008_20_1	1.00	1.4	1.2	F4_R16008_96_1	1.40	3	2.2
F4_R16004_119_1	1.40	1.2	1.3	F6_R16016_36_1	2.20	2.4	2.3
F4_R16013_9_2	1.20	1.4	1.3	F4_R16013_3_2	1.00	3.6	2.3
682	1.20	1.4	1.3	562	3.00	1.6	2.3

F4_R16008_66_1	1.00	1.6	1.3	F4_R16005_103_1	1.00	3.6	2.3
F4_R15180_27_2	1.60	1	1.3	F4_R16004_174_1	3.40	1.2	2.3
Macia	1.00	1.8	1.4	F7_R15183_23_2	1.00	3.8	2.4
F4_R15190_119_1	1.20	1.6	1.4	F4_R16022_1_1	1.60	3.2	2.4
F4_R16008_69_1	1.00	1.8	1.4	F6_R16005_180_2	1.80	3.4	2.6
F4_R15185_9_1	1.00	1.8	1.4	F4_R16016_38_1	3.20	2	2.6
F4_R16008_27_1	1.20	1.6	1.4	F6_R16008_129_1	1.80	3.6	2.7
270	1.00	2	1.5	F4_R15183_24_1	3.00	2.6	2.8
F4_R16008_57_2	1.00	2	1.5	F4_R16008_64_2	2.20	3.8	3
F6_R16011_38_1	1.20	1.8	1.5	F4_R16008_140_2	1.60	4.6	3.1
F4_R16008_135_1	1.00	2	1.5	779	2.80	3.4	3.1
F4_R16005_100_1	1.20	1.8	1.5	F4_R16008_210_1	2.80	3.4	3.1
F4_R16008_215_1	1.20	2	1.6				

Thousand seed weight

Analysis of variance indicated that thousand seed weight was non significant between locations. There were no significant variations between the genotypes and interaction of genotype and location. However grain yield per plot were significantly different between the locations and the analysis was performed separately for the locations (Table 45).

Table 45: ANOVA table of genotype, location and genotype and location interaction on 1000 seed weight and grain yield per plot

Source of variation	df	1000 seed weight	Grain Yield per plot

		Sum Square	Mean Square	Pr > F	Sum Square	Mean Square	Pr > F
Genotype	4	30.90	7.725	0.3370	11174103.66	2793525.91	<.0001
Location	1	6.99	6.994	0.3087	2384534.90	2384534.90	<.0001
Genotype*Location	4	13.18	3.294	0.7343	261868.41	65467.10	0.5770

Marara variety produced the highest grain yield per plot than the other standard checks and tested genotypes at Bako. About 47 genotypes recorded higher grain yield value than the grand mean of all genotypes and checks (Table 46).

Table 46: Grain yield of sorghum genotypes at Bako

No	Genotypes	Grain Yield per plot (gm/plot)	No	Genotypes	Grain Yield per plot (gm/plot)
1	Marara	1508.6	34	F4_R16008_135_1	279.4
2	F4_R16003_174_1	687.3	35	F4_R16004_119_1	271.9
3	F4_R16016_21_1	667.6	36	F4_R16008_57_2	270.7
4	F4_R16008_69_1	592.3	37	F4_R16004_179_2	266.6
5	F6_R16004_195_2	584.4	38	F6_R16003_110_1	260.6
6	F4_R16008_215_1	555.0	39	F6_R16007_35_1	249.0
7	F7_R15183_110_1	528.0	40	F4_R16007_134_2	244.2
8	F7_R15183_23_2	477.9	41	F6_R16004_176_1	240.9
9	F4_R16007_88_2	467.5	42	F7_R15184_13_2	234.9
10	F4_R16008_87_2	459.9	43	F4_R16008_95_1	232.6
11	F4_R16013_6_2	452.3	44	F6_R16013_1_1	232.0
12	F6_R16004_14_1	439.0	45	F4_R16008_115_1	229.0
13	F4_R16008_113_2	434.0	46	F4_R16016_19_2	225.4
14	F6_R16004_9_1	416.9	47	F6_R16016_46_2	224.4

15	F6_R16005_180_2	415.6	48	F5_R16008_95_2	223.0
16	F4_R15184_9_1	414.7	49	F6_R16016_8_2	222.6
17	F6_R16002_49_1	412.4	50	F4_R16015_3_2	221.0
18	F4_R15190_119_1	412.0	51	F4_R16008_66_2	220.0
19	Bonsa	373.5	52	F4_R16007_159_1	218.4
20	F4_R16008_171_1	350.4	53	F4_R16008_66_1	213.7
21	F6_R16004_171_1	348.4	54	F6_R16011_38_1	210.7
22	F4_R16008_116_2	347.1	55	F4_R16022_1_1	206.3
23	F4_R16019_14_1	345.2	56	F4_R15180_27_2	206.0
24	F4_R16007_141_1	339.9	57	F6_R16016_36_1	205.0
25	F4_R16011_7_2	338.8	58	F4_R16008_170_2	204.9
26	242	332.8	59	F4_R16003_206_2	203.8
27	F7_R15180_3_1	325.5	60	F4_R15185_9_1	200.3
28	F4_R16013_9_1	324.8	61	F4_R16003_146_1	200.0
29	F4_R16011_3_2	322.2	62	562	199.8
30	F4_R16004_14_2	321.0	63	F4_R16002_8_1	196.2
31	F4_R15180_20_2	289.4	64	F6_R16008_179_2	280.3
32	F4_R16016_23_1	284.5	65	KT148	196.1
33	F6_R16007_112_1	279.9	66	Dagim	195.2
	Check mean				482.67
	CV				55.45
	LSD				358.83

Table 47: Grain yield of sorghum genotypes at Gute

No	Genotypes	Grain Yield	No	Genotypes	Grain Yield

		(gm/plot)			(gm/plot)
1	Marara	1738.80	33	F4_R16004_179_2	214.80
2	Bonsa	941.52	34	F4_R16008_110_1	213.00
3	Dagim	715.16	35	F4_R16008_171_1	210.70
4	KT67	710.46	36	F4_R16008_135_1	208.60
5	KT148	491.24	37	F5_R16004_170_1	207.30
6	F4_R16008_26_2	461.40	38	F4_R16003_206_2	201.00
7	F4_R16011_38_1	416.80	39	294	200.70
8	F4_R16016_21_1	345.00	40	F5_R16008_95_2	200.60
9	F6_R16005_180_2	307.50	41	F4_R16004_68_1	199.50
10	F4_R16008_66_1	295.10	42	F4_R16007_159_1	198.90
11	F4_R16003_174_1	291.10	43	F4_R16013_6_2	192.20
12	F7_R15184_13_2	272.00	44	F4_R15184_9_1	190.20
13	F6_R16002_49_1	270.30	45	F4_R16008_106_2	189.90
14	F4_R15190_119_1	262.20	46	F4_R16004_32_1	189.30
15	F7_R15184_19_1	256.90	47	F6_R16008_32_1	188.50
16	F4_R16004_119_1	256.70	48	F6_R16016_46_2	185.80
17	F4_R16008_95_1	253.70	49	F6_R16013_1_1	185.50
18	F4_R16003_29_2	249.10	50	F4_R16008_65_2	182.40
19	F4_R16008_87_2	248.50	51	138	180.80
20	F4_R15180_20_2	247.70	52	F6_R16016_31_2	177.10
21	F4_R16002_8_1	244.10	53	F7_R15180_11_2	172.40
22	F6_R16016_36_1	239.10	54	1030	171.20
23	F6_R16004_10_1	238.60	55	F4_R16011_62_2	170.00
24	F7_R15184_19_2	238.50	56	F6_R16004_9_1	167.60
25	Macia	233.90	57	F6_R16008_179_2	161.10

26	F4_R16007_134_2	232.80	58	F4_R15180_27_2	157.80
27	F7_R15180_3_1	231.50	59	F4_R16008_144_1	157.30
28	270	229.70	60	F4_R16019_14_1	154.50
29	F4_R16016_23_1	225.90	61	F4_R16008_82_1	153.90
30	F4_R16008_140_2	225.10	62	F4_R16008_215_1	152.20
31	F4_R16007_88_2	221.00	63	F4_R16008_69_1	151.50
32	QL36	214.90	64	F4_R16005_103_1	146.80
	CV				35.94
	LSD				443
	P				0.0002

The yield performances of tested genotypes were lower than the standard checks at Gute. Marara variety showed the highest grain yield than the genotypes; however, the variety was harvested lately hence it had long maturity period.

Summary and Recommendation

The result indicated that anthracnose disease severity index intensity were different between the two locations. The reactions of the genotypes were different for the scored diseases. Most genotypes showed highly resistant reaction for anthracnose. Some genotypes (merely not the same) scored high resistance reaction for sooty stripe. Therefore, the resistant genotypes for their respective diseases should be used in different breeding programs.

References

Abuye T, Mekonnen D. and Worku T. 2021. Dry matter yields and quality parameters of ten Napier grass (Cenchrus purpureus) genotypes at three locations in western Oromia, Ethiopia

Berenji J, Dahlberg J, 2004. Perspectives of Sorghum in Europe. *Journal Agron Crop Sci* 1905: 332-338

CSA (Central Statistical Agency) (2020) Agricultural Sample Survey report on Area and Production of Major Crops (Private Peasant Holdings 'Meher' Season): Statistical Bulletin 585. Addis Ababa, Ethiopia.

FAO(2019). Food and Agriculture Organization of the United Nations Crops and livestock products

FAO(2017). Food and Agriculture Organization of the United Nations Crops and livestock products

House, L.R. (1985). A guide to sorghum breeding. 2ndedn. Patancheru, A.P. 502324, India: International Crops Research Institute for the Semi - Arid Tropics.

Rooney LW, Waniska RD.(2000). Sorghum food and industrial utilization, pp. 689-729. In: Smith CW, Frederiksen RA eds. Sorghum: Origin, History, Technology, and Production, John Wiley & Sons Inc., New York

Thakur RP, Frederiksen RA, Murty DS, Reddy BVS, Bandyaophayay R, Giorda LM, Odvody GN and Claflin LE. (1997). Breeding for disease resistance in sorghum. *in* Proceedings of theInternational Conference on Genetic Improvement of Sorghum and Pearl millet, September 22-27, 1996, Lubbock, Texas, INTSORMIL and ICRISAT. PP 303-315

Thakur, R.P. (1995). Status of international sorghum anthracnose and pearl millet downy mildew virulence nurseries. Pp. 75-92. In J.F. Leslie and R.A. Frederiksen, (eds.) *Disease Analysis Through Genetics and Biotechnology: Interdisciplinary Bridges to Improved Sorghum and Millet Crops*. Iowa State University Press, Ames, Iowa.

Sleper, D.A and J.M. Poehlman, (2006). Breeding field crops. 5th Eds., Wiley-Blackwell Publ., USA, ISBN: 978-0-8138-2428-4, PP: 424.

Valerio H, Resende M., Weikert-Oliveira R, Casela C. (2005) Virulence and molecular diversity in *Colletotrichumgraminicola*from Brazil. Mycopathol. 159:449-459

Determination of Critical Period of Weed Competition in Rice (Oryzae Sativa L.) at Bako and Chewaka, Western Oromia

Megersa Kebede , Lamma Lalisa[*]*, Dejene Hail1, Getu Abera*
Bako Agricultural Research Center, Western Oromia, Bako , P.O BOX 03 ,Ethiopia
*Corresponding author: lammaalalisaa2021@gmail.com

Abstract

*The weed effect is one of the important limiting factors for crop growth and productivity in agricultural crop production. But there is little information on the critical time of weed competition for the production of upland rice. Hence, this study was conducted at Bako and Chawaka;Western Oromiato evaluate the effect of the timing of weed removal and the duration of weed interference on yield and yield components and to determine the critical period of weed control on direct seeded up-land rice (*Oryzae sativa *L.) at Bako and Chewaka, Western Oromia. It was conducted during main cropping season of 2020 &2021.Theexperiment was carried out in randomized completely block design (RCBD) with three replications; In the first set of treatment; the crop was kept weed free until 10, 20, 30, 40, 50, 60 and 70days after crop emergence (DACE). In the second set; weeds were permitted to grow with in the crop until 10, 20, 30, 40, 50, 60 and DACE. Weedy and weed free were also included in the treatments as control checks. All replicated thrice. The data on the growth, yield components, and yield parameters of rice were collected, analyzed, and discussed accordingly. Except thousand seed weight; the weed competition duration had a significant influence on the plant height, Number of un-filled grain, Number of filled grain , panicle length ,No of effective tillers per plant and seed yield weight per hectare. Hence, the highest seed yield was obtained from the weed-free check (4153kg ha-1&4135kgha-1) Bako-Chewaka and followed by weed-free for 70 (3956kg ha-1 and 4003kgha-1) Bako- Chewaka respectively. Whereas the lowest was from the weedy-check (335kg ha-1 & 665kgha-1) Bako-Chewaka & followed weedy for 70 DACE (1411kgha-1 &1326kgha-1) Bako-Chawaka respectively. The yield loss of rice was estimated based on seed yield weight per hectare. Thus, the highest yield loss of seed yield was recorded in the weedy check (91.93%&83.92%) at Bako and Chawaka respectively whereas the lowest was in the weed-free check (0.00%) at both locations .To determine the beginning and the end of the critical period of crop-weed competition at 5% and 10% acceptable yield loss levels were used. Therefore, to reduce the yield losses by more than 10% and to obtain a higher economic return, weeds must be kept free within WF40 to WF70 to reduce the risk of economic yield losses as it has been found to be the critical period.*

Keywords: Weed free treatments, Weed interference treatments, weed free and weedy, Rice, yield,

Introduction

Rice (*Oryza sativa* L.) is one of the leading cereals of the world (Ashraf *et al*., 2006), and more than 50% of world population depend on rice for their daily sustenance (Chauhan and Johnson, 2011). It is the fifth most important cereal in Africa in terms of area harvested and the fourth in terms of production after sorghum (*Sorghum bicolor*), maize (*Zea mays*) and millet (*Eleusine coracana*) (FAO, 2015). In Ethiopia, rice is a recently introduced crop and its area and production have been increasing. Ethiopia has huge potential for rice production which is estimated about thirty million hectare (MOARD, 2010) of which the rain feed ecosystem takes the line share. It has wide range of uses. Its grain used as staple food, and source of income. Rice crop is known by its high caloric content and productivity. Although rice is introduced to the country recently, it has great potential and can play a critical role in contributing to food and nutritional security, income generation, poverty alleviation and socio-economic growth of Ethiopia(Getachew *et al*., 2017; MoARD, 2016).However, the production and productivity of the crop is limited due to various biotic and abiotic constraints. According to Tesfaye *et al*. (2005) lack of improved variety, recommended crop management practices, pre and post-harvest technology, other biotic and abiotic factors are production constraints of rice in Ethiopia.

Among biotic factors weed is the major problem, and thus effective weed management is needed to be employed to reduce associated yield losses. Getachew *et al*. (2017); Tilahun and Kifle (2015) reported that, weeds are major constraints to rice production in labor-limited, upland rice-based systems in Ethiopia. Weeds are the greatest yield-limiting constraint to rice (Chauhan and Johnson, 2011). Weeds cause 40 - 60% average yield losses in rice which may go up to 94 -96% with uncontrolled weed growth (Chauhan and Johnson, 2011, Dass et al., 2017, Islam *et al*., 2021. Weeds compete with rice plants severely for space, nutrients, air, water and light and thus adversely affecting growth and yield of rice. Weeds do not compete with crops throughout the growing season but there is a critical period when weed completion results in economic yield losses (Anwar *et al*., 2012). Therefore, that critical period must be kept weed free through manual weeding and/or chemical control. Appropriate timing of control, whether by the application of herbicides or by other means, represents a substantial opportunity to reduce reliance on herbicide by introducing control at optimum time, rather than repeatedly or prophylactically (Rajcan and Swanton, 2001).Weed control at proper timing and crop growth stages facilitated the significant improvement in crop production (Knezevic et al., 2002). The critical timing for weed removal (CTWR provides the information to reduce the yield losses for a specific crop (Knezevic et al., 2002).

Generally, effective weed management with due emphasize to integrated weed management (IWP) should be designed and developed for sustainable rice production and/or productivity in the country. The critical period for weed control (CPWC) is the key element to design/develop agronomical and economically effective integrated weed management even though such information is limited in many rice growing areas of Ethiopia. The CPWC is a key component of an IWM program. It is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses (Knezevic *et al*., 2003; Zimdahl, 2004). With the aid of CPWC it is possible to make decisions on the need for and timing of weed control and to control weeds only when efficient weed control is required (Evans et al., 2003; Uremis *et al*., 2009; Mahmoodi and Rahimi, 2009). Identifying the critical period for weed control (CPWC) in crops is one of the first steps in designing a successful integrated weed management (Evans *et al*., 2002). Critical period of weed control has got a beginning and an end as well. The beginning of CPWC is determined by estimating critical time for weed removal (CTWR) after which weed control must be initiated to ensure potential yield [M. R. Hall, C. J. Swanton, and G. W. Anderson & S. Z. Knezevic, S. P. Evans, and M. Mainz]. The end of CPWC, on the other hand, is determined by estimating critical weed-free period (CWFP) required from planting to avoid irrevocable yield loss [S. Z. Knezevic, S. P. Evans, E. E. Blankenship, R. C. Van Acker, and J. L. Lindquist & S. P. Evans, S. Z. Knezevic, J. L. Lindquist, C. A. Shapiro, and E. E. Blankenship]. The CPWC is determined by calculating the time interval between CTWR and CWFP. Critical period of weed control has commonly been reported as day after seeding (DAS), but due to differences in planting dates and environment, this may generate results with more variability among locations, seasons, and cultivars. Therefore, CPWC determination based on DAS has been criticized by many researchers [M. R. Hall, C. J. Swanton, and G. W. Anderson].Even though knowing and/ or determining of the critical period for weed control in rice crop play a crucial role in designing and/or developing effective weed management, nothing has been done concerning to CPWC on rice in western Oromia, Ethiopia. Therefore, there is a need to determine the critical period for weed control in rice. Realizing this, the present study is initiated with the following objectives.

The objectives were to evaluate the effect of the timing of weed removal and the duration of weed interference on direct seeded up-land rice yield and to determine the critical period of weed control on direct seeded up-land rice (*Oryzae sativa* L.) at Bako and Chewaka, Western Oromia.

Materials and methods

Treatments and Experimental Design

The treatments are categorized as weed free or weed interference at different days after crop emergence (DACE) (Table 1). In the weed free treatments, weeds were removed from rice emergence until 10, 20, 30, 40, 50, 60 and 70 DACE and then weed growth was allowed up to crop harvest. In the weed interference treatments, weed vegetation/plant was allowed to grow until 10, 20, 30, 40, 50, 60 and 70 DACE and then plots were maintained weed free up to crop harvest. Additionally, season-long weed free and weed infested checks were included for comparison. The 16 treatments were arranged in a randomized complete block design (RCBD) with three replications. Chewaka variety of Rice was sown on the plot size of 4m x 3m, and there was 0.2m, 0.5 m and 1m paths between the adjacent rows, plots and the blocks respectively. Weeds were removed by hand and hand hoeing in all plots according to treatments.

All management practices were applied as per area recommendation.

Data collected

Crop data

The rice growth ,yield and yield components/plant height, total number of tillers per plants, number of effective (spike bearing tillers per plant), number of spike per panicle, panicle length ,No of filled and un-filled grain and Grain yield data were recorded.

Data Analysis

Analyses of variances for the data recorded were conducted using the SAS version 9.3. Significance test and means were separated using Duncan Multiple Range Test (DMT) at $p < 0.05$. Yield of the crop was adjusted to 10% before economic analysis .To calculate the critical period of weed control in rice, the relative rice yield (Y) of each treatment was calculated as:

$$\mathrm{Y} = \left(\frac{\text{Rice yield in treatment}}{\text{Rice yield in weedy check}}\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Results and discussion

Effect of different weed competition periods on yield and yield components of Rice at Bako

The growth measurements of rice such as plant height, No. Of effective tillers, panicle length, Number of filled grain & Number of un-filled grain in the experiment indicated the significant impact of weed interference on the growth properties of rice plants (Table 1). It was found that the growth measurements of rice in the weed-free periods were higher than those in the weed-infested periods except Number of un-filled grain which is lower in the weed-free periods than those in the weed-infested periods. In the weedy plot, some growth criteria were significantly ($P < 0.05$) increased from the weed infestation to the weed-free period.

Grain yield (kg ha-1): The grain yield is the function of some yield attributing characters like number of effective tillers per plant, grains per panicle, panicle length per plant, etc.

The grain yield of Rice was affected significantly by different weed competition periods. The maximum and minimum grain yield of rice ((4153 kg ha-1&335kg ha) was recorded in Weed free and weedy treatment (Checks)   respectively(Table-2).The higher seed yield in weed free plots has also been reported by Sarandon et al. (2002), Ciuberkis *et al*. (2004) and Mubeen *et al*. (2009).The minimum yield in weedy check can be attributed to maximum weed density and minimum number of crop plants, No of effective tillers, panicle length, grain filled and 1000 seed weight. Again those treatments; Weed free for 70 DACE3956kg ha-1&Weedy for 70 DACE (1411kg ha-1) were resulted the second highest and lowest rice grain yield respectively (Table-48). The result also revealed that; with increasing in competition period; the grain yield of rice were decreased significantly and the grain yield of rice were increased with decreasing in competition periods (Table-48).

Plant height of the crop (cm): The study revealed that the Plant height was highly significantly affected by weed competition periods. The maximum and minimum plant height (124 cm & 95.6cm) were documented from weed free checks and in weedy check treatments respectively (Table-48). The second the highest and the lowest rice plant height were observed from in weed free for 30 DACE (121cm) and weedy for 70DACE treatments (96.4cm) respectively (Table-48). Greater plant height of rice crop in weed free treatment might have been due to more availability of resources in the absence of weeds. The minimum plant height in weedy check can be attributed to greater competition and suppressive effect of weeds. The results are similar with those of Hussain *et al*. (2009) who reported lower plant height in black seed with increased competition periods. Treatments such as weed free for 40, 50, 60, 70 DACE and weedy for 10DACE were shown statistical similarity of plant heights (Table-48). With increasing in competition period; the height of rice were decreased significantly and the height of rice were increased with decreasing in competition periods (Table-48). Similar findings have been reported for rice plants, where their height is significantly reduced when rice competes with weeds for 70 days or longer, and rice plant height is inversely proportional to weed competition length (Micheal *et al*., 2013). And Freckle ton and Freckleton and Watkinson, also reported the height of plants is often associated with their inter-specific competitive ability.

Panicle Length (cm): The Panicle length of rice crop was shown non- significant differences by weed competition periods. But the highest and lowest rice panicle were observed from treatments; weed free (22cm) and weedy checks (18.77cm)(Table 49). This might be due to draining of nutrients by weeds (Table 49). A similar result was obtained by Dubey *et al*. (2017); And the rest weed competition period treatments were shown similar statistical results (Table-48)

No. of Effective Tiller (No): Number of effective tillers of the rice crop was affected significantly by weed crop competition periods. The highest and lowest No. of effective tiller of rice were observed from treatments; weed free for 70 DACE (6.767 No/plant) and weedy for 70 DACE (4.1No/plant) (Table-48) .The result also revealed that; With increasing in competition period ;the No. of effective tiller of rice were decreased significantly and the No. of Effective tiller of rice were increased with decreasing in competition periods (Table-48).this is agreed with the findings of Reduced weed competition at critical crop growth stages results in increased availability of nutrients, water and light to the crops result in higher effective tillers per square meter .This agreed with the findings of (Bhurer *et al*., 2013).According to Belete *et al*. (2018), the production of more total tillers in weed-free plots may be attributed to better access to space, nutrients, water, and light, which allowed plants to produce more tillers m^{-2}, whereas the reduction in tiller number m^{-2} may be due to increased weed population and continuous competition reduced access to different resources.

Number of filled grain; Number of-filled grain of the rice was highly significantly affected by weed competition periods. The maximum and minimum No. filled grain of rice (141.7/panicle & 93/panicle) were recorded in Weed free and weedy treatment (Checks) respectively (Table-49). The second the highest and the lowest rice No. filled grain were observed from weed free checks

(132.4/panicle) and weedy for 70DACE treatments (94.3/panicle) respectively (Table-1). The result also revealed that; with increasing in competition period; the Number of filled grain of rice were decreased significantly and the Number of filled grain of rice were increased with decreasing in competition periods (Table-48).

Number of un-filled grain; Number of un-filled grain of the rice was highly significantly affected by weed competition periods. The maximum and minimum number of un-filled grains of rice (31/panicle&5.5/panicle) was recorded in Weed free for 10 DACE and weedy for 70DACE treatment s respectively (Table-48). The second the highest and the lowest rice of un-filled grain number were observed from weedy checks (24.19/panicle) and weedy for 30DACE treatments (5.8/panicle) respectively (Table-48). This result also shown that; with increasing weed competition periods; Number of un-filled grain of rice also increased.

Thousand seed weight (gm); Thousand seed weight of the rice was shown non-significant differences by weed competition periods. The result had shown that all the weights of thousand seed weights of the rice treatment statistically similar across the treatments. But there is numerical differences; so the highest (28.9gm) and the lowest (24.9gm) thousand seed weight were recorded from Weedy for 10 DACE and Weedy until crop harvest (Check) competition period treatments respectively (Table 48).The reason might be due to the weed control measures that shifted weed-crop competition in favor of rice crop thereby producing heavier grains and vice versa. Umm et al (2012) also performed an experiment that supported this result.

Yield loss (%);The losses that were shown due to each of the different weed competition periods were considered relative to the yield of weed-free checks compared with each treatment seed yield per hectare losses ranged from (11.99% to 91.93%) in increased duration of weedy periods while (0.00 - 64.7%) increased duration of weed-free periods (Table 48).Thus, the losses come through the results of weed-crop competitions regarding the nearby resources utilization during the growing period. The prolonged crop-weed competition resulted in reduced dry biomass accumulation which ultimately rendered the yields of parameters considered and higher yield losses for them. The result also indicated that the highest (91.93%) and the lowest (4.74%) yield loss were recorded from Weedy check and Weed free for 70 DACE competition period treatment respectively (Table 48).And as the competition period increases; the yield loss of the crop/rice yield loss/ would be decreased and as the competition period decreases the yield loss of the crop would be increased.

Relative Yield (%); The highest relative yield was obtained from weed free check (100%) and followed by weed free for 70 DACE (95.26%). The lowest relative yield was obtained from weedy check treatment (8.07%) and weedy for 70DACE ranks second lowest relative yield (33.98%).From this result it is possible to conclude that ;the relative yield increases with the weed free period increasing and decreases as the weed interference period increasing (table 1)

Table 48. Rice growth and yield components as affected by weed competition period treatments at Bako

Treatments (DACE)	Number of Effective Tiller(No)	Number of filled grain(No)	Number of un-filled grain(No)	Plant height (cm)	Pancle Length (cm)	Thousand kernel weight(gm)	Yield(kg/ha)	Yield loss(%)	relative yield(%)
Weed free for 10 DACE	4.6ab	107.8abcde	31e	112.8cdef	21abc	26.23ab	1466bc	64.70	35.30
Weed free for 20 DACE	4.6ab	112.4abcdef	8.8ab	114.9defg	19.8ab	27.97bc	2367ef	43.01	56.99
Weed free for 30 DACE	5.833abcd	125.9cdefg	11.6abc	121fg	21.47bc	27.73bc	3009g	27.55	72.45
Weed free for 40 DACE	5.9bcd	128efg	18.4cd	119.2efg	20.6abc	27.6bc	3762h	9.41	90.59
Weed free for 50 DACE	5.8abcd	123.8cdefg	11.2abc	118defg	21.27bc	28.77c	3779h	9.01	90.99
Weed free for 60 DACE	5.9bcd	140.6g	9.5ab	118.6defg	21.53bc	28.43bc	3884hi	6.48	93.52
Weed free for 70 DACE	6.767d	140.9g	5.5a	117.6defg	21.5bc	28.23bc	3956hi	4.74	95.26
Weed free until crop harvest(Check)	6.4cd	141.7g	6.07a	124g	22.6c	28.43bc	4153i	0.0	100
Weedy for 10 DACE	6.7d	132.4fg	10.07ab	116.4defg	21.83bc	28.9c	3655h	11.99	88.01
Weedy for 20 DACE	5.3abcd	127.9defg	15bc	110.8cde	19.83ab	26.97abc	3115g	24.99	75.01

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$ and Means within columns with the same alphabets are not significantly different at $P < 0.05$

Weedy for 30 DACE	5.267abcd	108.4abcde	5.8a	103.9abc	20.33abc	28.57c	2576f	37.97	62.03
Weedy for 40 DACE	4.933abc	107.6abcd	6.7a	109.1bcd	20.6abc	28.8c	2035de	51.00	49.00
Weedy for 50 DACE	4.567ab	106.8abc	10.4abc	99.5ab	20.6abc	27.4bc	1769cd	57.40	42.60
Weedy for 60 DACE	4.267ab	104.6bc	12.4abc	104.6abc	20.67abc	27.67bc	1578bc	62.00	38.00
Weedy for 70 DACE	4.1a	94.3ab	10.87abc	96.4a	19.8ab	26.13ab	1411b	66,02	33.98
Weedy until crop harvest(Check)	4.133a	93a	24.19de	95.6a	18.77a	24.88a	335a	91.93	8.07
P.Pr	0.023	<.001	<.001	<.001	0.021	0.054	<.001		
mean	5.35	119.1	12.34	111.39	20.76	27.67	2670		
l.s.d	1.748	20.33	8.142	9.82	2.347	2.318	351.2		
cv%	19.6	10.2	39.6	5.3	6.8	5	7.9		

Effect of different weed competition periods on yield and yield components of Rice at Chewaka

The growth measurements of rice such as plant height, No. Of effective tillers, panicle length, Number of filled grain & Number of un-filled grain in the experiment indicated the significant impact of weed interference on the growth properties of rice plants (Table 49). It was found that the growth measurements of rice in the weed-free periods were higher than those in the weed-infested periods except Number of un-filled grain which is lower in the weed-free periods than those in the weed-infested periods. In the weedy plot, some growth criteria were significantly ($P < 0.05$) increased from the weed infestation to the weed-free period.

Grain yield (kg ha-1): The grain yield of Rice was affected significantly by different weed competition periods. The maximum and minimum grain yield of rice (4135 kg ha^{-1} & 665kg /ha^{-1}) was recorded in Weed free and weedy treatment (Checks) respectively (Table-49). And the second maximum and minimum grain yield of rice were recorded in Weed free for 70DACE (4003kg/ha^{-1}) and weedy for 70 DACE treatment (1326kg/ha^{-1}) respectively (Table-2).The higher seed yield in weed free plots has also been reported by Sarandon et al. (2002), Ciuberkis *et al*. (2004) and Mubeen *et al*. (2009).The minimum yield in weedy check can be attributed to maximum weed density and minimum number of crop plants, No of effective tillers, panicle length, grain filled and 1000 seed weight. The result also revealed that; With increasing in competition period; the grain yield of rice were decreased significantly and the grain yields of rice were increased with decreasing in competition periods (Table-49). Similarly, Ahmad and Shaikh and Welsh *et al*. found that wheat yield decreased as the weed-infested duration increased.

Plant height of the crop (cm): Rice crop Plant height was highly significantly affected by weed competition periods. The maximum and minimum plant height (130.8cm & 100.2cm) were documented in weed free for 70 DACE and in weedy for 70DACE treatments respectively (Table-2). The second the highest and the lowest rice plant height were observed from weed free checks (127.7cm) and weedy check treatments (101cm) respectively (Table-49). Greater plant height of rice crop in weed free treatment might have been due to more availability of resources in the absence of weeds. The minimum plant height in weedy check can be attributed to greater competition and suppressive effect of weeds. The results are similar with those of Hussain *et al*. (2009) who reported lower plant height in black seed with increased competition periods. This result may give a conclusion that; the rice crop has low ability to compete with weed for long season. With increasing in competition period; the height of rice were decreased significantly and the height of rice were increased with decreasing in competition periods (Table-49).Similar findings have been reported for rice plants, where their height is significantly reduced when rice competes with weeds for 70 days or longer, and rice plant height is inversely proportional to weed competition length (Micheal *et al*., 2013).

Panicle Length (cm): The Panicle Length of rice crop was shown highly significant differences by weed competition periods. The highest and lowest rice panicle length (23.72.8cm & 17.73cm) were documented in weed free for 10 DACE and in weedy check treatments respectively (Table-49). Earl weed management is better than late weed management for the growth of rice panicle length.

No. of Effective Tiller (No); Number of effective tiller of the rice was highly significantly affected by weed competition periods. The maximum and minimum No. effective tiller of rice (8.083c/plant & 5.05/plant) were recorded in Weed free and weedy treatment (Checks) respectively (Table-49). The second the highest and the lowest rice No effective tiller were scored from weed free for 70DACE (7.625/plant) and weedy for 70DACE treatments (5.408/plant) respectively (Table-49). The result also revealed that; with increasing in competition period; the No. of Effective Tiller of rice were decreased significantly and the No. of effective tiller of rice were increased with decreasing in competition periods (Table-49). This agreed with those findings; According to Belete *et al*. (2018), the production of more total tillers in weed-free plots may be attributed to better access to space, nutrients, water, and light, which allowed plants to produce more tillers m-2 , whereas the reduction in tiller number m^{-2} may be due to increased weed population and continuous competition reduced access to different resources & Chowdhury *et al*. (2015) reported that the low number of tillers in the weedy plot was due to increased competition between crop plants and weeds for nutrients, air space, light, and water.

Number of un-filled grain; Number of un-filled grain of the rice was significantly affected by weed competition periods. The maximum and minimum numbers of un-filled grain of rice (15.13/panicle & 7.3/panicle) were recorded in Weed free for 20 DACE and weedy for 70DACE treatments at Chewaka respectively (Table-49). The second the highest and the lowest rice Number of un-filled grain were observed from weed free for 30 DACE (14.53/panicle) and weed free check treatments (8.5/panicle) respectively (Table-49). According to this observation result; short competition period can reduce the number of un-filled grain of rice crop and long competition period can increases the number of un-filled grain of rice crop.

Number of filled grain; Number of filled grain per panicle of the rice was highly significantly affected by weed competition periods. The maximum and minimum No. filled grain of rice (133.3/panicle & 85.2/panicle) were recorded in Weed free and weedy treatment (Checks) respectively (Table-49). The second the highest and the lowest rice No. filled grain were observed from weed free for 60DACE (130.5/panicle) and weedy for 50DACE treatments (92.2/panicle) respectively (Table-49). According to this observation result; short competition period can increase the number of number of filled grain of rice crop and long competition period can reduce the number of number of filled grain of rice crop.

Thousand seed weight (gm); Thousand seed weight of the rice was shown non-significant by weed competition periods. The result was shown that all the weights of thousand seed weights of the treatment statistically similar (Table-49). Numerically; the maximum (28.8gm) and the minimum (25.2gm) thousand seed weight was recorded from Weedy for 50 DACE and three competition period treatments (Weed free for 60 DACE, Weed free until crop harvest (Check) & Weedy for 10 DACE) (Table 49).The reason might be due to the weed control measures that shifted weed-crop competition in favor of rice crop thereby producing heavier grains and vice versa. Umm et al (2012) also performed an experiment that supported this result.

Yield loss (%); The losses that were shown due to each of the different weed competition periods were considered relative to the yield of weed-free checks compared with each treatment. Seed yield per hectare losses ranged from (9.75% to 83.92%) in increased duration of weedy periods while (0.00 - 56.61%) increased duration of weed-free periods (Table 49).Thus, the losses come through the results of weed-crop competitions regarding the nearby resources utilization during the growing period. The prolonged crop-weed competition resulted in reduced dry biomass accumulation which ultimately rendered the yields of parameters considered and higher yield losses for them. The result also indicated that the highest (83.92%) and the lowest (3.19%) Yield losses were recorded from Weedy check and Weed free for 70 DACE competition period treatment respectively (Table 49). And as the competition period increases; the yield loss of the crop/rice yield loss/ would be decreased and as the competition period decreases the yield loss of the crop would be increased.

Relative Yield (%); The highest relative yield was obtained from weed free check (100%) and followed by weed free for 70 DACE (96.81%). The lowest relative yield was obtained from weedy check treatment (16.08%) and weedy for 70 DACE ranks second lowest relative yield (32.07%). From this result it is possible to conclude that; the relative yield increases with the weed free period increasing and decreases as the weed interference period increasing (Table 49).

Table 49; Rice growth and yield components as affected by treatments at Chewaka

Treatments (DACE)	Number of effective tiller/plant (No)	Number of.filled grain/panicle (No)	Number of.un-filled grain/panie (No)	Plant height (cm)	Panicle Length (cm)	Thousand kernel weight(gm)	Yield(kg/ha)	Yield loss(%)	relative yield(%)
Weed free for 10 DACE	5.55ab	100.7abc	13.53a	116.2bcd	23.72c	27.3abcde	1794bc	56.61	43.39
(Weed free for 20 DACE	6.667abc	109.7bcde	15.13a	118bcde	21.2abc	26.1cde	2776de	32.87	67.13
Weed free for 30 DACE	6.758abc	126.5efg	14.53a	126cde	22.8bc	26.1cde	3231efg	21.86	78.14
Weed free for 40 DACE	6.958abc	124efg	9.6a	121.3cde	22.1abc	27.2abcde	3728fgh	9.84	90.16
Weed free for 50 DACE	7.25abc	113.7cdef	9.5a	116.4bcd	21.47abc	25.7de	3906gh	5.54	94.46
Weed free for 60 DACE	7.542abc	130.5fg	12.15a	123.2cde	21.93abc	25.2e	3987h	3.58	96.42
Weed free for 70 DACE	7.625bc	123.8efg	7.3a	130.8e	21.9abc	26.5bcde	4003h	3.19	96.81
Weed free until crop harvest(Check)	8.083c	133.3g	8.5a	127.7de	21.97abc	25.2cde	4135h	0.0	100

Weedy for 10 DACE	7.158abc	118.8defg	9.9a	124 cde	22.4abc	25.2e	3732fgh	9.75	90.25
Weedy for 20 DACE	5.95abc	116.8cdefg	10.2a	107.1ab	20.13abc	26.9abcde	3090ef	25.27	74.73
Weedy for 30 DACE	5.758abc	113.8cdef	11.4a	112 abc	20.33abc	26.2cde	2294cd	44.52	55.48
Weedy for 40 DACE	5.958abc	102.9bcd	12.3a	115.7bcd	22abc	27.7abcd	1844bc	55.41	44.59
Weedy for 50 DACE	5.917abc	92.2ab	12.13a	104.8ab	19.05abc	28.8a	1712bc	58.60	41.40
Weedy for 60 DACE	5.517ab	116.2cdefg	11.2a	106.8ab	18.97abc	28.4ab	1417b	65.73	34.27
Weedy for 70 DACE	5.408ab	94.1ab	7.67a	100.2a	18.25ab	27.6abcd	1326ab	67.93	32.07
Weedy until crop harvest(Check)	5.05a	85.2a	8.9a	101 a	17.73a	28.0abc	665a	83.92	16.08
P,Pr	<.001	<.001	0.019	<.001	<.001	0.055	<.001		
mean	6.38	112.63	10.87	115.7	21	26.5	2727		
l.s.d	1.248	9.081	4.332	7.266	2.528	3.6	348.9		
cv%	11.7	4.8	23.9	3.8	7.2	4.2	7.7		

*: p < 0.05, **: p < 0.01, ***: p < 0.001 and Means within columns with the same alphabets are not significantly different at P< 0.05

Table 50; Economic analysis of weed control method in Rice crop at Bako,

Weed management Practices	economic analysis					
	Production cost(Birr/ha-1)	Yield Kg/ha-1	Crop price(Birr/ Kg)	Gross Retarn(Birr/ ha-1)	Net profit (Birr/ha-1)	B.C Ratio
Weed free for 10 DACE	1200	1466	15	21990	20790	18.33
Weed free for 20 DACE	1800	2367	15	35505	33705	19.73
Weed free for 30 DACE	2400	3009	15	45135	42735	18.81
Weed free for 40 DACE	3000	3762	15	56430	53430	18.81
Weed free for 50 DACE	3600	3779	15	56685	53085	15.75
Weed free for 60 DACE	4200	3884	15	58260	54060	13.87
Weed free for 70 DACE	4200	3956	15	59340	55140	14.13
Weed free until crop harvest(Check)	5400	4153	15	62295	56895	11.54
Weedy for 10 DACE	4800	3655	15	54825	50025	11.42
Weedy for 20 DACE	4200	3115	15	46725	42525	11.13
Weedy for 30 DACE	3600	2576	15	38640	35040	10.73
Weedy for 40 DACE	3000	2035	15	30525	27525	10.18
Weedy for 50 DACE	2400	1769	15	26535	24135	11.06
Weedy for 60 DACE	1800	1578	15	23670	21870	13.15
Weedy for 70 DACE	1200	1411	15	21165	19965	17.64
Weedy until crop harvest(Check)	0	335	15	5025	5025	#DIV /0!

Table 51; economic analysis of weed control method in Rice crop at Chawaka

Weed management Practices	economic analysis					
	Production cost(Birr/ha-1)	YieldKg/ha-1	Crop price(Birr/Kg)	Gross Retarn(Birr/ha-1)	Net profit (Birr/ha-1)	B.C Ratio
Weed free for 10 DACE	1200	1794	15	26910	25710	22.43
Weed free for 20 DACE	1800	2776	15	41640	39840	23.13
Weed free for 30 DACE	2400	3231	15	48465	46065	20.19
Weed free for 40 DACE	3000	3728	15	55920	52920	18.64
Weed free for 50 DACE	3600	3906	15	58590	54990	16.28
Weed free for 60 DACE	4200	3987	15	59805	55605	14.24
Weed free for 70 DACE	4200	4003	15	60045	55845	14.30
Weed free until crop harvest(Check)	5400	4135	15	62025	56625	11.49
Weedy for 10 DACE	4800	3732	15	55980	51180	11.66
Weedy for 20 DACE	4200	3090	15	46350	42150	11.04
Weedy for 30 DACE	3600	2294	15	34410	30810	9.56
Weedy for 40 DACE	3000	1844	15	27660	24660	9.22
Weedy for 50 DACE	2400	1712	15	25680	23280	10.70
Weedy for 60 DACE	1800	1417	15	21255	19455	11.81
Weedy for 70 DACE	1200	1326	15	19890	18690	16.58
Weedy until crop harvest(Check)	0	665	15	9975	9975	#DIV/0!

Conclusion & recommendation

The critical period for weed control (CPWC) is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses. Knowing the CPWC is useful in making decisions on the need for and timing of weed control .There was an overall sensitivity of up-land rice crops to the presence of weeds, which demonstrates the need for weed control techniques. It can be concluded from the results that for obtaining a better yield more than 90% yield of rice yield, it has to be weed-free which lies between 40 to 70 days after emergence of the crop as it is found to be the critical period of weed crop competition for up-land rice. It is therefore recommended that farmers should be adopted rice variety “Chewaka with keeping weed free for 40 to 70 days after crop emergency to increase rice production in the study area /Western Oromia/.

The study was done at two-test sites (Bako and Chawaka) representing the Western Oromia for two main cropping seasons. To verify and recommend for further, research should be repeated at different season and agro-ecology.

References

Ahmad R and Sheikh AS, 2003. Common weeds of wheat and their control. Pakistani Journal of Water Resource, 7: 73-74.

Belete, B., Dalga, D., Sorsa, Z. (2018): Effect of weed management on yield components and yield of bread wheat (Triticum aestivum L.) at Wolaita Sodo in Southern Ethiopia. – Int J Res Agri Forest 5(10): 34-43.

Ciuberkis, S., B. Stasys, R. Steponas and J. Felix (2004). Effect of Weed emergence time and intervals of weed and crop competition on potato yield. J. Weed Tech., 21(1): 213-218.

Chowdhury, I. F., Ali, M. H., Karim, M. F., Masum, S. M., Rahman, A. (2015): Weed control strategies affecting yield potential of aromatic rice. – Pak. J. Weed Sci Res 21(4): 453-466

Freckleton RP and Watkinson AR., 2001. Predicting competition coefficients for plant mixture: reciprocity, transitivity, and correlations with life-history traits. Ecological News Letter. 4: 348–357. doi: 10.1046/j.14610248.2001. 00231.x.

Hussain A., A. Nadeem, I. Ashraf and M. Awan (2009). Effect of competition periods on growth and yield of blackseed (Nigella sativa L.). Pakistan J. Weed Sci. Res., 15(1): 71-81.

Micheal, J. S. A., Juraimi, A. S., Selamat, A., Man, A., Anwar, P., Uddin, K. (2013): Critical period of weed control in aerobic rice system. – Aust J Crop Sci 7(5): 665-673.

Mubeen, K., A. Tanveer, M. A. Nadeem, N. Sarwar and M. Shahzad (2009). Critical period of weed-crop competition in fennel (Foeniculum vulgare Mill.) Pakistan J. Weed Sci. Res., 15(2-3): 171- 181.

Sarandon, M. V., G. E. Sanchez-Vallduvi, C. C. Flores and R. C. Barreyro (2002). Competence of natural weed community at different stages if linseed crop development. Crop Research Hisar, 23(2): 269-276

Welsh JP, Bulson HAJ, Stopes CE, Froud-Williams RJ, and Murdoch AJ., 1999. The critical weed-free duration grown winter wheat. Annuals Applied Biology, 134: 315-320.

Effect of Herbicides Rates and their Combination with Hand Weeding on Yield and Yield Components of Sorghum [Sorghum Bicolor (L.) Moench] at Bako and Gute

Megersa Kebede , Lamma Lalisa, Dejene Haile, and Getu Abera*
Bako Agriculture Research Center, P. O. Box: 03, Bako, Ethiopia
*Corresponding author: lammaalalisaa2021@gmail.com

Abstract
Field experiment was conducted at Bako regional agricultural research center and at its sub-site (Gute) during the main cropping season of 2020 & 2021 to evaluate the effect of weed management practices on weeds, and growth, yield and yield components of sorghum and to determine optimum rates of herbicides, and their combination hand weeding and hoeing for weed management in sorghum [Sorghum bicolor (L.) Moench] at Bako and Gute ,Western Oromia. The experiment was carried out in randomized completely block design (RCBD) with three replications; wherein there was combination of hand weeding with each herbicide rates(Zura1ltha1, Zura0.75ltha1, Zura 1ltha1+1HW40DAS, Zura0.75ltha1+1HW40DAS, 2.4-D 1Lt ha1, 2,4-D0.751ltha1, 2,4-D 1Lt ha1+1HW40DAS, 2.4-D0.751ltha1+1HW40DAS, Hand Weeding and as well as weed free and un-weeded check),all replicated thrice. ANOV results show that yield and yield a component of sorghum was significantly affected by weed management practices. The highest sorghum grain yield (2686kgha-1 & 2912 kgha-1) Bako-Gute and lowest (545kgha-1 & 196kgha-1) Bako-Gute were recorded from weed free &Weedy check respectively. Of the herbicide weed management practices Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS ranks first. The result also revealed that, both grass and broad leaved weed density, dry weed biomass, and total weed biomass were highly significantly influenced by the treatments. Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS proved to be efficient technique for the management of both types of weeds at both locations, Bako and Gute.

Keywords: herbicides, herbicides rate, Sorghum, weedy, weed free, yield, Yield Component

Introduction

Sorghum [*Sorghum bicolor* (L) Moench] is one of the most important cereal crops supporting the lives of millions of people across the globe and particularly in the developing world (Chala *et al.*, 2010). It serves as a staple crop for millions of people in Africa and Asia (Ejeta and Grenier, 2005). In Ethiopia, sorghum is one of the major staple crops grown in the poorest and most food insecure regions of Ethiopia (Fetene *et al*., 2011). The crop is typically produced under adverse conditions such as low input use and marginal lands. It is well adapted to a wide range of precipitation and temperature levels and is produced from sea level to above 2000 m.a.s.l (Fetene *et al*., 2011). Sorghum accounts for the third largest share of total cereal production. Area under sorghum cultivation expanded from 1.83 million hectare in 2014/15 to 2.01 million in 2015/16 (CSA, 2016). The national average sorghum productivity in Ethiopia is 2.0 tonnes/ha (CSA, 2013); which is far below the global average of 3.2 tonnes/ha. This low yield is due to many factors which include both biotic and abiotic one. Sorghum production and productivity is affected by different biotic constraints; among which weed is the important pest that pose pronounce losses in this crop.

Weeds compete with sorghum plants for water, nutrients, and light; their presence, even in small numbers, may result in a lower grain yield (Smith *et al*., 1990; Smith and Scott, 2010). Weeds in grain sorghum cause yield losses ranging from 30% to 50% and higher under specific, unfavorable conditions (Graham *et al*., 1988; Knezevic *et al*., 1997; Stahlman and Wicks, 2000; Silva *et al.*, 2014); they also lower crop quality and contribute to an increase in pest and disease pressure (Ngugi *et al*., 2002; Showemimo *et al*., 2011). The low competitive ability of sorghum plants occurs mostly at the early growth stages and calls for effective weed control (Wilson and Westra, 1991; Knezevic *et al*., 2002). In sorghum, the critical period of weed control was from 14 to 58 days after emergence (Silva *et al.,* 2014). Sorghum is very often infested by warm-season grass and broadleaved weeds (Peerzada *et al.,* 2017; Vencill and Banks, 1994; Knezevic *et al*., 1997). Thus, the most important consideration should be given to control both broad and grasses during emergence, seedling development and growth of the sorghum.

Weed management in sorghum is essential if high yields and efficient harvest are to be achieved; however, good weed control in sorghum is often difficult to achieve due to the slow initial growth of sorghum and scarcity of herbicides registered for use in this crop (Ferrell *et al*., 2018; Peerzada *et al.,* 2017; Silva *et al*., 2014). In addition, sorghum will not tolerate many of the herbicides that can be effectively used on corn. Therefore, it is essential to integrate the possible available and/or compatible options to achieve effective and successful weed management in this crop.Thompson *et al*. (2011) stated that, weed control in sorghum is usually achieved by using pre-emergence herbicides such as acetochlor, alachlor, propazine, prosulfuron, S-metolachlor, and saflufenacilin the United States. However, sorghum is usually grown under dry conditions, and the lack of soil moisture hindersherbicidal activities (Armel *et al*., 2003). Moreover, Douglas (2002) and Zhang *et al.* (2002) represented that integrating reduced doses of available herbicides with other management methods such as cultural and mechanical practices, including cultivation, planting pattern, selection of highly competitive cultivars and cover crops would efficiently suppress weeds.

In Western Oromia, weed is one of the major pests that pose huge yield losses to sorghum. However, only a little effort has been done to manage weeds in sorghum field in growing areas of Western Oromia. The crop is planted at wider inter-row spacing in addition to slow growing habit of the crop especially at early growth stage which exposes it to severe weed infestation. Hand weeding alone which is being practiced by most farmers is tedious, time consuming and expensive though it is effective against most weeds in sorghum field. Moreover, some farmers used2, 4-D 1lt ha^{-1} to control weeds; but, this herbicide is narrow spectrums and effective only against broad leaf weed; while the grass species still left un-controlled. Similarly, Zura herbicide is one of the recently introduced post-emergence herbicide known to control broad leaf weeds in sorghum and maize field. Besides, there is a need to evaluate and/or consider these herbicides in integrated weed management with available options. Thus, there is a call for attention to investigate and/or develop effective and environmentally safe weed management practice (s) to enhance the production and productivity of sorghum in major growing areas of Western Oromia. In view of this, the present study is initiated with the following objectives.

The objectives of this experiment were to evaluate the effect of weed management practices on weeds, and growth, yield and yield components of sorghum and determine optimum rates of herbicides, and their combination with hand weeding and hoeing for weed management in sorghum at Western Oromia.

Materials and Methods

Treatments, experimental design and procedure

A totally of 11 weed management practices were evaluated for their effectiveness' table-1 below. The 11 treatments were arranged in a randomized complete block design (RCBD) in three replications. The sorghum variety, "Gamedi" was used, and sown at inter row spacing of 75cm with the seed rate of 10 kg ha^{-1}.Accordingly, it was drilled in the row on the plot size of 4.5m x 5m = 20.25m^2 depend on the treatment, and there was 1 m and 1.5m paths between the plots and the blocks, respectively. Similarly, spacing between plants was adjusted to 30cm. The herbicides, 2, 4-D (Yilagristar-Trade name) and 2, 4-D 720 g/l A.E (Zura Herbicide-Trade name) were applied as post-emergence onto the weed plant as per the treatment at 25 days after sowing (DAS). Moreover, the herbicides were supplemented with one (1) times hand weeding and hoeing at 40 DAS depend on treatment. Two times hand weeding and hoeing treatment was done at 25 and 40 DAS, whereas weed free plots was kept clean until harvesting (i.e., weeding was applied at 10 days interval). The spray volume of water was 200 lts ha^{-1}. Except the treatments, all other recommended crop husbandry practices were also been adopted uniformly throughout the seasons.

Table 52. The details of treatment combinations

No.	Treatments
T-1	Zura 1lt ha^{-1}
T-2	Zura 0.75lt ha^{-1}
T-3	Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS
T-4	Zura 0.75 lt ha^{-1} + hand weeding and hoeing @ 40 DAS
T-5	Yilagristar 1.0 lt ha^{-1}
T-6	Yilagristar 0.75 lt ha^{-1}
T-7	Yilagristar 1.0 lt ha^{-1} + hand weeding and hoeing @ 40 DAS
T-8	Yilagristar 0.75 lt ha^{-1} + hand weeding and hoeing @ 40 DAS
T-9	Hand weeding and hoeing 25 and 40 DAS
T-10	Weed free
T-11	Weedy check

Data collected

Weed data (Parameters for Weed Control)

Weed density and weed biomass; Weed infestation was assessed and scored in number and species (weed density) by throwing quadrant of 50 cm x 50 cm area two times per plot at 25, 75 DAS and at harvesting using method described by (Cruz *et al*., 1986). The counted weeds were categorized as broad leaved, grass and sedge. The dry weight of weeds samples (weed biomass) were recorded after air drying for 4-5 days and oven drying at 65° C for 48 hours. The dry weight of each group of weed was taken by an electrical balance and expressed in $g/m^{-2.}$

Weed Control Efficiency (WCE): worked out taking into consideration the reduction in weed population in treated plot over weed population in unweeded check. It is expressed in %.

WCE = WPC − WPT/WPC X 100 Where, WPC = Weed population in control (unweeded) plot. WPT = Weed population in treated plot.

Weed Index (WI): Weed index is the measure of the efficiency of a particular treatment when compared with a weed free treatment. It is expressed as percentage of yield potential under weed free. More conveniently weed index is the per cent yield loss caused due to weeds as compared to unweeded (weedy check). Higher weed index mean greater loss. It is worked out by subtracting the yield of treated plot from yield of weed free plot and divided by yield of weed free plot multiply by 100. It is expressed in %. WI = YWF − YT /YWF X 100

Where, YWF= Yield from weed free plot. YT= Yield from treated plot.

Herbicide Efficiency Index (HEI): This index indicates the potential of herbicides for killing weeds and their phytotoxicity on the crop and was computed using the following formula: as described by Chandrasekaran. B.K. Annadurain and E. Somasundaram, 2010 and Krishnamurthy et al., 1975)

HEI = ($\underline{Yt – Yc}$) × 100 $\underline{Yt/}$WDMt ×100 /WDMc

Where, HEI - Herbicide efficiency index, Yt- crop yield from treated plot Yc- crop yield from weedy check plot WDMt-weed dry matter in treated plot WDMc-weed dry matter in weedy check plot

Weed Control Index (WCI): worked out taking into consideration the reduction in weed dry weight in treated plot over weed dry weight in unweeded check (control). It is expressed in %.

WCI = WC − WT/ WC X 100 Where, WC = Weed dry weight in control (unweeded) plot. WT= Weed dry weight in treated plot

Percentage of weed inhibition (PWI); was calculated by the formula of:

(PWI) = (NWC-NWT/NWC)*100

Where, NWC & NWT are number of weeds (m^{-2}) in weedy check and any particular treatment, respectively.

Sorghum data

Data on agronomic traits such plant height (cm), head diameter/width (cm), head length (cm), head length (cm), thousand seed weight (gm), biomass and yield data were recorded.

Yield Loss (%); The following informations were needed:

• Weedy yield: average yield from the non-treated weedy plot (yield using best management practices but no weed control), and

• Weed-free yield: average yield from a herbicide control plot with > 95% control for each

weed species (yield with best management practices and excellent weed control)

• Yield loss (%) was determined for each individual treatment.

YL% = (weed-free yield–weedy yield)/ weed-free yield* 100

Partial budget analysis

The partial budget analysis was done as described by CIMMYT (1988) to determine the economic feasibility of the weed control methods. It was calculated by taking into account the additional input costs (variable costs) involved and the gross returns obtained from different weed control treatments. The variable cost was also include the herbicide cost, labor cost involved for herbicide spraying, weeding and hoeing, harvesting, threshing and winnowing as their cost may varied according to the treatment. Actual yield was adjusted downwards to 10% of experimental yield to represents the farmer`s yield. Similarly, for determining gross returns the prevailing local market price (Birr/kg) at the harvest of sorghum was considered. The net return was calculated by subtracting the cost of treatment from the gross returns as RNR = GR-VC, where, RNR = Relative net returns, GR = Gross returns, and VC = Variable cost.

Statistical Analysis

Analyses of variances for the data recorded were conducted using the SAS version 9.3 software. Significance test and means were separated using Least Significance Difference (LSD) at $p < 0.05$. Weed data was transformed for variance before analysis, using the square-root transformation formula $\sqrt{(x+0.5)}$.Yield of the crop was adjusted to 10% before economic analysis.

Results ad Discusion

Effect of herbicides rates and their combination with hand weeding on growth and yield of Sorghum at Bako

Grain yield(kg/ha^{-1}); The results was indicated that weed management practices highly significantly increased the yield over weedy check (unweeded control).So, the grain yield of sorghum was highly significantly influenced by the weed management practices. The highest sorghum grain yield were recorded from weed free and followed by Hand weeding and hoeing @25 and 40 DAS weed management practices treatments (2686 kg ha^{-1}and 2560kg ha^{-1}) respectively (Table 53). The lowest grain yield was recorded from Weedy check (545kg ha^{-1}) (Table 2). Grain yield of sorghum was highest under weed free conditions that reduced by 79.71 % due to uncontrolled weed growth. The raise in sorghum grain yield with in weed free treatment could be due to absence of weeds, weed growth, weed dry biomass accumulation and efficient utilization of resources in weed free that favored increased in yield attributes such as head length, head width and thousand grain weight. This is in conformity with the findings of Kausik and Shaktawat (2005) and Satheeshkumar *et al*. (2011), Dawit *et al*, (2014). The rate of the herbicide hadn't shown significant difference to each other on yield but the supplement/s of hand weeding with herbicide rate had high significance differences on the yield of sorghum to sole herbicides rate (Table 53). Yield reduction increased as the herbicide rate decreased and viceversa.

Plant height (cm); The plant height significantly influenced by the weed management practices with herbicides rates and their combination with hand weeding .The tallest sorghum height was recorded from Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS treatment (274cm) and shortest 2, 4-D 0.75 lt ha^{-1} treatment (239.8cm) (Table 53). The herbicide rate and combination with hand weeding have an advantage than using sole herbicide.

Head Length (cm): The head length was significantly influenced by herbicides rates and their combination with hand weeding. Application of Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS was shows tall sorghum head length (28.52cm). And Application of 2, 4-D 0.75 lt ha^{-1} was shows shortest sorghum head length (24.87cm). The herbicide rate combinations with hand weeding have an advantage than using sole herbicide.

Head Width (cm): The head width of sorghum was highly significantly affected by weed management practices. The maximum and minimum head width of sorghum (8.733cm&5.8a) were recorded in Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS and weedy treatment (Checks) respectively(Table-53). The result was also indicated that; it is better using herbicide with hand weeding combination/s rather than using single herbicide rate.

Thousand seed weight (gm); Thousand seed weight of the sorghum was shown highly significant differences by weed management practices. The result was shown that all the weights of thousand seed weights of the treatment statistically similar differences (Table-53). Off these weed management practices, Hand weeding and hoeing @25 and 40 DAS was resulted highest thousand seed weight (22.37gm) (Table 53). This is because due to absence of accumulation of dry matter in weeds, dry weed biomass and the crop efficient use of resources/nutrients .The minimum thousand grain weight was recorded from Weedy check (17.25gm) (Table 53). The minimum thousand grain weight could be due to Severe competition among plants in the weedy plots that caused reduction of assimilates synthesis .Similarly, Tomar *et al*., (2003), Kawa *et al*., (2016) reported that the weed free crop stand produced robust grains and ultimately resulted in more thousand grain weight. As the rate of herbicide combination increased; thousand grains weight also increased with it but, the combination of herbicide rate with hand weeding had better thousand grain weight than using a single herbicide rates.

Table 53: sorghum yield and yield components as influenced by treatments at Bako

Treatments /weed management practices	Plant Height (cm)	Head Length (cm)	Head Width (cm)	1000seed weight (gm)	Yield (kg/ha-1)
Zura 1lt ha-1	265.2cde	26.67abcd	7.217bcd	19.95b	1477b
Weed free	268.4de	26.1abc	8.6e	20.73bc	2686f
Weedy check	252.2abc	25.97abc	5.8a	17.25a	545a
Zura 0.75lt ha-1	246.7ab	28.1cd	8.017de	20.73bc	1467b
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	274e	28.52d	8.733e	21.85bc	2479de
Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	266.6cde	28.13cd	7.683de	19.87b	2361cd
2, 4-D 1.0 lt ha-1	263.2cde	25.4ab	6.133ab	21.22bc	1477b
2, 4-D 0.75 lt ha-1	239.8a	24.87a	6.483abc	21.3bc	1345b
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	261.2bcde	27.87cd	7.35cd	21.5bc	2267c
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	266.1cde	27.68cd	7.3cd	22.05c	2269c
Handweeding and hoeing @25 and 40 DAS	255.5abcd	27.3bcd	7.3cd	22.37c	2560ef
F.Pro	0.007	0.027	<.001	<.001	<.001
mean	259.9	27	7.3	20.7	1903
l.s.d	15.88	2.2	1.13	1.78	136.3
cv%	3.6	4.8	9	5	4.2

*: p < 0.05, **: p < 0.01, ***: p < 0.001 and Means within columns with the same alphabets are not significantly different at P< 0.05

Effect of herbicides rates and their combination with hand weeding ongrowthand yieldof Sorghum at Gute

Grain yield (kg/ha^{-1}); The results indicated that different weed control measures highly significantly increased the yield over weedy check (unweeded control). So, the grain yield of sorghum was highly significantly influenced by the weed management practices. The highest sorghum grain yield was recorded from weed free followed by Hand weeding and hoeing @25 and 40 DAS weed management practices treatments (2912 kg $ha^{-1}$and 2766kg ha^{-1}) respectively (Table 54). Grain yield of sorghum was highest under weed free conditions that reduced by 93.27 % due to uncontrolled weed growth. The raise in sorghum grain yield with in weed free treatment could be due to absence of weeds, weed growth ,weed dry biomass accumulation and efficient utilization of resources in weed free that favored increased in yield attributes such as head length, head width and thousand grain weight. This is in conformity with the findings of Kausik and Shaktawat (2005) and Satheeshkumar *et al*. (2011), Dawit *et al*., (2014). The lowest grain yield were recorded from Weedy check (196kg ha^{-1}) (Table 54).The minimum sorghum grain yield was due to basically weed infestation, accumulation of high dry matter in weeds,nutrient removal by weeds and occurrence of different weed species in weedy plots.Pandey *et al*. (2001), Singh *et al*. (2007) and Satheeshkumar *et al*. (2011) reported similar findings. There was about 2716 kg ha^{-1}yield difference with in weedy check and weed free plots of weed management practices. Similarly, Massinga *et al*, (2003), Canner *et al*., (2002) reported that yield reduction can vary greatly as a result of weed species .The rate of the herbicide hadn't shown significant difference to each other on yield but the supplement/s of hand weeding with herbicide rate had high significance differences on the yield of sorghum to sole herbicides (Table 54).

Plant height (cm); The plant height significantly influenced by the weed management practices with herbicides rates and their combination with hand weeding (Table 3).The tallest sorghum height was recorded from Weed free treatment (257.2cm) and shortest 2, 4-D 1.0 lt ha^{-1} treatment (223.9cm followed by 2, 4-D 0.75 lt ha-1 (227.3cm)) (Table 54). The herbicide rate and combination with hand weeding have an advantage over using sole herbicide rate.

Head Length (cm); The Head Length significantly influenced by herbicides rates and their combination with hand weeding. Weed free treatment was shows tall sorghum head length(25.03cm)followed by Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS() 24.75cm) and application of 2, 4-D 0.75 lt ha^{-1} was shows shortest sorghum head length (21.67cm). The herbicide rate combinations with hand weeding have an advantage than using sole herbicide (Table 54).

Head Width (cm); The head width of sorghum was highly significantly affected by weed management practices. The maximum head width of sorghum were recorded in Zura lt ha^{-1} + hand weeding and hoeing @ 40 DAS (7.467cm) followed by Hand weeding and hoeing @25 and 40 DAS (7.367cm) and minimum head width of sorghum (5.633cm) from Weedy check (Table-54). The herbicide rate combination with hand weeding have an advantage than using sole herbicide rate.

Thousand seed weight (gm); Thousand seed weight of the sorghum was shown highly significant differences by weed management practices. The result was shown that all the weights of thousand seed weights of the treatment statistically similar differences (Table-54). Maximum thousand grain weight was recorded at weed free treated plots (24.58gm). This because due to absence of accumulation of dry matter in weeds, dry weed biomass and the crop efficient use of resources/nutrients .The minimum thousand grain weight was recorded at the weedy plots (19.43gm). The minimum thousand grain weight could be due to Severe competition among plants in the weedy plots that caused reduction of assimilates synthesis. Similarly, Tomar *et al*., (2003), Kawa *et al*., (2016) reported that the weed free crop stand produced robust grains and ultimately resulted in more thousand grain weight. As the rate of herbicide combination increased; thousand grains weight also increased with it but, the combination of herbicide rate with hand weeding had better thousand grain weight than using a single herbicide rates.

Table 54: sorghum yield and yield components as influenced by treatments at Gute

Treatments /weed management practices	Plant Height (cm)	Head Length (cm)	Head Width (cm)	1000 seed weight (gm)	Yield (kg/ha-1)
Zura 1lt ha-1	228.2a	23.33abcde	6.5bcde	22.83b	1724c
Weed free	257.2b	25.03e	6.8def	24.58c	2912g
Weedy check	237.7a	21.8ab	5.633a	19.43a	196a
Zura 0.75lt ha-1	227.1a	22.37abc	5.767ab	22.03b	1418b
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	234.6a	24.75e	7.467f	23.1bc	2629ef
Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	231.9a	24.2de	6.53cde	22.7b	2415d
2, 4-D 1.0 lt ha-1	223.9a	22.53abcd	6.13abcd	22.03b	1455b
2, 4-D 0.75 lt ha-1	227.3a	21.67a	5.93abc	21.93b	1386b
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	238.8a	23.9cde	6.8def	23.43bc	2496de
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	237.7a	23.6cde	7.03ef	21.7b	2467d
Handweeding and hoeing @25 and 40 DAS	238.1a	23.53bcde	7.36f	22.4b	2766fg
F.Pro	0.012	0.007	<.001	<.001	<.001
mean	234.8	23.34	6.5	22.47	1987.7
l.s.d	14.91	1.763	0.74	1.753	160.54
cv%	3.7	4.4	6.7	4.6	4.7

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$ and Means within columns with the same alphabets are not significantly different at $P < 0.05$

Effect of herbicides rates and their combination with hand weeding on weed control efficiency (%),weed density, weed biomass, and total weed biomass at Bako

Weed Density (No/m2); The effects of weed management practices on weed density (both broad & grass leaf weeds) were highly significant (Table 4). All the herbicide treatments significantly reduced the weed density compared to the weedy control. Among the weed management practices the maximum and minimum broad leaf weed density were recorded in Weedy check & Weed free check (26.667 (5.21m2) & 0 (0.707m2) respectively (Table 4). But the maximum and minimum grass leaf weed density were recorded in 2, 4-D 0.75 lt ha^{-1} which numerically almost equal with 2, 4-D 1.0 lt ha-1 and Weed free (19.5 (4.468m2)) & 0 (0.707m2) weed management practices respectively (Table 4). Herein 2, 4-D herbicide was less effective than Zura herbicide to control grass leaf weeds and Zura herbicide was less effective than 2, 4-D to control broad leaf weeds (Table 55). Again the maximum and minimum total weed density were recorded from Weedy check and Weed free (41.67 (9.142m2) & 0 (0.707m2) weed management practices respectively (Table 4). These findings are in accordance with result of (Munsif1, *et al*., 2012) who stated that weed population is lower in herbicides treated plot than control plot and Ashiq, *et al*. 2007. The results also revealed that; as a herbicides' rate increases the effectiveness of the herbicide also increase (Table 4).The results are in line with those of (Tunio *et al*., 2004) and (Khan, *et al*., 2002). All the herbicides caused significant reduction in total weed density as compared to weedy control at all weed management practices while none of the treatment could reach to the level of weed free conditions. This may be because of effective control of weeds by different weed management practices. These results corroborate the findings of Rao *et al*., (2007) and Changseluk (2003). This reduction was also may be due to their phytotoxic effect on grassy and broad leaf weeds. Similar results have been obtained by Singh (2002) and similar finding's has also been reported by Banga *et al*., (2003).

Weed Biomass (gm/m2); The effects of weed management practices on Weed Biomass (both broad & grass leaf weeds) were highly significant. All the herbicide treatments significantly reduced the weed dry weight compared to the weedy control. The maximum and minimum broad leaf Weed biomass were recorded in weedy check & weed free (273.5gm/m^2 (16.549gm/m^2)) & 0 (0.707m^2) respectively. But the maximum and minimum grass leaf weed biomasses were recorded in Zura 0.75lt ha^{-1} and Weed free (106.38h (10.338gm/m^2) & 0 (0.707gm/m^2) weed management practices respectively. Again the maximum and minimum total weed biomass were recorded from weedy check and weed free (329.13(24.041)gm/m^2)) & (0(0.707))gm/m^2) weed management practices respectively. The highest total weed biomass was recorded from uncontrolled treatment /weedy check/, it was mainly due to higher and uninterrupted growth of weeds viz., and grasses and broad leaved which made best use of the growth resources. These results were also in agreement with the work of (Iqbal., 2003), who verified that weed free check and mixed broad spectrum herbicide that reduced the weed dry weight as compared to narrow spectrum herbicide and weedy check. The results also revealed that; as a herbicides' rate increases the effectiveness of the herbicide also increase (Table 55). All the herbicides caused significant reduction in total weed dry weight as compared to weedy control at all the weed management practices while none of the treatment could reach to the level of weed fee conditions. This may be because of effective control of weeds by different weed management practices. These results corroborate the findings of Rao *et al*. (2007) and Changseluk (2003). This reduction was also may be due to their phytotoxic effect on grassy and broad leaf weeds. Similar results was reported by Singh (2002) and Banga *et al*., (2003).

Effects of weed control treatments on various agronomic indices in sorghum crop at Bako

The values of weed indices like weed control efficiency (WCE), weed control index (WCI), herbicide efficiency index (HEI), weed index (WI) and weed persistency index(WPI) were inferior in plots receiving no any weed control throughout the growing season (Table 56).

Weed Control Efficiency (%); The highest weed control efficiency (92.23%) was recorded at weed free condition and the lowest at un-weeded check condition (0.00%) (Table 56). Off herbicide weed management practices, Zura lt ha-1 + hand weeding and hoeing @ 40 DAS weed management ranks first (45.08%) to weed free condition (Table 5). Herein as the rate of Zura and 2, 4-D herbicide increases their weed control efficiency also increase. The higher weed control efficiency with these treatments could be attributed to the lower weed population as well as dry matter accumulation of weeds in these treatments/ i.e; weed free condition and Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS weed management practices/ .This result revealed that the herbicides rate, their combinations and hand weeding had better weed control efficiency than that of weedy check plots

Weed Persistence Index (PWI); The highest and the lowest weed Persistence Index was scored from Weedy check (1%) and Zura 0.75lt ha-1 (0.24%) weed management practices respectively (Table 56). The results also revealed that; as herbicides' rate increases the weed Persistence Index also increased.

Herbicide Efficiency Index (HEI) (%); It is weed killing potential of herbicides treatments and their phytotoxicity on the crop. The highest Herbicide efficiency index was recorded from Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS (1.42%) and followed by 2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS (1.37%) whereas; the lowest was recorded in 2, 4-D 0.75 lt ha-1 (0.72%) (Table 56). From this result it is possible to conclude that the herbicide had high efficiency index when using herbicide combination with hand weeding than that of using sole herbicide.

Weed Index(%); It is the per cent yield loss caused due to weeds as compared to unweeded (weedy check). Higher weed index mean greater loss. The highest Weed Index was recorded from weedy check (79.71%) and followed by 2, 4-D 1.0 lt ha-1 (49.93%) whereas; the lowest was recorded in weed free check (0.00%) followed by Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS (7.71%). The result indicated that there was lowest yield losses when using Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS next to weed free condition (Table 56).

Weed Control Index (%); It indicates the per cent reduction in the dry weight in treated plots compared to weedy plots. There was high Weed Control Index in weed free condition (97.05%) and low in weedy check (0.00%) weed management practices (Table 56).

Table 55: Weed biomass and Weed density as influenced by weed management practices at Bako

	Weed Biomass(gm)			Weed Density/m2		
Treatments /Weed management practices	Braod leaf	Grass Leaf	Total	Braod leaf	Grass Leaf	Total
Zura 1lt ha-1	6.17(2.58)b	49.22(7.05)e	55.38(9.63)f	4.333(2.19)bc	13.17(3.70)e	17.5(5.89)d
Weed free	0(0.71)a	0(0,71)a	0(0,71)a	0(0.71)a	0(0.71)a	0(0,71)a
Weedy check	273.5(16.55)g	55.63(7.49)e	329.13(24.04)h	26.67(5.21)g	15(3.93)e)	41.67(9.14)g
Zura 0.75lt ha-1	5.48(2.44)b	106.38(10.34)g	111.87(12.78)g	5.5(2.45)c	15(3.93)e	20.5(6.38)e
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	19.12(4.31)de	25.33(5.08)d	44.45(9.39)ef	9(3.08)d	3.25(1.94)c	12.25(5.02)c
Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	36.25(6.06)f	5.75(2.45)b	42(8.52)de	16.17(4.08)f	5.83(2.52)d	22(6.60)e
2, 4-D 1.0 lt ha-1	24.52(4.99)e	74.58(8.66)f	99.1(13.66)g	3.5(1.99)b	18.75(4.38)f	22.25(6.37)e
2, 4-D 0.75 lt ha-1	8.62(3.01)bc	17(4.18)c	25.62(7.19)c	8.75(3.04)d	19.5(4.47)f	28.25(7.51)f
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	35.17(5.94)f	3(1.87)b	38.17(7.80)cd	11.58(3.47)e	2(1.58)b	13.58(5.05)c
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	11.85(3.51)cd	4.33(2.17)b	16.18(5.68)b	9.33(3.14)d	4.5(2.34)b	13.83(5.48)b
Handweeding and hoeing @25 and 40 DAS	23.47(4.89)e	19.25(4.40)c	42.72(9.29)ef	10.2(3.24)de	2.08(1.60)b	12.8(4.84)bc
F.Pro	<.001	<.001	<.001	<.001	<.001	<.001
mean	40.4(5)	32.77(4.94)	73.1(9.94)	9.53(2.96)	8.73(2.74)	18.27(5.7)
l.s.d	11.33(0.88)	5.40(0.63)	12.74(1.06)	1.78(0.28)	2.01(0.29)	1.91(0.32)
cv%	16.5(10.4)	9.7(7.5)	10.2(6.3)	11(5.5)	13.5(6.4)	6.1(3.3)

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$ and Means within columns with the same alphabets are not significantly different at $P< 0.05$

Table 56 : Effect of different weed control treatment on Weed Control Index (WCI), Weed Control Efficiency (WCE), Weed Persistence Index (WPI), weed index(WI) and herbicide efficiency index (HEI) in Sorghum crop (Average of two years) at Bako

Treatment/Weed management practices	WCE(%)	WCI(%)	WI(%)	HEI(%)	WPI(%)
Zura 1lt ha-1	35.56	59.94	45.01	0.98	0.62
Weed free	92.23	97.05	0.00	-	0.39
Weedy check	0.00	0.00	79.71	-	1
Zura 0.75lt ha-1	30.2	46.84	45.38	0.90	0.24
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	45.08	60.94	7.71	1.42	0.29
Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	27.79	64.56	12.10	1.07	0.48
2, 4-D 1.0 lt ha-1	30.31	43.18	45.01	0.91	0.82
2, 4-D 0.75 lt ha-1	17.83	70.09	49.93	0.72	0.37
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	44.75	67.55	15.60	1.37	0.58
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	40.04	76.37	15.52	1.27	0.40
Handweeding and hoeing @25 and 40 DAS	47.05	61.36	4.69	-	0.74

WCE= weed control efficiency, WCI = weed control index, WI = weed index, HEI = herbicide efficiency index, , WPI = weed persistence index,

Effect of herbicides rates and their combination with hand weeding on weed control efficiency (%), weed density, weed biomass, and total weed biomass at Gute

Weed Density (No/m^2); The effects of weed management practices on weed density (both broad &grass leaf weeds) were highly significant (Table 57). All the herbicide treatments significantly reduced the weed density compared to the weedy control. Among the weed management practices the maximum and minimum broad leaf weed density were recorded in Weed free and Weedy check (34.17 (5.886m^2) & 0 (0.707m^2) condition respectively (Table 57). Comparatively 2, 4 D herbicide had high advantage than Zura herbicide in controlling broad leaf weed next to weed free condition .The maximum and minimum grass leaf weed density were recorded in Zura 0.75lt ha-1and Weedy (20.83m^2 (4.617m^2) & 0 (0.707m^2) weed management practices respectively (Table 6). Again the maximum and minimum total weed density were recorded from Weedy check and Weed free (47.83m^2 (9.646m^2) & 0 (1.414m^2) weed management practices respectively (Table 6). These findings are in accordance with result of (Fazal *et al*., 2012) who stated that weed population is lower in herbicides treated plot than control plot (Ashiq *et al*., 2007). The results also revealed that ;as a herbicides' rate increases the effectiveness of the herbicide also increase; even with the combination of hand weeding (Table 57); i.e in this research; as the herbicide rate increases weed density would be decreased. The results are in line with those of (Tunio *et al*., 2004) and (Khan *et al*., 2002). All the herbicides caused significant reduction in total weed density as compared to weedy control at all weed management practices while none of the treatment could reach to the level of weed free conditions .This may be because of effective control of weeds by different weed management practices. These results corroborate the findings of Rao *et al*. (2007) and Changseluk (2003).This reduction was also may be due to their phytotoxic effect on grassy and broad leaf weeds. Similar results have been obtained by Singh (2002) and similar findings has also been reported by Banga *et al*., (2003). Moreover, herbicides combinations showed better weed reduction in comparison with single type of herbicides.

Weed Biomass (gm/m^2): The effects of weed management practices on Weed Biomass (both broad & grass leaf weeds) were highly significant. All the herbicide treatments significantly reduced the weed dry weight compared to the weedy control. The maximum and minimum broad leaf Weed Biomass were recorded in Weedy check &Weed free (846.3 (29.073gm / m^2 & 0 (0.707m^2) conditions respectively. But the the maximum and minimum grass leaf Weed Biomass were recorded in Zura 0.75lt ha-1 and Weedy (53.78 (7.284) gm/m^2) & 0 (0.707gm/m^2) weed management practices respectively. Again the maximum and minimum total Weed Biomass were recorded from Weedy check and Weed free (876.3 (34.58gm/m^2)) & 0 (0,707gm/m^2) weed management practices respectively. The highest total weed biomass was recorded from uncontrolled treatment, it was mainly due to higher and uninterrupted growth of weeds viz., and grasses and broad leaved which made best use of the growth resources. These results were also in agreement with the work of (Iqbal., 2003), who verified that weed free check and mixed broad spectrum herbicide that reduced the weed dry weight as compared to narrow spectrum herbicide and weedy check. All the herbicides caused significant reduction in total weed dry weight as compared to weedy control at all the weed management practices while none of the treatment could reach to the level of weed fee conditions. This may be because of effective control of weeds by different weed management practices. These results corroborate the findings of Rao *et al*. (2007) and Changseluk (2003). This reduction was also may be due to their phytotoxic effect on grassy and broad leaf weeds. Similar results have been obtained by Singh (2002) and similar finding has also been reported by Banga *et al*., (2003).

Effects of weed control treatments on various agronomic indices in sorghum crop at Gute

The values of weed indices like weed control efficiency (WCE), weed control index (WCI), herbicide efficiency index (HEI), weed index (WI) and weed persistency index (WPI) were inferior in plots receiving no any weed control throughout the growing season (Table 7).

Weed Control Efficiency (%); The highest weed control efficiency was recorded at weed free condition (92.64%). Of the herbicide treatments Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS ranks first by scoring (30.26%) weed control efficiency. The lowest weed control efficiency was recorded at unweeded check condition (0.00%) and followed by 2, 4-D 1.0 lt ha^{-1} + hand weeding and hoeing @ 40 DAS (12.64%) (Table 7). The higher weed control efficiency with these treatments could be attributed to the lower weed population as well as dry matter accumulation of weeds in these treatments/ i.e ;weed free condition and Zura 1 lt ha^{-1} + hand weeding and hoeing @ 40 DAS weed management practices/ .This result revealed that the herbicides rate, their combinations and hand weeding had better weed control efficiency than that of weedy check plots.

Weed persistence Index (WPI); The highest and the lowest Percentage of weed inhibition were scored from Weedy check (1%) and weed free (0.27%) weed management practices respectively.

The result also revealed that; as the rate of theZura herbicide increased the Weed persistence Index was increased and decreased with 2, 4-D herbicide rate increased (Table 7).

Herbicide Efficiency Index (HEI) (%); It is weed killing potential of herbicides treatments and their phytotoxicity on the crop. The highest Herbicide efficiency index was recorded from Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS (3.92%) and followed Zura 0.75 lt ha^{-1} + hand weeding and hoeing @ 40 DAS (3.90%) whereas; the lowest was recorded in 2, 4-D 0.75 lt ha^{-1} (1.62) (Table 7). From this result it is possible to conclude that the herbicide had high efficiency index when using herbicide combination with hand weeding than that of using sole herbicide. And Zura herbicide superior to 2, 4-D herbicide (Table 7).

Weed Index(%); It is the per cent yield loss caused due to weeds as compared to unweeded (weedy check). Higher weed index mean greater loss. The highest Weed Index was recorded from weedy check (93.27%) and followed by 2, 4-D 0.75 lt ha^{-1} (52.40%) whereas; the lowest was recorded in weed free check (0.00%) (Table 58) and followed by Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS (9.72%). The result indicated that there was lowest yield losses when using Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS next to weed free condition.

Weed Control Index (%); It indicates the per cent reduction in the dry weight in treated plots compared to weedy plots. There was high Weed Control Index in weed free condition (97.95%) and low in weedy check (0.00%) weed management practices. Of herbicide treatment Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS was ranks first (Table 58).

Table 57: Weed biomass and Weed density as influenced by weed management practices at Gute

Treatment/Weed management practices	Weed Biomass(gm)			Weed Density/m2		
	Broad leaf	Grass Leaf	Total	Broad leaf	Grass Leaf	Total
Zura 1lt ha-1	105.4(10.29)d	53.12(7.32)f	158.5(17.61)e	11.5(3.46)b)	15.6(4.01)g)	27.1(7.47)de
Weed free	0(0.71)a	0(0.71)a	0(0.71)a	0(0.71)a	0(0.71)a	0(0.71)a
Weedy check	846.3(29.07)f	29.95(5.51)e	876.3(34.58)f	34.17(5.89)f	13.67(3.76)g	47.83(9.65)h
Zura 0.75lt ha-1	67.8(8.26)c	53.78(7.28)f	121.6(15.55)d	10.75(3.35)b	20.83(4.62)h	31.58(7.97)fg
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	28.2(5.35)b	7.65(2.85)c	35.9(8.21)bc	18.8(4.39)cd	5(2.34)c	23.8(6.73)c
Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	24(4.95)b	8.72(3.01)c	32.7(7.96)b	26.1(5.16)e	5.5(2.45)d	31.6(7.61)def
2, 4-D 1.0 lt ha-1	56.1(7.30)c	43.8(6.62)f	99.9(13.92)d	18(4.30)c	8(2.91)ef	26(7.21)d
2, 4-D 0.75 lt ha-1	132.7(11.50)d	46.36(6.85)f	179.1(18.34)e	21(4.63)d	9.67(3.18)f	30.67(7.82)ef
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	24(4.94)b	15.47(3.99)d	39.5(8.93)bc	31.83(5.69)f	7.03(2.74)de)	38.87(8.43)g
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	44.1(6.61)bc	12.25(3.56)cd	56.3(10.17)c	21(4.64)d	9.5(3.16)f	30.5(7.79)ef
Handweeding and hoeing @25 and 40 DAS	281.7(16.79)e	2.4(1.69)b	284.1(18.48)e	16.83(4.16)c	2.5(1.73)b	19.33(5.88)b
F.Pro	<.001	<.001	<.001	<.001	<.001	<.001
mean	146.4(9.61)	24.9(4.49)	171.3(14.11)	19.09(4.21)	8.85(2.87)	27.93(7.09)
l.s.d	55.54(1.81)	12.07(0.93)	57.78(2.01)	2.71(0.32)	2.03(0.30)	3.68(0.47)
cv%	22.3(11)	28.5(12.2)	19.8(8.4)	8.3(4.4)	13.5(6.2)	7.7(3.9)

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$ and Means within columns with the same alphabets are not significantly different at $P < 0.05$

Table 58: Effect of different weed control treatment on Weed Control Index (WCI), Weed Control Efficiency (WCE), Weed Persistence Index (WPI), weed index (WI) and herbicide efficiency index (HEI) in Sorghum crop (Average of two years) Gute

Treatment/Weed management practices	WCE(%)	WCI(%)	WI(%)	HEI(%)	WPI(%)
Zura 1lt ha-1	22.59	49.01	40,80	1.74	0.66
Weed free	92.64	97.95	0.OO	-	0.27
Weedy check	0.00	0.OO	93.27	-	1.00
Zura 0.75lt ha-1	17.41	55.03	51.30	1.92	0.54
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	30.26	76.98	9.72	3.92	0.34
Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	21.14	76.26	17.07	3.90	0.29
2, 4-D 1.0 lt ha-1	25.28	59.75	50.03	2.15	0.54
2, 4-D 0.75 lt ha-1	18.96	46.96	52.40	1.62	0.65
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	12.64	74.18	14.29	3.57	0.30
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	19.27	70.59	15.28	3.13	0.36
Handweeding and hoeing @25 and 40 DAS	39.07	46.56	15.01	--	0.87

WCE= weed control efficiency, WCI = weed control index, WI = weed index, HEI = herbicide efficiency index, WPI = weed persistence index,

Table 8; economic analysis of weed control method in sorghum crop at Gute

Weed management Practices	Economic analysis							
	Chemical price (Birr/L)	Labour Wage (Birr/ha-1)	Total cost production(Birr /ha-1)	Yield Kg/ha -1	Crop price (Birr /Kg)	Gross Retarn (Birr/ ha-1)	Net profit (Birr/ha-1)	B.C Ratio
Zura 1lt ha-1	750	1350	2100	1724	15	25860	23760	12.31
Weed free	0	6000	6000	2912	15	43680	37680	7.28
Weedy check	0	2400	2400	196	15	2940	540	1.23
Zura 0.75lt ha-1	562.5	1350	1912.5	1418	15	21270	19357.5	11.12
Zura 1lt ha-1 + hand weeding and hoeing @ 40 DAS	750	2400	3150	2629	15	39435	36285	12.52

Zura 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	562.5	2400	2962.5	2415	15	36225	33262.5	12.23
2, 4-D 1.0 lt ha-1	850	1350	2200	1455	15	21825	19625	9.92
2, 4-D 0.75 lt ha-1	637.5	1350	1987.5	1386	15	20790	18802.5	10.46
2, 4-D 1.0 lt ha-1 + hand weeding and hoeing @ 40 DAS	850	2550	3400	2496	15	37440	34040	11.01
2, 4-D 0.75 lt ha-1 + hand weeding and hoeing @ 40 DAS	637.5	2400	3037.5	2467	15	37005	33967.5	12.18
Handweeding and hoeing @25 and 40 DAS	0	3600	3600	2766	15	41490	37890	11.53

Conclusion and recommendation

Weeds are one of the most important limiting factors in enhancing sorghum production, with substantial losses that vary from region to region, depending on the cultivation system, predominant weed communities and weed control methods employed by the farmers. Sorghum productivity is remarkably reduced by weed infestation in the midland agro-ecology like in the study areas. Farmers are aware of weed problem in their fields but often they cannot cope-up with heavy weed infestation during the peak-period of agricultural activities because of labor shortage, hence most of their fields are weeded late or left un-weeded. Therefore, this study was conducted with the following objectives of evaluating the effect of weed management practices on weeds, and growth, yield and yield components of sorghum and to determine optimum rates of herbicides, and their combination hand weeding and hoeing for weed management in sorghum at the study area. The study revealed that recommendation weed free check and their combination with Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS had very high significant effect on all growth parameters of sorghum at both the study area (Bako and gute site), but there is numerical differences between weed free check, two times hand weeding and hoeing at 25 & 40 DAS and application of Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS on sorghum yield. Combined application of Zura 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS has more yield than single application of Zura herbicide in the same sorghum variety. It is therefore recommended that farmers should adopted sorghum variety, "Gamedi with application of Zura at 1lt ha^{-1} + hand weeding and hoeing @ 40 DAS to increase sorghum production in the study area /Western Oromia/. The study was done at two-test sites (Bako and gute) representing the Western Oromia for two main cropping seasons. To verify and recommend for further, research should be repeated at different season.

Referance

Ashiq, Noor Muhammad and Noor Ahmad, 2007. Comparative efficacy of different herbicides against broadleaved weeds in wheat. *Pakistan Journal of Weed Science Research*, 13(3-4): 149-156.

Chandrasekaran. B.K. Annadurain and E. Somasundaram, 2010. A text book of Agronomy: New age International (P) limited publishers, New Delhi.

Changsaluk, S. 2003. Early post-emergence application to control weeds in sweet corn. (In) Proceeding of Annual Conference, Kasetsari University, pp. 532–538

Fazal Munsif1, Kawsar Ali, Iftikhar Khan, Hujjat Ullah Khan, 2012. Efficacy of various herbicides against weeds and their impact on yield of spring wheat. Pak. J. Weed Sci. Res. 15 (2-3): 191-198.

Iqbal M., 2003.Efficacy of herbicides and row spacing on weeds and yield and yield components of what. Sarhad Journal of Agriculture, 1 pp 23-41.

Kaushik, M.K. and Shaktawat, M.S. 2005. Effect of row spacing, nitrogen and weed control on growth, yield and nutrient uptake of sorghum (Sorghum bicolor). Indian Journal of Agronomy 50(2): 140–142.

Khan, M.A., K.B. Marwat, G. Hassan and N. Khan 2002. Impact of weed management in maize planted at night. Pak. J. Weed Sci. Res. 8(1-2): 57-62.

Pandey, A.K., Prakish, V., Singh, R.D. and Mani, V.P. 2001. Integrated weed management in maize (Zea mays). Indian Journal of Agronomy 46(2): 260–265.

Rao, S.S., Regar, P.L., Jangid, B.L. and Singh, Y.V. 2007. Effect of nutrient and weed management on forage sorghum (Sorghum bicolor) under rainfed condition. Indian Journal of Agronomy 52(3): 139–142.

Satheeshkumar, N., Thukkaiyannan, P., Ponnuswamy, K. and Santhi, P. 2011. Effect of sowing and weed management methods and intercrops on weed control and grain yield of sorghum under intercropping situation. Crop Research 41(1–3): 46–51

Singh, R., Sharma, A.R. and Behera, U.K. 2007. Tillage and crop establishment practices for improving productivity of maize under different weed control methods. Indian Journal of Agricultural Sciences 77(11): 731–737.

Tunio, S.D., S.N. Kaka, A.D. Jar war and M.R.Wagan.2004. Effect of integrated weed management practices on wheat yield. Pak. J. Agric. Engg. Vet. Sci.20 (1): 5-10.

Evaluation of Sesame genotypes for Resistance to Bacterial Blight (Xanthomonas campestris pv. sesami) of sesame (Sesamum indicum L.) under Field Conditions at Bako

Abay Guta[1*], Abreham Negera[1] and Dinberu Kebede[2]
[1] Bako Agricultural Research center, P. O. box 3, Bako
[2] Ambo agricultural research center
*Corresponding author: abbayg12@gmail.com

Abstract

Sesame is an important source of edible oil and is widely used as one of the ingredients in food products especially in bakery foods and animal feed. Its production in Ethiopia has been increasing extensively in terms of area from 64,000 ha to 420,494 from 2007 to 2015. Diseases are the major constraints in sesame production worldwide, affecting not only plants during germination and/or growth, but also present even in storage. In Ethiopia, sesame bacterial blight intensity varies depending on topography, altitude, and weather conditions. This activity was initiated to identify sesame genotypes resistant and moderately resistant to Bacterial blight disease. After symptom of the pathogen observed on plant leaves, the diseased plant part collected and maintained in laboratory of Ambo agricultural research center. Inoculum was suspended in distilled water and adjusted turbidimetrically to a final concentration of about 10^7 colony-forming units per milliliter ($1x10^7$cfu/ml). A total of 77 treatments were arranged in alpha lattice design, seven by ten blocks. Two rows for one entry with three replications and one block contain seven genotypes. Disease severity was assessed from 8 per-tagged plants as the percentage of the total leaf surface covered with bacterial blight lesions on each expanded leaflet separately at regular intervals using a 0–6 scale. During 2019 cropping season among 77 genotypes, none was found 54 genotypes found to be moderately susceptible (21.-50% severity) and 8 genotypes found to be susceptible (50.1-70% severity). During 2021 cropping season 77 genotypes, similar to first year none was found immune or resistant but, 23 genotypes found to be moderately resistant (10.1-20% severity), 57 genotypes found to be moderately susceptible (21.-50% severity index) and 7 found to be susceptible (50.1-70% severity).it was investigated that significant variation observed in bacteria blight, growth, grain yield and yield components among the 77 genotypes evaluated at Bako. Some sesame genotypes were found as potential source for resistance and better yield performances, could serve to develop superior high-yielding and disease resistant genotypes.

Keywords: Sesame, Evaluation of genotypes, Resistance, Bacterial Blight

Introduction

Sesame (*Sesamum indicum* Linn.) from a member of the order tubiflera and family Pedaiaceae, is an old and important lowland oilseed crop being cultivated in tropics, subtropical region of India and other parts of the world (Karuppaiah and Nadarajan, 2013).It is an erect herbaceous annual plant that has two growth characteristics: indeterminate and determinate, with heights of up to two meters. Most varieties show an indeterminate growth habit, which is also shown as a continuous production of new leaves, flowers and capsules as long as the environment remains suitable for growth (Carlsson *et al.*, 2008). Sesame seed are small and ovate with two distinct types, cream colored and black (Ali and Jan, 2014). It is grown in areas with annual rainfall of 625-1100mm and temperature of >27^0C and well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams (Geremew *et al.*,2012).

It is an important source of edible oil and is widely used as one of the ingredients in food products especially in bakery foods and animal feed (Ali *et al*., 2007). It is also used in confectioneries, cookies, cake, margarine and bread making and the oil is used in the manufacture of soaps, cosmetics, perfumes, insecticides and pharmaceutical products (Karuppaiah and Nadarajan, 2013). Sesame oil has medicinal and pharmaceutical value and is being used in many health care products (Ali *et al*., 2007).

Sesame is widely cultivated in tropical and sub-tropical parts of the world. India was the leading country in area followed by Mynmar, China, Ethiopia, Nigeria and Uganda while in production Mynmar was followed by India, China, Ethiopia, Nigeria and Uganda during 2011 (FAOSTAT, 2013).

Sesame production in Ethiopia has been increasing extensively in production area from 64,000 ha to 420,494 from 2007 to 2015 (CSA, 2007; CSA, 2015). Despite the country's immense potential to increase sesame production and productivity and significantly increase the international market's demand for sesame, both the production and marketing system of sesame are full of challenges inhibiting the potential for all involved parties. The level of productivity of sesame (seven quintals/hectare) is by far below 50% of the estimated potential of the country and the average productivity level of other sesame-producing countries (Gelalcha, 2009).

The factors responsible for the low and variable yield of sesame are poor or inadequate agronomic practices, absence of disease resistant varieties and other biotic/abiotic factors which may include unsuitable environmental conditions or pests and diseases. Diseases are the major constraints in sesame production worldwide, affecting not only plants during germination and/or growth, but also present even in storage. The traditional cultivation methods still persist, increasing the vulnerability of the crop to biotic and abiotic problems (Firdous *et al*., 2009 and Geremew *et al.*, 2012).

Bacterial blight cause significant losses in tropical, subtropical and temperate climates and has been reported from all sesame growing areas of the world (Singh, 1970; Kolte, 1985; Geremew and Asfaw, 1992). In Ethiopia, sesame bacterial blight intensity varies depending on topography, altitude, and weather conditions. Disease incidence reach up to 100% in areas such as Wellega, Pawe, and Gambella where high humidity persists for longer time, while it is about 10-50% in semi-arid areas like Werer and Humera. Water logging encourages the spread of the disease (Geremew*et al.*, 2012).

Therefore, we must find the solution to stop it from being epidemic. The ideal and most economical means of managing the sesame bacterial blight would be the use of resistant varieties. Thus, this activity was initiated with the objectives to screen sesame genotypes resistant and moderately resistant to Bacterial blight disease

Materials and Methods

Description of the Study Area

The activity was conducted in Bako Agricultural Research Center (BARC). It is located at 9º05'33.366 N latitude and 37 º 02'41.202 E longitudes and at an altitude of 1654 m.a.s.l. the annual mean minimum and maximum temperature are 14.5^0C and 29.3^0C, respectively, while the annual rainfall is 1605mm.

Bacterial isolates and culture conditions:

To insure disease isolation first, the effected seeds were sawn on pot early before two-month regular sawing time and sesame plants were grown on pots. After symptom of the pathogen observed on plant leaves, the diseased plant part was collected and maintained in Lab. (lab. of Ambo plant protection center). *Xanthomonas campestris* pathogen was extracted and isolated on Nutrient Glycerol Agar (NGA) at 4ºC (Bashir, 2007 and Ahmad, 2004). The purity of isolates were confirmed on nutrient broth sucrose agar (NSA) dishes (Lelliot & Stead, 1987) by incubating at 25ºC for 48 h. for confirmation of yellow colonies. Pure culture was kept in glass culture tubes containing 10 ml of NGA (Lelliot & Stead, 1987) grown at 25ºC for 48 h and again maintained at 4ºC

Inoculum was suspended in distilled water and adjusted turbidimetrically to a final concentration of about 10^7 colony-forming units per milliliter ($1x10^7$cfu/ml). For inoculation, plants were inoculated with fine droplets of suspension by using atomizer and inoculation were done twice. The inoculation was done when sesame plants were 4 and 6 leaves growth stages. Field Experimental materials and design

77 sesame genotypes were used in this experiment. Seeds of sesame were obtained from Bako Agricultural Research Center (BARC). A total of 77 treatments were arranged in alpha lattice design, seven by ten block. Two rows for on entry with three replications and one block contain seven genotypes. One block size was consisted of 3m x 5.6m area. between block and replication 1m and 1.5m, an inter-row and intra-row spacing of 40 cm and 10 cm, respectively.

Disease assessment

Disease Incidence: the mean percentage of infected leaves of showing typical symptom of the disease per total leaves of plant units were assessed at nine days interval from the beginning of disease symptom. Both diseased and healthy plants were counted from the row plants and the percentage of disease incidence (PDI) was calculated according to the formula used by Wheeler (1969) and ICARDA (1986):

$$PDI(\%) = \frac{Number of diseased plants}{Total number\ of plants inspected} x\ 100$$

Disease severity was assessed from 8 per-tagged plants as the percentage of the total leaf surface covered with bacterial blight lesions on each expanded leaflet separately at regular intervals using a 0–6 scale (Table 1) (Sarwar *et al.* (2006).The severity grades were converted into percentage severity index (PSI) according to the formula by Wheeler (1969) and ICARDA (1986).

$$PSI(\%) = \frac{\sum Individual\ numerical\ ratings}{(Total\ number\ of\ plants\ assessed\ x\ Maximum\ score\ in\ the\ scale)} x\ 100$$

Table 59: Percent of infection and scale for sesame bacterial blight

Scale	Description
0	0% Immune
1	0.1-5% Highly Resistant
2	5.1-10% Resistant
3	10.1-20% Moderately Resistant
4	20.1-50%Moderately Susceptible
5	50.1-70% Susceptible
6	> 70 % Highly Susceptible

Source: Sarwar *et al.* (2006).

Area Uder Disease Progress Curve (AUDPC)

The progress of bacterial blight was plotted over time using mean percentage severity index(PSI) for each sesame variety at each plot, and the PSI values was also used to calculate apparent infection rate (*r*). The AUDPC values (%-day) were calculated for each genotype according to the mid-point rule formula (Berger, 1981; Campbell and Madden, 1990).

$$\mathbf{AUDPC} = \sum_{i=1}^{n-1} 0.5(X_{i+1} + X_i)(t_{i+1} - t_i)$$

Where *Xi* is the disease severity of bacterial blight at I th assessment date, *Ti*is the time of the I th assessment in days from the first assessment date and *n* is the total number of disease assessments. Because severity was in percentage and time in days, AUDPC was express in proportion days.

Growth parameters

a. Days to 50% emergence: Days from planting to the emergence of 50% plants per row was recorded.

b. Days to 50% flowering: Days to flowering was recorded for each plot when 50% of the plants in a plot flowered.

c. days to 50% capsule setting: Days to capsule setting was recorded for each plot when 50% of the plants in a plot capsule setting.

d. Days to 90% maturity: days to 90 % maturity of the crop when 90% of the capsule reached physiological maturity.

e. Plant height (cm): The height of plants from the ground to the tips plants were measured eight randomly selected plants per row at maturity.

Yield and yield components

a. Number of capsule per plant: Number of capsule per plant was counted on five randomly taken plants from 8 tagged plants means were recorded as number of capsules/plant.

b. Seed yield per row (g): The grain yield per row was recorded.

Adjusted yield per plot = (Fw (100-Amc) x)/RDW

Where: Fw = Field weight; Amc = Actual moisture content; RDW = Recommended dry weight

c. Total grain yield (t ha^{-1}): The grain yield in gram per row was calculated in per hectare basis.

Data Analysis

The analysis of variance (ANOVA) was performed for the disease parameters (incidence, severity, AUDPC) and yields parameters using GenStat software (GenStat 18^{th}ed.).Least significant difference (DMR) values were used to separate treatment means (P<0.05). ANOVA analysis using GenStat, 18^{th}editionsoftware, following analysis using the standard procedure (Gomez and Gomez, 1984).

Result and Discussion

Disease incidence

Bacteria blight was first observed on susceptible genotypes 72 days after sowing (DAS) in early September in both years (2019 and 2021).The blight spread to almost all genotypes three to seven days later from first observation. The incidence recording started ten days later. There was a significant difference (P<0.05) between genotypes bacterial blight incidence recorded (Table 2). The mean final bacterial blight disease incidence ranged from 46.6% to 95.7% in 2019 and from 34.0% to 100% in 2021. The highest (95.7%) bacteria blight incidence was observed on genotype E4, flowed by E16 (95.0%), E27 (95.0%), E6 (92.7%) and etc. during the 2019 cropping season. In 2021, the highest final bacteria blight disease incidence was recorded onE11 (100%) followed by E55 (100%), E45 (99.3), E20 (95.1%) and etc. the disease was more rapidly spread on the susceptible genotypes which showed maximum level of final disease incidence (100%).Disease severity

Screening in 2019 cropping season at Bako revealed that among seventy-seven genotypes, none was found immune or resistant, fifteen genotypes found to be moderately resistant (10.1-20% severity),. Fifty-four genotypes were found to be moderately susceptible (21.-50% severity),.and eight genotypes were found to be susceptible (50.1-70% severity), (Table 60).

Screening of genotypes in 2021 cropping season revealed that out of seventy-seven genotypes, similar to first year none was found immune or resistant but, twenty-three genotypes found to be moderately resistant (10.1-20% severity), , E21, etc. and seven found to be susceptible (50.1-70% severity), Screening of genotypes during both years (2019 and 2021) cropping season done revealed that out of seventy-seven genotypes, no genotype was immune or resistant but, nine genotypes found to be moderately resistant in both years (10.1-20% severity), The analysis of variance indicates that there were significant ($p<0.01$) differences among the genotypes, at Bako where the mean final blight severity ranged from 13.3% to 60.7% in 2019 and from 15.5% to 59.7% in 2021. The highest (60.7%) bacteria blight severity was observed on genotype E45, flowed by E45 (56.7%). . In 2021, the highest final disease severity index was recorded on E45 (59.7%) followed by PTY6 (59.7%). Area under disease progress curve (AUDPC)

The analysis of variance indicates that there were significant ($p<0.001$) different among genotypes and cropping season for AUDPC value. Area under disease progress curve of the blight ranged from 283.5%-days to 1135.5%-days in 2019 and from 255.0%-days to 910.5% in 2021.The highest (1135.5%-days) AUDPC value computed from genotypes E18 followed by E4 and E20 (988.5%-days).. In 2021, The highest (910.5%-days) AUDPC value computed from genotypes E45 followed by PTY6 (906.0%-days). (Table 60).

Table 60: Mean disease incidence, severity and AUDPC of bacterial blight on sesame genotypes at Bako during 2019 and 2021 main cropping season.

Genotypes	**Disease parameters**					
	2019			2021		
	PDI (%)	PSI (%)	AUDPC (%-days)	PDI (%)	PSI (%)	AUDPC (%-days)
E-1	53.3	20.3	448.5	77.3	19.3	337.5
E-10	65.7	41.0	736.5	52.3	30.0	436.5
E-11	54.4	14.7	354.0	100.0	19.3	334.5
E-12	63.5	19.7	393.0	35.7	16.7	255.0
E-13	48.7	13.7	385.5	49.3	18.0	331.5
E-14	53.3	18.0	429.0	59.3	19.3	355.5
E-16	95.0	52.7	988.5	91.7	54.7	813.0
E-17	60.1	24.0	532.5	53.2	26.3	549.0
E-18	91.1	60.7	1135.5	78.3	45.3	799.5
E-19	83.2	37.3	783.0	95.1	51.0	823.5
E-2	54.4	26.3	589.5	56.7	19.7	318.0
E-20	80.9	53.7	862.5	95.1	20.0	342.0
E-21	85.0	20.0	415.5	65.7	35.0	562.5
E-22	84.3	41.0	813.0	95.0	19.7	309.0
E-23	74.8	42.0	852.0	72.7	35.7	598.5
E-24	61.2	29.3	607.5	79.7	53.0	762.0
E-25	80.9	56.7	879.0	78.6	47.7	786.0
E-26	75.9	42.7	823.5	49.3	25.3	427.5
E-27	95.0	48.3	891.0	64.3	32.3	463.5

E-29	52.1	15.7	462.0	34.7	15.7	286.5
E-3	62.3	30.0	580.5	84.9	50.0	769.5
E-30	48.7	25.3	499.5	64.3	19.3	334.5
E-31	90.0	50.0	972.0	67.7	36.0	592.5
E-33	68.5	37.0	744.0	52.0	23.3	363.0
E-34	77.1	19.7	385.5	76.5	17.3	322.5
E-37	70.7	49.3	868.5	70.7	34.3	561.0
E-38	77.5	39.7	754.5	69.3	44.0	673.5
E-39	74.8	43.7	837.0	68.7	33.3	577.5
E-4	95.7	54.7	988.5	43.3	22.7	418.5
E-40	91.1	48.7	889.5	64.3	45.0	753.0
E-41	82.1	45.0	816.0	52.3	19.7	346.5
E-42	80.5	46.0	804.0	51.3	43.0	711.0
E-43	64.6	37.3	741.0	48.7	19.3	298.5
E-44	91.1	51.3	891.0	93.3	52.0	814.5
E-45	63.5	41.0	802.5	99.3	59.7	910.5
E-46	58.9	20.0	378.0	90.0	49.0	796.5
E-48	72.5	36.7	808.5	74.4	41.7	630.0
E-49	72.5	32.3	675.0	76.7	20.0	313.5
E-5	83.9	44.3	801.0	55.7	36.0	568.5
E-50	61.2	28.3	577.5	46.7	22.7	366.0
E-51	58.9	18.3	447.0	60.9	39.0	646.5
E-53	68.0	41.0	721.5	84.0	48.3	831.0
E-54	47.6	23.3	489.0	53.3	19.7	334.5
E-55	81.6	46.3	880.5	100.0	44.7	760.5
E-56	44.2	13.3	283.5	75.5	44.7	727.5
E-57	51.0	20.0	474.0	68.7	18.0	268.5
E-58	57.8	35.7	699.0	71.0	16.3	315.0
E-59	75.9	40.3	700.5	75.0	49.0	798.0
E-6	92.7	52.3	951.0	73.3	37.7	601.5
E-60	57.8	14.7	381.0	44.8	19.0	346.5
E-61	79.3	41.7	777.0	71.0	27.7	420.0
E-62	72.5	42.0	709.5	54.0	25.3	450.0
E-7	80.5	47.3	786.0	67.3	36.7	496.5
E-8	71.4	35.7	721.5	52.3	25.3	369.0
E-9	87.7	43.7	784.5	53.3	30.7	603.0
Obsa	90.0	43.0	814.5	94.0	47.3	796.5
PYT-1	66.2	35.7	679.5	63.7	50.7	711.0
PYT-10	82.1	37.0	679.5	52.0	36.3	531.0
PYT-12	80.5	41.3	756.0	70.0	19.7	295.5
PYT-13	77.1	19.3	385.5	73.3	31.3	600.0
PYT-14	79.3	39.0	837.0	76.3	35.7	595.5
PYT-15	72.5	37.3	672.0	45.7	33.3	504.0
PYT-16	78.2	35.3	718.5	42.7	29.0	513.0
PYT-17	78.7	44.3	787.5	34.0	18.0	270.0
PYT-18	83.2	47.0	840.0	45.7	25.7	427.5
PYT-2	74.8	19.7	361.5	62.3	32.3	567.0
PYT-20	86.6	51.7	933.0	64.3	31.7	561.0
PYT-21	74.8	38.0	739.5	51.7	23.3	393.0

PYT-24	60.1	19.3	397.5	73.0	19.3	328.5
PYT-3	82.7	48.3	892.5	62.3	19.7	291.0
PYT-4	72.5	37.3	729.0	69.0	40.0	607.5
PYT-47	73.7	32.7	673.5	47.3	31.3	510.0
PYT-5	85.0	47.7	889.5	87.3	42.3	733.5
PYT-6	79.8	49.3	930.0	95.0	59.7	906.0
PYT-7	83.2	49.0	879.0	37.3	30.7	495.0
PYT-9	63.5	42.7	826.5	69.0	40.0	652.5
Walin	83.7	43.0	822.0	45.3	22.0	345.0
Mean	73.2	36.8	704.5	66.2	32.5	527.5
LSD(0.05)	22.40**	23.1**	222.71**	15.01**	10.824**	165.86**
CV(%)	19.0	14.3	19.6	14.0	20.7	19.5

PDI= percentage disease incidence, PSI= percentage severity index, AUDPC= area under disease progress curve, LSD= least significant difference, CV= coefficient of variations, *= significant difference at $p < 0.05$), **= highly significant difference at $p < 0.01$)

Growth parameter

Combined analysis of growth parameters showed significant variation between genotypes in both cropping seasons except for days to 50% emergence. The analysis of variance (ANOVA) on days to 50% emergence revealed that genotypes were not significantly different ($p<0.05$). All the genotypes were not different on days to emergence and seeds planted in all plots almost uniformly emerged (Table 3).The analysis showed that there was no significant ($p<0.05$) differences on day to 50% flowering among all genotypes (Table 3). The longest (78.7 days) period of flowering was recorded on the genotypes E61 while the shortest (74.0 days) period of flowering was recorded in the genotypes (E34, E45 and E48). However, the genotypes did not show any significant variations, in days to 50% flowering (Table 3). There were not significant differences ($p<0.05$) in days to capsule setting. The longest (93.7 days) of capsule setting was recorded on the genotypes E30 while the shortest (84.3 days) days was recorded in the genotypes E31. The analysis also showed that there were significant differences ($p<0.05$) in days to 90% maturity of genotypes. The longest duration of 136.3 days was recorded on the genotypes E56 while the shortest 124.7 days was recorded in genotype PTY2. There were significant differences ($p<0.05$) in plant height of the genotypes. The highest plant height of 122.2 cm was recorded by the genotypes E16 whereas the shortest 84.5 cm was recorded in genotypes PTY17 (Table 3).

Yield and yield components.

In combined analysis of variance, yield and yield components showed significant variations among genotypes in both cropping seasons (2019 and 2021). Number of capsule per plant was significantly different ($p<0.05$). The highest number of capsule per plant (46.6) was recorded by PTY18 while the smallest number of capsule per plant (22.5) was recorded in genotypes E13 (Table 3). There was highly significant difference ($p<0.001$) in grain yield in Kg/ha among the genotypes. The highest (1067.5 Kg/ha) yield was recorded from genotype E56, followed by E30 (969.3 Kg/ha), There was highly significant different ($p<0.01$) in grain yield among moderately resistant and susceptible genotypes.

Table 61: Growth parameters, Yield and yield components of sesame genotypes at Bako during 2019 and 2021 main cropping season

Genotypes	**Growth parameters, Yield and yield components**					
	DF	DCS	PH	DM	CPP	Yield Kg/ha
E-1	75.7	90.7	91.3	133.3	28.2	788.8
E-10	77.0	87.7	93.1	128.3	35.5	513.7
E-11	76.0	87.3	99.8	131.3	32.7	810.2
E-12	76.3	89.0	103.0	132.7	30.9	806.5
E-13	75.3	90.3	95.5	134.3	22.5	748.6
E-14	77.0	89.3	92.9	131.3	38.3	844.7
E-16	77.3	88.7	122.2	130.7	42.6	380.9
E-17	76.3	89.0	90.7	131.7	31.4	632.7
E-18	74.7	86.3	92.4	127.0	31.8	350.5
E-19	75.7	87.3	94.0	128.7	33.4	503.7
E-2	77.7	89.3	100.3	130.0	33.5	690.2
E-20	76.0	87.7	102.9	128.0	33.5	716.5
E-21	78.3	89.0	107.0	130.3	33.3	624.9
E-22	75.7	89.7	102.9	131.7	37.9	741.8
E-23	77.3	87.3	95.1	127.0	25.9	499.0
E-24	74.3	89.7	95.3	132.7	41.9	731.2
E-25	74.0	85.7	95.6	127.0	31.0	480.5
E-26	75.7	87.7	104.9	129.0	31.0	651.7
E-27	75.7	86.7	99.8	127.0	27.4	454.0
E-29	76.3	89.0	94.3	133.3	31.9	832.2
E-3	75.3	87.0	97.9	130.7	29.4	731.5
E-30	76.0	93.7	112.3	136.0	36.0	949.3
E-31	76.7	84.3	86.6	127.3	22.9	503.0
E-33	75.0	90.7	91.9	133.0	41.5	573.1
E-34	74.0	88.3	93.1	132.7	28.1	754.2
E-37	74.7	85.7	111.0	127.0	34.6	470.0
E-38	76.0	88.0	101.9	130.3	32.9	685.2
E-39	75.0	85.7	97.9	128.3	41.7	500.9
E-4	78.0	88.0	93.9	127.0	34.1	647.0
E-40	75.0	86.7	91.1	129.0	31.9	409.6
E-41	76.3	87.3	96.1	126.7	26.6	423.6
E-42	75.3	85.7	105.8	127.0	34.1	537.7
E-43	77.7	90.0	97.3	132.0	28.5	576.5
E-44	75.0	86.0	89.9	127.7	30.0	470.2
E-45	74.0	86.7	90.3	131.0	29.4	498.4
E-46	73.7	87.7	97.9	128.7	34.2	887.7
E-48	74.0	86.7	92.3	130.3	30.1	372.3
E-49	74.7	88.0	102.2	133.7	44.6	769.9
E-5	77.3	90.3	92.5	132.0	29.7	484.6
E-50	76.3	88.7	102.6	133.7	33.8	646.5
E-51	73.7	87.7	101.7	131.3	38.1	814.6
E-53	75.7	86.7	101.0	127.3	31.8	487.1
E-54	77.3	91.7	103.4	136.0	34.2	948.1
E-55	74.3	88.0	97.2	131.7	39.9	515.8

E-56	74.7	89.3	100.5	136.3	43.9	1067.5
E-57	76.0	89.3	107.7	133.7	41.7	847.5
E-58	78.3	90.7	113.9	134.3	35.8	760.1
E-59	76.3	91.0	95.5	133.7	37.8	487.7
E-6	76.7	87.7	103.0	129.7	30.3	414.4
E-60	73.7	90.0	97.4	134.0	23.4	815.4
E-61	78.7	90.0	89.5	131.3	35.8	541.0
E-62	74.7	86.7	102.3	130.3	37.6	510.8
E-7	78.3	88.3	92.8	130.0	28.5	402.0
E-8	77.0	89.7	102.2	131.3	30.9	664.0
E-9	77.0	88.0	92.5	130.3	34.6	497.4
Obsa	74.0	87.0	85.1	128.7	26.9	545.8
PYT-1	77.3	88.7	108.3	126.7	23.9	676.8
PYT-10	76.0	85.7	87.6	125.7	28.7	572.9
PYT-12	76.3	87.7	96.3	129.0	33.1	569.6
PYT-13	76.0	88.7	94.7	129.3	36.4	728.7
PYT-14	76.0	88.0	98.1	129.0	31.3	586.0
PYT-15	77.3	88.0	91.7	129.0	35.0	572.3
PYT-16	74.7	87.3	102.3	128.7	40.1	697.1
PYT-17	75.7	85.3	84.5	127.3	23.7	453.1
PYT-18	75.7	87.7	95.8	129.0	46.6	575.2
PYT-2	75.0	85.7	101.2	124.7	28.1	485.4
PYT-20	75.3	85.7	102.5	126.7	34.3	399.0
PYT-21	77.3	88.7	92.8	130.7	32.8	398.9
PYT-24	76.0	87.3	79.9	126.3	27.2	781.7
PYT-3	75.0	85.7	93.1	125.7	32.2	486.8
PYT-4	75.7	86.7	96.7	129.3	38.7	432.5
PYT-47	72.7	86.7	102.6	129.3	24.8	682.2
PYT-5	74.0	85.3	89.6	127.0	34.2	432.0
PYT-6	76.0	87.0	90.3	129.3	29.6	384.9
PYT-7	77.0	89.0	113.9	128.0	37.1	483.6
PYT-9	77.3	88.0	104.5	127.0	28.0	513.7
Walin	75.3	86.3	90.3	127.3	27.8	686.2
Mean	75.9	88.0	97.7	129.9	32.9	605.3
LSD (0.05)	NS	NS	16.95*	4.85**	8.99**	125.23**
CV (%)	3.1	2.9	10.8	2.3	16.9	12.8

DF= days of flowering, DCS=days of capsule setting, PH= plants height, DM= days of maturity, CPP= capsules per plant, Kg/ha= kilo gram per hectare, LSD= least significant difference, CV= coefficient of variations, *= significant difference at $p < 0.05$), **= highly significant difference at $p < 0.01$)

Conclusion and Recommendation

This study result showed that sesame genotypes had different reaction to the bacteria blight disease under field condition. Significant variation was recorded in bacteria blight disease reaction, growth, grain yield and yield components among the 77 genotypes evaluated at Bako. Bacteria blight was most important and dominant disease occurred on the evaluated sesame genotypes. Some sesame genotypes were found as potential source for resistance and better yield performances, could serve to develop superior high-yielding and disease resistant varieties. Around 22 genotypes are recommended for high grain yield as well as sources of resistance to bacterial disease.

Reference

Ahmad, Z. 2004. Isolation and Characterization of bacterial blight of sesame in rainfed areas of Pakistan. M. Sc. Thesis. Department of Plant Pathology, Faculty of Food and Agriculture Sciences. PMAS Arid Agriculture University Rawalpindi, Pakistan.

Ali, G. M., Seki-Katsuta, M., Yasumoto S. 2007. Assessment of genetic diversity in sesame (*Sesamumindicum*L.) detected by Amplified Fragment Length Polymorphism markers. Electronic Journal of Biotechnology 10 :12-23.

Ali, S. and Jan, A. 2014. Sowing dates and nitrogen level effect on yield and yield attributes of cultivars. Sarhad J. Agric, 30:203-209.

Bashir, S. 2007. Pathogenic variation in *Pseudomonas syringae*pv. *sesam*i and *Xanthomonascampestris*pv. *Sesame* associated with blight of sesame. M. Sc. Thesis.Department of Plant Pathology. PMAS Arid AgricultureUniversity, Rawalpindi.

Berger, R.D. 1981. Comparison of the Gompertz and Logistic equation to describe plant disease progress.*Phytopathology*, 71: 716-719.

Campbell, C. L. and Madden, V. L. 1990. Introduction to Plant Disease Epidemiology. Wiley, New York, USA. 532 pp.

Carlsson, A.S., N.P. Chanana, S.Gudu, M.C. Suh, and B.A.Were, 2008. Sesame. In: Kole, C., *et al.* (Eds.) *Compendium of transgenic crop plant- Transgenic oilseedcrops*. pp. 227- 246. Texas, USA: Wiley Blackwell; 2. ISBN 978-1-405-16924- 0.Center), Mexico.

CSA (Central Statistical Agency). 2007. Federal Democratic Republic Ethiopia: Central statistics Agency, Agricultural sample survey 2007/2008 (2000 E.C) (September- December 2007). Volume I: Report on: Area and production of crops (private peasant holdings, *meher*season), Statistical Bulletin 417, Addis Ababa, June, 2008. Pp.1-17.

CSA (Central Statistical Agency). 2015. Federal Democratic Republic Ethiopia: Central statistics Agency, Agricultural sample survey 2014/2015 (2007 E.C) (September- December 2010). Volume I: Report on: Area and production of major crops (private peasant holdings, *meher*season), Statistical Bulletin, Addis Ababa, May, 2015. Pp.1-121.

FAOSTAT, 2013. Food and Agriculture Organization of the United Nations.

Firdous, S.S., 2009. Virulence anlysis of *Xanthomonascampestris*pv. s*esami*and*Pseudomonas syringae*pv. s*esami*the causal organisms of Sesame (*Sesamumindicum*L.) bacterial blight. Department of Botany, PMASAAUR Rawalpindi.

Gelalcha, S. D. 2009. Sesame trade arrangements, costs and risks in Ethiopia: a baseline survey, WageningenUR.

GeremewTerefe, AdugnaWakjira, MuezBerhe and HagosTadesse, 2012. Sesame Production Manual. EIAR and Embassy of the Kingdom of the Netherlands.pp.1-34.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. 2ndedition. *A Wiley Interscience Publications,* New York. 680 pp.

ICARDA, 2006. Technology Generations and Dissemination for Sustainable Production of Cereals and Cool Season Legumes. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. pp. 256.

Lelliot, R.A. and D.E. Stead (ed.), 1987. Methods for the Diagnosis of Bacterial Diseases of Plants. Backwell Scientific Publications, London, UK: p. 211.

Karuppaiah, V. and Nadarajan, L. 2013. Host plant resistance against sesame leaf webbeand capsule borer, *Antigastracatalaunalis*Duponchel (Pyraustidae: Lepidoptera). African Journal of Agricultural Research 8(37): 4674-4680.

Sarwar, G. and M.A. Haq. 2006. Evaluation of sesame germplasm for genetic parameters and disease resistance. J. Res. 44:89-95.

Van der Plank, J.E. 1963. Plant diseases: Epidemics and control. *Academic Press*, New York. 334 pp.

Wheeler, B.E.J. 1969. An Introduction to plant diseases. Wiley and Sons, London.374 pp.

Screening of red small common bean genotypes for Resistance to angular and Cercospora leaf spot diseases in Bako and East Wollega Zone

Abay Guta* and Abreham Negera
Bako Agricultural Research center, P. O. box 3, Bako, Shoa, Ethiopia
*Corresponding author: abbayg12@gmail.com

Abstract

Common bean has significant economic importance both in income and as food with high nutritional value in developing countries in Africa, Asia and Latin America. Despite theseimportances of the crop, actual smallholder farm yields are by far below the potential production. The effect of diseases may be restricted to certain production systems, locations and cropping seasons. In this study,common bean genotypes resistant or moderately resistant to Angular and cercospora leaf spot diseasesare identified.. 121 genotypes were used in the experimental arranged in simple lattice design with two rows for one genotype. Disease severity was assessed from 8 per-tagged plants as the percentage with regular intervals using a 1-9 scale. The highest final angular leaf spot and cercospora leaf spot disease severity index was recorded in G27

(61.7%) and G92 (38.3%) followed by G172 (60%), and G163 (37.7%). From the genotypes none was found immune or resistant, 49 genotypes were found to be moderately resistant (10.1-20%) severity), Three genotypes were found to be immune or resistant (1-10% severity), and 32 genotypes found to be moderately resistant (10.1-20% severity) toangular leaf spot, None of genotypes were found to be susceptible (50.1-70% severity) to cercospora leaf spot. , Significant variations were observed in angular and cercospora leaf spot disease resistance, growth, grain yield and yield components among the 121 genotypes..

Keywords: Screening, common bean, Resistance, disease

Introduction

Common bean (*Phaseolus vulgaris* L.) is an important crop worldwide, comprising of both dry beans and snap (green) beans. It is widely grown in the temperate and sub-tropical Africa and on other continents (FAO, 2007). According to Broughton *et al*. (2003), the common bean is the most important legume consumed by man and 30% of the crop is produced by small-scale farmers in Latin America and Africa. The crop has significant economic importance both in income and food sources with high nutritional value in developing countries of Africa, Asia and Latin America (FAOSTAT, 2020). The crop is rich in protein and micronutrients, such as calcium, folate iron, zinc, magnesium, phosphorus, potassium and vitamin B (Mederos, 2006; Beebe *et al*., 2014; Petry*et al*., 2015). The crop offers the second most important source of dietary fiber for humans and the third most important source of calories among all agricultural products in Eastern and Southern Africa (Pachico, 1993). Although beans vary considerably in seed size, shape and color, their nutritional components are remarkably similar (Geil and Anderson, 1994). The edible leaves, pods and seeds are low in fat content but packed with protein, carbohydrates, vitamins and minerals (Lanza*et al*., 2006).

Common bean is widely grown in Ethiopia and is an increasingly important commodity in the cropping systems of smallholder farmers for food security and income generation. The major production areas are in the Rift Valley areas and Southern parts of Ethiopia (SNNPR). Farmers grow a wide range of bean types, in terms of color and size, but the most common types are the pure red and white beans. Most of the beans produced, traded and consumed in the domestic Ethiopian bean markets, are the medium and small red beans whereas white beans are virtually all exported. These market types of beans are a valued source of foreign exchange with an annual value in the range of USD 25-30 million (Ferris and Kaganzi, 2008). Moreover, for more than 40 years it has been an export crop (Rahmeto, 2007). It is cultivated in a wide range of agro ecologies and farming systems including well-watered and drought-stressed areas (Asrat*et al*., 2009).

Despite the economic and food security importance of these crops, actual smallholder farm yields are by far below the potential production. For instance, the national average yield of common bean is 1.15 t/ha (2011 cropping season) while the potential yield at research stations and researcher managed farmers' field is 3.4 t/ha (CVR, 2012). There are various production constraints that contribute to the low yields of common bean.

Diseases are known to be the major factors, which directly or indirectly, affect the production of this crop in Ethiopia. Common bean is attacked by a wide range of diseases that affect leaf, stem, root, and seed. The major diseases that are threatening common bean production in Ethiopia include anthracnose [*Colletotrichum lindemuthianum*(Sacc. & Magnus) Lams.Scrib], rust (*Uromycesappendiculatus*), common bacterial blight (*Xanthomonas phaseoli*), halo blight (*Pseudomonas syringaepv*. phaseolicola), angular leaf spot (*Phaeoisariopsisgriseola*), Ascochyta blight (*Ascochytaphaseolorum*) and bean common mosaic virus. Fungal and bacterial diseases are among the main production constraints in the major bean growing areas of the country (Fininsa*et al*., 2002). The effect of diseases may be restricted to certain production systems, locations and cropping seasons (Habtu*et al*., 2009). Among the listed disease of beans in Ethiopia, common bacterial blight, rust, anthracnose and angular leaf spot are economically important (Fininsa*et al*., 2002).

Amongst the important and common fungal diseases affecting beans in the tropical and sub-tropical regions is angular leaf spot (ALS) caused by *Pseudocercosporagriseola* (Sacc.) Crous& U. Braun (Crous et al., 2006; Lima et al., 2010). It is the second important limiting factor after nitrogen deficiency in Africa causing yield losses of 40 - 80 % (Wortman et al., 1998; Muthomi et al., 2011). Some conditions favor disease spread through accelerating pathogen proliferation, premature defoliation, reducing photosynthetic capacity, and retarding the grain filling process which eventually reduces yield (Benett, 2005).

Also Another most important common bean disease, is anthracnose caused by ***Colletotrichum****lindemuthianum* is the most devastating seed-borne disease of common bean (Schwartz., 1983) Infested debris and soils are among the potential sources of primary inoculum. Sharma et al. (2008) reported maximum disease incidence and severity occurrence on highly susceptible cultivars on both seed-borne infection and background contamination. Also, the disease drastically affects the growth parameters and yield components in susceptible cultivars causing significant reduction in yield of both the crops raised from internally infected seeds and under background or surface contamination. Seed-borne infection causes more yield losses than background contamination. Further, the pod infection has direct effect on seed quality (Sharma et al. 2008). The pathogen causes an estimated yield loss of 63% in Ethiopia (Tesfaye, 1997) and 42.4% at Haramaya (Amin et al., 2013).

In western parts of Ethiopia angular leaf spot and anthracnose are serious problem which most destructive disease. Anthracnose is the most common disease of white seeded common bean due to high rainfall intensity and warm temperature and it makes common bean out of production (BARC, 2011). Previously, Mohammed and Somsiri (2005) reported that the intensity of anthracnose on white type common bean was higher at Bako. Therefore, we must find the solution to reduce it from being epidemic. The ideal and most economical mean of managing the common bean angular leaf spot and anthracnose disease would be the use of resistant genotypes. Thus, this activity was initiated with the following objective of to screen resistance, moderately resistance and susceptible Common bean genotypes against to Anthracnose and Angular leaf spot disease of common bean.

Materials and Methods

Description of the Study Area

The experiment was conducted in Bako Agricultural Research Center (BARC). It is located at 9º05’33.366 N latitude and 37º02’41.202 E longitude and at an altitude of 1654 m.a.s.l. the annual mean minimum and maximum temperature of the is 14.5^{0}C and 29.3^{0}C, respectively, while the annual rainfall is 1605mm.

Experimental materials and designused

121 common genotypes were used in the study. The treatments were arranged in simple lattice design in two rows for one genotype in two replications. The plot size was 3m x 0.8m, 1m and 1.5m, an inter-row and intra-row spacing of 40 cm and 10 cm, respectively.

Disease assessment

Disease Incidence: the mean percentage of infected leaves showing typical symptom of the disease per total leaves of plant units was assessed at ten days interval from the beginning of disease symptom. Both diseased and healthy plants were counted from the row plants and the percentage of disease incidence (PDI) was calculated according to Wheeler (1969) and ICARDA (1986):

$$PDI(\%) = \frac{Number of diseased plants}{Total number of plants inspected} x\ 100$$

Disease severity: was assessed from 8 per-tagged plants as the percentage of the total leaf surface covered with angular and cercospora leaf spots lesions on each expanded leaflet separately at regular intervals using 1-9 scale (Table 1) (Sarwar*et al.* (2006). The severity grades were converted into percentage severity index (PSI) according to Wheeler (1969) and ICARDA (1986).

$$PSI(\%) = \frac{\sum Individual numerical ratings}{(Total number of plants assessed x Maximum score in the scale)} x\ 100$$

Table 62: Percent of infection and scale for common bean anthracnose and leaf spot

Scale	Description
0	no visible infection rate
1	a few dot-like accountings for less than 5% of total leaf area
3	discrete spots less than 2 mm in diameter (6–25% of leaf area)
5	numerous scattered spots with a few linkages, diameter 3–5 mm (26–50% of leaf area) with a little defoliation
7	confluent spot lesions (51–75% of leaf area), mild sporulation, half the leaves dead or defoliated
9	complete destruction of the larger leaves (covering more than 76% of leaf area), abundant sporulation, heavy defoliation and plants darkened and dead

Source: (Ding et al., 1993)

Area under Disease Progress Curve (AUDPC)

The progress of angular and cercospora leaf spots was plotted over time using mean percentage severity index (PSI) for each genotype at each plot, and the PSI values were calculated AUDPC values (%-day) for each genotype according to the mid-point rule formula (Berger, 1981; Campbell and Madden, 1990).

$$\mathbf{AUDPC} = \sum_{i=1}^{n-1} 0.5(X_{i+1} + X_i)(t_{i+1} - t_i)$$

Where *Xi* is the disease severity of angular leaf spot and cercospora leaf spot at Ith assessment date, *Ti* is the time of the I th assessment in days from the first assessment date and *n* is the total number of disease assessments. Because severity was in percentage and time in days, AUDPC was express in proportion days.

Growth parameters

a). Days to 50% emergence: Days from planting to the emergence of 50% plants per row b). Days to 50% flowering: was recorded for each row when 50% of the plants in a plot flowered.

C). Days to 90% maturity: when 90% of the pod reached physiological maturity.

d). Plant height (cm): The height of plants from the ground to the tips of the plants were measured from eight randomly selected plants per plot at maturity.

Yield and yield components

a. Number of pod per plant: was counted on 8 randomly taken plants from 8 tagged plants and the mean was recorded as number of pods/plants.

b. Seed yield per row (g): The grain yield per row was recorded.

Adjusted yield per plot = (Fw (100-Amc) x)/RDW

Where: Fw = Field weight; Amc = Actual moisture content; RDW = Recommended dry weight

c. Total grain yield (t ha^{-1}): The grain yield in gram per row was calculated per hectare basis.

Data Analysis

The analysis of variance (ANOVA) was performed for the disease parameters (incidence, severity, AUDPC) and yields parameters using GenStat software (GenStat 18th ed. 21 May, 2015). DMR values was used to separate treatment means ($P<0.05$) among the treatments.

Result and Discussion

Disease assessments

Disease parameters, growth, grain yield and yield components showed significant variations except for days to 50% emergence. Therefore, results were separately presented for disease, growth, yield and yield components. Angular leaf spot (ALS), Cercospora leaf spot (CLS) and Anthracnose occurred in high incidence in 2021 cropping season. There was high variation disease incidence and severity observed between genotypes, it might be due to the difference in resistance levels of the genotypes. Angular leaf spot

ALS was first observed on susceptible genotypes 45 days after sowing (DAS) in 2021 and recorded after ten days.. There was a significant difference (P<0.05) between genotypes disease incidence. (Table 2). The mean final incidence ranged from 21.33% to 92.33% in 2021 cropping season. The highest (92.33%) angular leaf spot incidence was recorded on genotype G59 and L25, flowed by L108 (91.0%). during the 2021 cropping season.

Disease severity

The analysis of variance indicates that there were significant (p<0.01) differences among the genotypes, The mean final angular leaf spot disease severity ranged from 15% to 61.7% in 2021. The highest final angular leaf spot disease severity index was recorded G27 (61.7%) followed by G172 (60%).

Screening of genotypes done during in 2021 cropping season at Bako revealed that among seventy-seven genotypes, none was found immune or resistant, forty-nine genotypes found to be moderately resistant (10.1-20% severity), Sixty-one genotypes were found to be moderately susceptible (21.-50% severity). Twenty genotypes found to be susceptible (50.1-70% severity), (Table 63).

Area under disease progress curve (AUDPC)

There were significant (p<0.001) differences among genotypes and cropping season for AUDPC value. Area under disease progress curve of angular leaf spot ranged from 313.5%%-days to 1000.5%-days in 2021. The highest (1000.5%-days) AUDPC value computed from genotypes G65 followed by G69 (898.5%-days), (Table 2).

Cercospora leaf spot

Disease incidence

The disease was first observed on susceptible genotypes 47 days after sowing (DAS) in 2021cropping season Disease data recording started after eight days. There was a significant difference (P<0.05) between cercospora leaf spot disease incidence that ranged from 16.3% to 55% in 2021 cropping season. The highest (55.0%) incidence was observed on genotype G65, flowed by G14 (53.3%) during 2021 cropping season. Disease severity

There were significant (p<0.01) differences among the genotypes.The mean final disease severity ranged from 8% to 38.3% in 2021. The highest final disease severity index was recorded inG92 (38.3%) followed by G163 (37.7%).

Among 121 genotypes, three genotypes were found immune or resistant (1-10% severity). Thirty-two genotypes were found to be moderately resistant (10.1-20% severity). Eight-five genotypes were moderately susceptible. None of the genotypes were susceptible (50.1-70% severity) (Table 63).

Area under disease progress curve (AUDPC)

There were significantly (p<0.001) different variations among genotypes and cropping season for AUDPC value. The AUDPC ranged from 129%-days to 577.5%-days in 2021. Thehighest (577.5%-days) AUDPC value was computed from genotypes G164 followed by G73 (553%-days). (Table 2).

Table 63: Mean disease incidence, severity and AUDPC of common bean Angular leaf spot and cercospora leaf spot on common bean genotypes at Bako during 2021 main cropping season.

Genotypes	Angular leaf spot			Cercospora leaf spot		
	INC.	SEV.	AUDPC	INC.	SEV.	AUDPC
G10	35.7	15.7	397.5	28.3	16.7	223.5
G101	64.0	46.0	649.5	27.3	19.0	259.5
G107	40.0	16.7	421.5	26.7	13.0	265.5
G109	57.7	37.0	544.5	34.3	17.7	222.0
G11	71.3	28.0	516.0	20.3	15.3	241.5
G110	65.7	41.7	628.5	32.3	11.7	129.0
G115	54.7	17.3	433.5	39.0	26.7	337.5
G116	73.0	45.7	705.0	31.3	12.3	141.0
G119	73.3	44.7	601.5	33.0	18.0	238.5
G120	33.0	16.3	369.0	42.0	19.7	255.0
G121	57.7	18.7	409.5	29.0	17.3	181.5
G122	85.7	53.3	651.0	34.3	11.3	148.5
G127	39.0	18.0	471.0	42.3	25.0	330.0
G128	32.3	20.0	427.5	26.7	12.0	142.5
G137	67.7	42.0	622.5	40.3	19.0	249.0
G139	77.7	37.3	577.5	28.7	16.7	181.5
G145	29.7	18.7	361.5	22.3	8.0	180.0
G145.1	80.0	52.7	861.0	23.3	11.3	148.5
G147	25.0	18.0	403.5	42.7	23.3	352.5
G15	66.0	38.0	640.5	42.3	22.7	360.0
G152	19.7	18.7	402.0	36.7	25.7	382.5
G153	87.3	57.7	825.0	43.3	23.7	423.0
G154	87.0	55.7	841.5	40.3	28.7	294.0
G156	37.0	17.7	387.0	29.0	13.0	138.0
G157	84.7	57.7	796.5	16.3	9.7	174.0
G158	47.7	19.3	516.0	39.7	23.3	229.5
G16	54.0	40.0	643.5	21.7	20.0	286.5
G160	55.7	29.7	526.5	50.0	33.3	381.0
G162	65.7	49.0	735.0	32.7	27.0	319.5
G163	31.7	17.7	334.5	31.3	20.3	234.0
G164	62.7	41.7	693.0	53.3	37.7	577.5
G165	88.7	57.7	813.0	27.0	20.0	259.5
G166	69.0	52.0	834.0	41.3	23.7	300.0
G167	45.7	29.7	531.0	51.7	33.0	349.5

G168	30.3	19.0	393.0	33.7	23.7	261.0
G169	48.7	28.0	517.5	28.0	18.0	214.5
G17	87.3	58.7	871.5	28.7	15.7	210.0
G170	67.0	40.3	646.5	31.3	12.0	157.5
G172	84.0	60.0	825.0	25.7	11.3	210.0
G173	47.0	32.0	622.5	32.0	22.0	301.5
G174	71.0	40.7	708.0	50.7	28.0	373.5
G177	44.3	20.0	559.5	37.0	25.0	267.0
G178	67.0	42.0	687.0	39.3	24.7	298.5
G180	82.0	39.7	687.0	43.3	24.0	307.5
G19	87.3	57.3	1000.5	45.7	24.3	336.0
G2	74.3	50.0	793.5	43.3	23.7	348.0
G21	29.7	18.3	369.0	37.0	17.7	228.0
G22	40.7	25.0	472.5	27.3	17.0	219.0
G26	30.3	18.7	369.0	32.3	22.3	243.0
G27	91.7	61.7	934.5	43.7	27.3	324.0
G29	68.3	49.0	753.0	36.3	24.3	297.0
G35	25.7	19.0	444.0	38.0	25.0	279.0
G36	78.0	46.0	753.0	44.7	22.3	289.5
G38	21.3	19.3	517.5	33.3	19.7	300.0
G4	74.0	34.3	615.0	51.0	30.3	405.0
G40	35.7	20.3	472.5	40.3	24.7	297.0
G43	31.7	19.7	390.0	47.3	28.7	307.5
G46	33.3	19.7	409.5	47.0	34.3	519.0
G47	35.3	16.3	336.0	40.0	26.7	376.5
G49	42.3	25.7	486.0	55.0	37.0	414.0
G5	42.0	19.7	397.5	34.0	17.7	283.5
G50	82.7	44.0	804.0	31.0	20.3	282.0
G55	77.0	41.0	699.0	45.0	36.3	330.0
G59	92.3	46.0	759.0	30.3	17.0	280.5
G60	49.3	24.3	492.0	32.0	23.0	285.0
G62	44.7	18.3	361.5	34.3	22.0	283.5
G63	40.0	19.0	330.0	42.3	24.0	342.0
G65	37.3	17.3	313.5	41.0	27.0	357.0
G66	61.3	23.7	502.5	27.3	22.7	325.5
G66.1	64.0	48.0	768.0	43.0	26.7	358.5
G67	70.3	41.0	718.5	30.7	21.3	256.5
G69	87.3	50.7	898.5	33.7	18.3	265.5
G7	71.0	40.7	633.0	32.0	21.3	268.5
G70	70.7	41.7	559.5	35.0	25.0	306.0
G73	72.0	38.7	643.5	50.0	34.0	552.0
G74	53.7	19.3	415.5	27.3	15.0	171.0
G76	60.3	36.0	636.0	42.0	23.3	391.5
G79	51.7	22.3	477.0	34.7	25.7	366.0
G8	48.7	18.3	351.0	29.0	8.3	174.0
G80	34.0	19.7	349.5	34.0	29.0	393.0
G81	90.0	50.3	831.0	37.0	28.0	391.5
G82	39.7	19.7	394.5	43.0	27.7	354.0
G85	87.7	51.0	853.5	41.3	27.3	321.0

G86	44.3	18.3	337.5	47.0	26.3	330.0
G87	85.7	51.7	801.0	35.0	27.3	388.5
G89	49.0	19.7	472.5	45.3	22.3	303.0
G9	89.3	49.7	777.0	34.7	26.3	363.0
G92	88.3	50.0	751.5	45.7	22.3	321.0
G93	87.0	52.3	765.0	52.7	29.3	435.0
G96	51.3	19.3	393.0	31.7	17.0	180.0
G97	69.7	38.7	636.0	36.0	21.7	324.0
G98	67.0	41.7	681.0	40.3	22.7	259.5
G99	74.7	41.0	741.0	36.7	28.3	381.0
L102	59.0	30.7	534.0	34.0	21.0	316.5
L103	60.7	32.0	570.0	20.7	14.3	159.0
L108	91.0	56.0	799.5	28.0	20.7	256.5
L112	63.3	41.0	694.5	28.3	20.0	205.5
L117	67.0	33.7	603.0	30.0	22.3	243.0
L13	34.0	18.7	345.0	49.0	24.7	325.5
L141	61.3	38.7	597.0	42.7	30.7	403.5
L18	67.3	44.3	681.0	43.3	28.7	376.5
L24	66.7	32.7	621.0	52.7	38.3	405.0
L25	92.3	53.0	757.5	41.3	24.0	433.5
L28	49.3	18.0	342.0	35.0	23.0	291.0
L3	49.3	18.3	372.0	41.3	24.3	321.0
L39	60.3	32.3	550.5	28.7	23.3	259.5
L44	69.3	47.0	697.5	28.7	22.7	351.0
L45	60.7	41.3	711.0	35.0	26.7	354.0
L53	66.7	44.7	654.0	47.3	31.7	381.0
L54	52.3	17.3	361.5	53.0	32.0	441.0
L6	90.3	51.0	784.5	35.3	24.7	321.0
L61	56.3	29.7	517.5	41.3	28.3	352.5
L64	58.7	32.7	561.0	50.7	29.7	375.0
L72	71.0	47.7	709.5	37.3	23.7	300.0
L75	48.0	15.7	340.5	39.0	26.0	327.0
L83.1	61.0	31.0	469.5	41.7	27.7	328.5
L84	75.0	48.0	666.0	47.0	23.7	325.5
L88	46.3	18.0	352.5	33.0	21.3	319.5
L91	67.3	33.3	636.0	42.0	20.3	300.0
L94	66.0	54.3	834.0	47.3	36.3	546.0
Mean	60.3	34.5	587.6	37.2	23.0	303.0
LSD (P<0.05%)	10.48**	7.715**	115.24**	9.30**	6.745**	83.5**
CV	10.8	13.9	12.2	15.6	18.2	17.1

Growth parameters

There were significant ($P \leq 0.05$) differences on day to 50% flowering among all genotypes. The longest (days 51.3) period of flowering was recorded on G49, G97and L28 genotypes, while the shortest (days 41) period of flowering was recordedin the genotype G167. There were also significant differences ($P \leq 0.05$) indays to 50% pod setting and 90 % maturity. The longest (days 100) period of maturity was recorded on G164 while the shortest (days 86.67) period of maturity was recorded on G139 genotype (Table 64).

Yield and yield components

Data on yield parameters showed highly significant differences (P<0.01) among genotypes in the number of pods per plant, seeds per pod, 100 seed weight and yield kg per hectare (Table 3). There were significant differences (p<0.05) innumbers of pods per plant, number of seedsper pod ad hundred seeds weight among the genotypes. The highest number of pod per plant (25.2) was recorded on the genotypes G26 while the least number of pod per plant (6.73) was recorded by genotypes L108 (Table 64). The highest (26.6gram) hundred seeds weight was recorded from genotypes G162.

There was highly significant difference (p<0.001) on grain yield in Kg/ha among the genotypes. The highest (3093 Kg/ha) yield was recorded from genotype G35, flowed by G152 (2952 Kg/ha).

Table 64: Growth parameters, Yield and yield components of common bean genotypes at Bako during 2021 main cropping season

Genotypes	FD	PSD	MD	PH	PPP	SPP	HSW	G.Yld/kg
G10	43	53.33	92.33	61.8	14.43	3.947	23.93	2628
G101	43.33	54	92.67	66.33	9.63	3.493	21.7	1654
G107	47.33	56.33	95.33	58.53	13.1	4.193	20.27	2267
G109	49.33	59.33	95	65.93	9.33	5.027	24.2	1599
G11	42	54.33	89	59.4	10.27	4.457	22.43	1672
G110	43.67	54.67	94	53.53	8.37	4.507	22.6	1571
G115	46	55.67	88.33	58.13	15.07	3.293	20.5	1860
G116	44	54.67	95.33	40	7.4	4.187	23.63	1196
G119	49.33	56.33	87	55.53	10.2	4.077	23.6	1031
G120	46.67	57.33	98.67	48.07	12.17	4.167	22.93	2099
G121	45	55.67	95.33	70.1	16.17	4.26	21.43	1785
G122	45.67	57.33	99.33	42.07	12.4	4.28	22.97	1288
G127	44.67	54.33	91.33	48	11.6	3.653	25.1	2127
G128	48.33	57	91	53.13	12.93	3.377	22.93	2229
G137	45.67	55.33	93.67	52.34	14.33	3.9	22.87	1566
G139	48	56.67	86.67	51.47	12.53	3.667	24.7	1295
G145	50.67	59.33	90.67	45.93	14.4	4.333	21.13	2326
G145.1	48	59.33	93.33	38.27	11.53	4.08	21.07	1181
G147	49	57.33	96	55.64	15.4	2.667	25.67	2213
G15	46	57	94.67	61.93	10.23	3.133	23.03	1756
G152	49.67	60	93.67	69.2	21.67	3.313	19.23	2952
G153	45.33	54.67	96.67	63.67	11.93	3.043	19.73	1335
G154	46.67	57	98.67	44.6	10	3.8	23.6	1430
G156	49	60	99.33	51.13	13.33	4.833	21.97	2203
G157	46.33	57.67	92.33	47.47	9	3.347	21.5	1312
G158	44.33	54.33	89.33	58.13	14.47	3.457	20.47	2118
G16	43.33	53.33	94.33	53.33	15.8	3.17	23	1793
G160	49.33	61.33	94.67	53.6	14.27	2.757	19.67	2082
G162	42.67	52.67	84.67	50.67	9.73	3.583	26.6	1705
G163	46.67	56	94.67	55.4	11.8	3.337	24.03	2627

G164	47.33	56.67	100	65.07	14	3.987	21.6	2080
G165	46.33	56.67	95	35.67	11.07	2.917	21.27	1482
G166	41	53	88	53.87	14	3.487	22.77	1677
G167	41.33	52.33	93.33	55.87	16.4	3.83	27.6	1982
G168	47.67	56	92.33	54.6	14.93	3.003	22.7	2389
G169	46	56	95	56.8	10.07	3.45	20	1902
G17	51.67	55	95	60.93	10.6	3.813	20.73	1447
G170	48.33	58	91.33	65.87	13.53	3.343	19.83	1565
G172	45	57.67	97.33	52.4	7.53	4.217	21.9	1315
G173	46.33	56	97	75.6	16.13	2.54	21.17	2083
G174	46.67	58	96.67	52.87	12.57	4.15	20.07	1703
G177	47.33	59.67	93	58.4	12.07	3.32	21.4	1931
G178	45.33	55	91.67	48.93	13.67	4.547	24.17	1737
G180	48.33	58	97.33	67.8	11.67	3.513	20.43	1621
G19	46.67	56.33	94.33	40.87	10.33	3.27	21.63	1387
G2	44	55.67	91.67	51	10.33	3.847	22.5	1656
G21	43.33	54	94	56.4	14.87	4.287	24.6	1872
Gabisa	46.67	58.33	93	43.73	12.53	3.34	23.33	2387
G26	45.33	55.33	95.33	53.4	25.2	3.09	22.73	2284
G27	44	56	95.67	52.53	12.6	3.037	21.87	1510
G29	45	53.67	93.67	48.67	9.47	4.277	20.43	1676
G35	46.33	56.67	94	55.33	20.33	3.397	24.8	3093
G36	43	54	93.67	57.6	13.5	3.737	22.93	1776
G38	50	62.33	91	75.6	17	3.477	17.5	1918
G4	44.33	55.67	96	64.27	15.07	3.59	21.1	1767
G40	44.67	56	94.33	45.67	11.33	3.217	22.1	2073
G43	46.67	56	92	50.8	17.33	2.76	26.27	2115
G46	42.67	55.33	99	53.67	12.73	3.457	23.4	2116
G47	43.67	55.67	91.33	51.73	15.13	4.607	22.57	1982
G49	51.33	62.33	95.33	50.07	11.87	3.93	21.67	1990
G5	47	56	88.67	56.87	11	3.943	20.47	1901
G50	45.33	55	94	39.6	16.47	2.863	20.33	1748
G55	42	49.33	90.33	43.34	12.6	3.347	22.83	1704
G59	45.67	55.67	91	38.13	8.27	4.43	22.53	1523
G60	45.67	56	96.67	49.73	9.6	4.163	22.07	1814
G62	47	56.67	90	62.07	14.67	3.49	23.73	2820
G63	45.33	55	94	55.87	14.4	3.847	23.97	2662
G65	46	58.33	97.67	55.4	15.93	4.1	21.47	2243
G66	45	56	94.33	51.93	17.2	2.553	24	1914
G66.1	44.67	57.67	90.33	73.47	10.63	3.927	22.17	1671
G67	49.67	58.67	96	44.74	12.07	3.393	23.03	1810
G69	45.33	56	95.33	61.13	9.8	4.36	21.87	1307
G7	43	58.33	94.33	64.94	10	4.43	20.43	1799
G70	44.33	55.67	95.33	39.4	16.27	2.7	23.23	1818
G73	48	57.33	91	54.8	14.6	4.497	19.43	1804
G74	46.67	56	96	71.33	12.67	3.513	21.6	1933
G76	45.67	51.67	90.33	51.47	12.27	3.06	22.13	1679
G79	44.67	57.67	98.33	60.67	10.6	4.677	22.27	1953
G8	51	60.33	93.67	67.47	21.47	2.69	17.67	2619

G80	44	53.67	96.67	63	15.53	4.833	25	2293
G81	44	55	92	46.33	20	2.367	21.9	1406
G82	45	58	95.33	47.75	17.4	3.747	22.43	2171
G85	44.33	56.67	89.33	46.73	11.33	3.423	18.17	1379
G86	42.33	57	91.67	68.2	17.2	3.99	23.1	2409
G87	45	55.33	92	62.6	12.8	4	21.3	1538
G89	48.67	58.33	97.67	67.07	20.6	2.447	16.93	2236
G9	50	61.67	99.67	54.27	13.93	4.183	19.8	1567
G92	42.67	56.67	95	62.93	11.67	3.877	23.5	1683
G93	44	59	92.33	58	10.07	4.493	23.1	1352
G96	46	58.67	95.33	49.13	16.67	3.03	22.37	2218
G97	51.33	61.33	95.33	59.81	10.53	3.473	22.1	2039
G98	44.67	55.67	92.67	65.63	20.87	3.193	22.37	2029
G99	43.67	55.33	93	63.47	9.17	3.027	20.03	1586
L102	48	58	95.67	63.53	11.53	3.423	23.37	2007
L103	43.67	53	93.67	51.07	9.2	3.307	23.83	1942
L108	43.67	53.67	95.33	49.67	6.73	4.11	21.43	1149
L112	49	58.33	92.33	42.4	15.6	2.613	19.8	1678
L117	49.33	59	99.33	65.33	9.2	3.457	21.4	1657
L13	43.67	54.67	92	46.47	18	3.717	24.27	2504
L141	48.67	57.33	94.33	47.67	11.33	3.58	21.63	1748
L18	43.67	55.33	95.67	58.33	10	4.577	22.63	1778
L24	45.67	55.33	90.67	60.73	17.8	3.16	21.47	1639
L25	42	53.67	91.67	57.6	13.87	3.44	20.9	1251
L28	51.33	60.33	93.33	61.73	13.6	3.017	21.27	2304
L3	45	53.67	90.67	58.07	13.8	4.063	25.07	2290
L39	47.67	58.33	89.33	45.67	11.27	3.463	23.4	1951
L44	42.67	55.33	94.33	70.33	13.93	4.367	21.93	1621
L45	44.67	56	88.67	64.73	14.4	2.887	21.9	2110
L53	41.67	52	89.67	49.53	6.8	3.973	20.77	1320
L54	48.33	59	96.33	42.8	12.6	4.083	23.83	2542
L6	45	57.33	88.67	41.4	9.8	4.033	22.77	1429
L61	48	59.33	93.33	60	10.4	4.13	22.5	1828
L64	43	53.33	91.67	44.6	12.87	3.513	24.37	2156
L72	44.67	55	93	56.2	10.33	3.697	24.07	1847
L75	48	58.67	93	58.6	16.47	3.75	20.17	2387
L83.1	41.33	54	93.33	62.33	13.2	3.63	25.2	1883
L84	43.67	55.33	89	60.13	9.6	3.73	23.1	1597
L88	45	54.67	94.67	55.27	11.8	3.93	22.23	2483
L91	48	58	86.67	64.73	23.07	2.3	20.07	2048
L94	42	54.67	91.67	50.47	12.4	3.767	23.67	1676
Mean	45.86	56.39	93.47	55.3	13.16	3.66	22.22	1874
CV	6.3	4.3	8.3	19.2	20.9	19.3	8.8	18.2
LSD(p<0.05%)	4.6*	3.86*	5.73*	17.12**	6.75*	1.13*	3.13*	548.3**

Summary and Recommendation

Significant variation was observed in angular and cercospora leaf spot diseases resistance, growth, grain yield and yield components among the 121 genotypes evaluated at Bako. The study revealed that angular leaf spot and cercospora leaf spot were most important and dominant disease occurred on the screened common bean genotypes. Some common bean genotypes canbe used as potential source for resistance and better yield performances, and serve to develop superior high-yielding and disease resistant varieties. Around forty-six genotypes could be recommended for high grain yield as well as sources of resistance to angular and cercospora leaf spot diseases.

References

AsratAsfaw, Blair, M.W. and Almekinders, C. 2009. Genetic diversity and population structure of common bean (*Phaseolus vulgaris* L.) landraces from the East African highlands. Theoretical and Applied Genetics 120: 1–12.

BARC (Bako Agricultural Research Center). 2011. Bako Agricultural Research Center progress report of pulse crop team.

Bennett, R.A., 2005. Integration of Soybean rust research-USDA perspective. Agricultural Outlook Forum. US Department of Agriculture.

Beebe, S.E., Alma, V., Gonzalez, Judith, R., 2014. Research on trace minerals in the common bean. The United Nations University Food and Nutrition Bulletin 21 (4), 387–391.

Broughton, W.J., Hernández, M., Blair, M., Beebe, S., Gepts, P. and Vanderleyden, J. 2003. Beans (Phaseolus spp.) - Model food legumes. Plant and Soil 252:55-128.

Crous, P.W., Liebenberg, M.M., Braun, U. and Groenewald, J.Z. 2006. Re-evaluating the taxonomic status of Phaeoisariopsisgriseola, the causal agent of angular leaf spot of bean. Stud. Mycol. 55:163-173.

CVR (Crop Variety Registration), 2012. Ministry of Agriculture and Rural Development. Crop Development Department, Addis Ababa, Ethiopia.

FAOSTAT (Food and Agriculture Organization of United Nations), 2020. Dry Bean. Statistical Database. Accessed on 22 June 2021. http://faost at.fao.org/site/567/default.aspx#ancor.

Ferris S and Kaganzi E. 2008. Evaluating marketing opportunities for common beans in Ethiopia IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 7. ILRI (International Livestock Research Institute), Nairobi, Kenya. 68 Pp

Fininsa C, Yuen J. 2002. Temporal progression of bean common bacterial blight (XanthomonasCampestrispv. phaseoli) in sole and intercropping system. EurJ plant pathol 108: 485- 495.

Food and Agricultural Organization (FAO). 2007. Statistics of the Food and Agricultural Organization (FAO) of the United Nations, Rome, Italy. http:// faostat.fao.org.

Geil, P. G. and J. W. Anderson. 1994. Nutrition and health benefits of dry beans: A review. Journal of the American College of Nutrition, 13: 549-558.

Habtu A, Abiye T 2009. Disease management in low land pulse progress and possibilities for unintegrated approach pp: 141.

Lanza, E., T. J. Hartman, P. S. Albert, R. Shields, M. Slattery, B. Caan, E. Paskett, F. Iber, J. W. Kikendall, P. Lance, C. Daston and A. Schatzkin. 2006. High dry bean intake andreducedrisk of advanced colorectal adenoma recurrence among participants in the polyp prevention trial. Journal of Nutrition. 136: 1896-1903.

Lima, S.S., Abadio, A.K., Araûjo, E.F., Kitalima, E.W., Sartorato, A.and de Quieroz, M.V.2010. Mycovirus in Pseudocercosporagriseola, the causal agent of angular leaf spot in commonbean. Can. J. Microbiol. 56 (5): 359-365.

Mederos, Y., 2006. Quality indicators in bean grain (Phaseolus vulgaris).Cultural Tropics 27, 55–62.

Mohammed Yusuf and Somsiri, S. 2005. Seed transmission and epidemics of Colletotrichumlindemuthianum in the major common bean growing areas of Ethiopia. KasetsartJournal(Natural Science) 39: 34 – 45.

Muthomi, J.W., Muimui, K.K. and Kimani, P.M. 2011. Inheritance of resistance to angular leaf spot in yellow beans. A. C. S. J. 19(4): 267-275.

Pachico, D. 1993. The demand for food technology. In: Henry, G. (Ed.), Trends in CIAT commodities 1993, Centro Internacional de Agricultura Tropical, Cali, Colombia. pp. 60-73.

Petry, N., Boy, E., Wirth, J.P., Hurrell, R.F., 2015. The potential of the common bean (Phaseolus vulgaris) as a vehicle for iron biofortification. J. Nutr. 7, 1144–1173.

Schwartz RF, Pastor-Corrales MA, Singh SP 1983. New sources of resistance to anthracnose and angular leaf spot of bean (Phaseolus vulgaris L.). Euphytica 31: 741-754.

Sharma, P.N., Sharma, O.P., Padder, B.A. And Kapil, R. 2008. Yield loss assessment in common bean due to anthracnose (Colletotrichumlindemuthianum) under sub-temperateconditions of Northwestern Himalayas. Indian Phytopathology, 6: 323-330.

Singh, H. and Rao, M.V.1989. Area under the disease progress curve: Its reliability as a measure of slow rusting resistance. Plant Breeding, 103: 319-323.

RahmetoNegash 2007. Determinants of adoption of improved haricot beans production package in Alaba Special Woreda, Southern Ethiopia, Unpublished M.Sc. thesis, HaramayaUniversity, Ethiopia.

Tesfaye, B. (1997). Loss assessment study on haricot bean due to Anthracnose. Pest Management Journal of Ethiopia 1: 69-72.

Wortman, C.S., Kirkby, R.A., Eledu, C.A. and Allen, D.J. 1998. Atlas of common bean (Phaseolus vulgaris L.) production in Africa. Publication No. 297. CIAT- PanAfrican Research Alliance, Kampala, Uganda.