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Deriving appropriate pest management technologies for smallholder tomato (*Solanum lycopersicum* Mill.) growers: A case study of Morogoro, Tanzania

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IPM, pests, small holder growers, tomato

1 SUMMARY

The current standard farmer practice for insect pests and disease control in tomatoes is routine weekly pesticide sprays which are not always required. Field experiments were conducted at Morogoro, Tanzania to evaluate the effect of seven management practices (sub plots) on pest incidence and yields during May-September 2007 (normal production season) and October 2007 - February 2008 (off-season) using two determinate varieties CAL-J and Tanya (main plots) in a RCBD with five replications. Practices involving intercropping with *Vigna unguiculata* or *Cleome gynandra*, application of fertilizer or mulch were severely infested by insects particularly thrips (*Frankinlla occidentalis*) which averaged 30 insects/plant at 64 days after transplanting. The standard and integrated pest management (IPM) practices led to similar low levels of insect pest and disease control though in the IPM only 3 pesticide sprays were applied compared to 10 for the standard practice. In the normal season, disease incidences of early blight (*Phytophthrora infestans*), late blight (*Altenaria solani*), leaf spot (*Septoria lycopersici*) and leaf curl were low ($\leq$10%) except for fertilizer and mulch treatment where incidences were close to 50%. The greatest fruit damage ($\geq$50%) was ascribed to *Helicoverpa armigera*. Purple nutsedge *(Cyperus rotundus),* the most dominant weed, was initially controlled by pre-transplanting application of Round-up® and mulch suppressed the growth of the dominant broadleaf weeds *Digera muricata* (false amaranth)*; Amaranthus spp* (pigweeds) and *Commelina benghalensis* (wondering jew). In the normal season, tomato yields with current farmer practice were highest averaging 18.5 t/ha which was not significantly different (P=0.05) from mulch application (14 t/ha) followed by IPM (12.1 t/ha). Similarly, in the off-season crop, yields were highest and similar for mulch and standard practice (4.8 t/ha) followed by IPM (3.4 t/ha). Farmers selected mulch application and IPM for on-farm demonstration to verify production costs and benefits.

2 INTRODUCTION

Tomato is grown in many parts of Tanzania but the majority of farmers cultivate not more than one hectare per household (UMADEP, 2003). Tomato yields in the tropics vary widely (between one to 23 t/ha) compared to the temperate regions, where yields of 10 to 22 t/ha can be realized (Lanny, 2001). Yields are generally lowest in tropical Africa as a result of both abiotic and biotic factors of which the latter include primarily insect pests, diseases and weeds (Gielen *et al.*, 1996; Abate *et al.*, 2000; Tumwine *et al.*, 2002).

Recent survey results in Morogoro, eastern Tanzania, indicated that under current management practices, tomato yields vary greatly ranging from 2.2 to 16.5 tons/ha (Maerere *et al.*, 2006). The differences in yield levels were ascribed to cultural practices incorporating pest prevalence and pest management. According to CABI (2004), tomato yield losses in East Africa can be as high as 88% and pests account for 56% of that loss. However, yield losses of near 100% are common under heavy pest infestation of insects, diseases or weeds singly or in combination (UMADEP, 2003). Weeds compete for light, moisture and nutrients with tomato. Zimdahl (1980) showed that tomato weights were reduced by 50% in a situation where sufficient nutrients were supplied but weeds were not controlled.

A survey by Maerere *et al.* (2006) revealed that the current tomato diseases and insect pests management strategy is based on regular use of pesticides (89% of farmers surveyed) and two to three manual (hand hoe) cultivations for weed control. The total reliance on pesticides to control insects and diseases and, often without observing requirements for applicator safety and/or consumers, increases both the cost of production and the potential for health and environmental risks associated with pesticides.

The main objective of this study was to develop an efficient IPM package for tomato production under Morogoro conditions for possible dissemination to other tomato growing areas. The specific objectives were to identify and assess pest and beneficial insects' population dynamics under different pest management techniques; determine the efficacy of different management practices on major pests of tomato; and to determine yield response of tomato to pest pressure and management practices.

3 MATERIALS AND METHODS

3.1 Location and design of the experiment:

A field experiment was set up to evaluate seven pest management practices in tomato farming (Table 1). The experiment was conducted at Sokoine University of Agriculture (SUA) Horticulture Unit (6^o 05'S; 37^o37'E; 525 meters above sea level), from October 2006 to February 2007 (off-season for tomato production in Morogoro) and repeated in May-September, 2008 (normal season). Two determinate tomato varieties, 'CAL-J' and 'Tanya', were used in the study subjected to seven tomato production management practices. The treatment arrangement was a split plot with tomato cultivars as main plot treatments and management practices as subplot treatments on 4.8 x 3.6 raised beds. The experiment was laid out in a randomized complete block design (RCBD) with five replications. Subplots which received the herbicide (Round up® 360EC) treatment were sprayed seven days prior to transplanting. The herbicide was applied at the rate of 3 kg a.i/ha using a knapsack sprayer at a spraying volume of 400 l/ha.

All other subplots, except the untreated check, were cultivated manually (by hand hoe) one day prior to transplanting. Starter fertilizer (Table 1) was applied in designated subplots. Four week-old tomato seedlings were transplanted, one seedling per hole in rows 90 cm apart and an intra-row spacing of 60 cm was maintained to obtain a plant population of 18,519 plants/ha. After transplanting, soil on both sides was collected towards the planting row to create shallow ridges that facilitated furrow irrigation. All plots were watered to field capacity every two days using surface irrigation along the furrows (Plate 1).

Plate 1: General field layout of the first on-station experiment.

Table 1: Treatments/Management practices evaluated

	Treatment	Description
1.	Fertilizer application	Urea (46%N) was applied at recommended rate of 180 kg N/ha applied in three splits of 10 g/plant as basal application, 5g at beginning of flowering and 5g three weeks late.
2.	Mulching	Dried bermuda grass (*Cynodon dactylon*) at a thickness of 10 cm applied one day after transplanting
3.	IPM	Round up® herbicide (Glyphosate 360 EC) applied one week prior to transplanting at the rate of 3 kg a.i/ha to control existing weeds + insecticide (Karate 5% EC) and fungicide Ridomil applied at a rate of one cc in two cc of water and 2.4 kg a.i/ha, respectively, based on need.
4.	Intercrop with cowpea	Cowpea (cv. Tumaini) was intercropped in between rows of tomato. Cowpeas were introduced after the first weeding (2 WAT) and planted at an intra-row spacing of 50 cm.
5.	Current farmer practice	No basal fertilizer followed by application of Urea fertilizer (46%N) at 10g/plant after first weeding and another 10g/plant at flower setting + weekly applications of a mixture of fungicide (Ridomil) and insecticide at rates described in treatment 3 above.
6.	Intercrop with spider plant	Tomato intercropped with spider plant (*Cleome gynandra* L) (green stem). Spider plants directly sown in between rows of tomato at an intra-row spacing of 40 cm.
7.	Untreated check	No control measure on diseases, insect pests and weeds + no fertilizer application.

3.2 Assessment of insect pests and beneficial insects: Data on insect pests were collected once every week from a sample of six plants in the two central rows in each plot (Plate 2). Before flowering, scouting was done on the three uppermost full leaves (1st, 2nd and 3rd) from the tip and after flowering, the third leaf included was just below the first flower cluster. The same leaves were used for counts of insect pests and beneficial predators/insects. The first flowers were observed for presence (+) or absence (-) of aphids. After flowering, thrips were counted on five randomly selected flowers per plant. Medium-aged (4th, 5th and 6th) leaves were used for recording whitefly colonies and mites and for observing presence (+) or absence (-) of leaf miner infestation.

Plate 2: A mulched plot showing area marked for insect and disease scouting.

3.3 Assessment of diseases: The incidence of diseases was assessed on the six sample plants (Plate 2) by inspection on a weekly basis to determine the general impression of the diseases' distribution and severity. Three representative leaves in each sample plant were selected and scored for early blight, late blight and leaf spot diseases. Disease severity was scored on a scale of 1-4 where; 1=0% (no damage); 2= < 10% severity (low, a few spots); 3 = 10-50% (medium severity) and 4= > 50% (high severity).

3.4 Pesticide application: Pest counts from scouting were used to make decisions on the need to spray with an insecticide or fungicide in the subplots subjected to the IPM management treatment. The required pesticides were applied when at least three insects per plant were recorded or disease incidence was at least 10% on the sample plants.

3.5 Assessment of incidence of nematodes: Nematode infestation was assessed during the sixth harvesting schedule during the normal season at 14 weeks after transplanting (WAT). Five non-senesced plants were randomly uprooted from the two middle rows of each plot and washed using tap water to remove soil particles. The plants were inspected for presence (+) or absence (-) of root knot (galls). The number of infected plants was recorded as percentage.

3.6 Weed assessment: Weed counts were recorded twice; first at two WAT and at four WAT. Two quadrats of 0.5 m x 0.5 m were established, over the two central rows, and at least one meter away from both ends of each plot. All weeds in the quadrat were counted and recorded separately as grass, broadleaf or sedge. Dominant species in each weed group were recorded. Prior to the last harvest of tomatoes, weed top growth in each quadrat was cut at ground level and separated into the respective biological groups. The weed shoots were oven-dried at 80°C for 72 hours to obtain weed dry weight.

3.7 Yield and yield components: To determine tomato yields, fruits were harvested from the two centre rows on the six adjacent sample plants, three on either row. Fruits were considered ready for picking when 50% of fruits turned yellow or red. Harvested fruits were categorized as clean marketable fruits (smooth, glossy surface and firm skin) or unmarketable if they had symptoms of damage by insects, disease infection or other physiological disorder. The weights of marketable and unmarketable fruits were recorded separately.

3.8 Evaluation of treatments by farmers: Fifty tomato growers were brought to the field trial at the beginning of harvesting to evaluate the normal season (May-September) trial and make preliminary selection of promising management practices (Plate 3). A simple evaluation guide was used to determine the best three treatments for further evaluation in farmers' fields

3.9 Data analysis: Before proceeding with analysis of variance (ANOVA), insect and weed count data were subjected to square-root transformation and percentage of insect infested plants data was transformed using arc-sine (Gomez & Gomez, 1984). All data were subjected to analysis of variance using MSTATC statistical program (MSU, 1993) at P=0.05. Significant subplot treatment means were separated using Duncan's Multiple Rage Test (DMRT).

Plate 3: Farmers evaluating tomato pests management practices in the May-September on-station trial at Sokoine University of Agriculture Horticulture Unit

4 RESULTS AND DISCUSSION

4.1 Insects: Thrips (*Frankinnela occidentalis*) were the most abundant insect pests, attaining maximum infestation levels at 64 days after transplanting (DAT) which coincided with flowering and early fruit development (Fig. 1). In the normal season, infestation levels for whiteflies (Plate 4) and thrips were not significantly different between the two tomato varieties while in the off-season, significant (P=0.05) varietal differences for thrips' infestation were recorded at 64 DAT, when flowering began. Cultivar 'Tanya' hosted significantly more thrips (mean 58 insects per plant) than 'Cal-J' tomato (mean 8 insects per plant). This suggests that cultivar 'Cal-J' is more tolerant to thrips compared to cultivar 'Tanya'. In the same season, differences in thrips, aphids (*Aphis gossypii*) and bollworm (*Helicoverpa armigera*) counts were significantly influenced by management practices at 64 DAT (Table 2) and most of the insects were located on the third leaf (Fig. 2). These results suggest that scouting efficiency for insects can be enhanced by focusing more on the young parts of the tomato plant.

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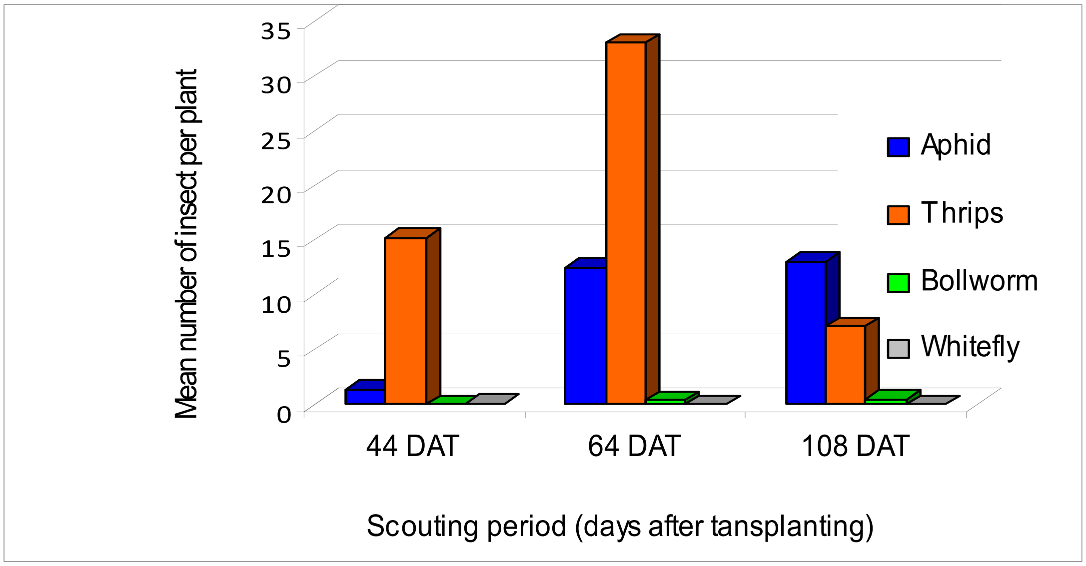

Figure 1: Mean variation in insect pests' counts over time on tomato cultivars CAL-J and Tanya.

Table 2: Insect counts per plant at second scouting (64 DAT) – normal season

Treatment	Mean number of aphids/plant	Mean number of Bollworms/plant	Mean number of Thrips/plant
Fertilizer application	24a	0a	40ab
Mulching	10bc	1a	42ab
IPM	7bc	0.1a	43ab
Cowpea intercrop	14ab	0.2a	30ab
Current farmer practice	4c	0.4a	32b
Untreated check	5c	0.3a	9c
Spider plant intercrop	24a	0.5a	36ab
Mean	12.45	0.357	33.053
SE ±	0.49	0.067	0.480
CV (%)	44.41	23.78	27.90

Means within the same column followed by the same letter(s) are not significantly different at (P≤0.05) according to Duncan's Multiple Range Test.

Aphids (Plate 5) infested tomato plants in all management practices tested but at variable levels of intensity. Tomatoes which either received the fertilizer treatment, mulch or were intercropped with either cowpea or spider plants were infested the most compared to other treatments (Table 2). Intercropping with spider plant increased the alternative host range for pests, but the intercrops failed to reduce infestation by thrips and aphids significantly compared to other treatments. This is contrary to results reported from other studies which suggest that intercrops which are infested by similar insect pests as the main crop may help lure the pest away from the main crop (Tumwine *et al.*, 2002; Cook *et al.*, 2007). In this study, higher aphid incidence on plants in plots with fertilizer treatments is attributed to improved vegetative performance of the crop. Plants growing vigorously tend to encourage aphid infestation by providing succulent material to feed on and shelter. The low aphid incidence in current farmer practice was a result of the routine insecticide spraying having direct contact effect on aphids.

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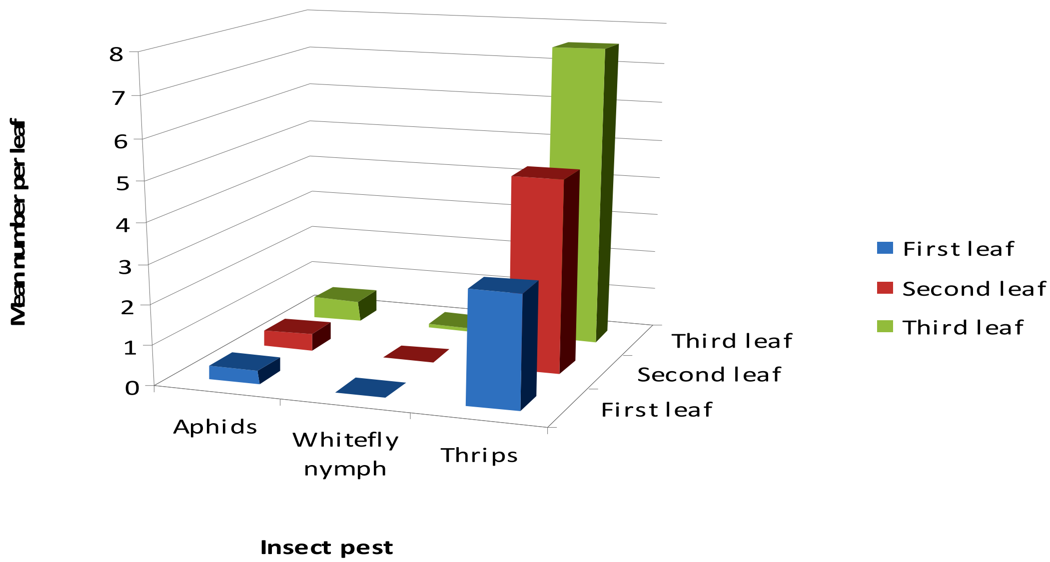

Figure 2: Major tomato insect pests and their distribution on tomato cultivars CAL-J and Tanya at second scouting (64 DAT).

Plate 4: Infestation of tomato leaf by whitefly

Plate 5: Aphids infestation on a tomato leaf

Overall, the current farmer practice had the lowest insect prevalence amongst the different management practices. The relatively low insect pests infestation observed in this treatment is attributed to the routine spraying. However, the IPM and mulch treatments were equally effective against thrips, aphids and bollworms (Plate 6) suggesting that the current farmer practice which involved weekly spraying of a mixture of insecticide and fungicide beginning two WAT is not necessary. Mulching crops with dried leaves and other plant material provides protected, cool and moist sites suitable for the breeding and resting of natural enemies such as predatory ants, spiders, centipedes and ground beetles (Frank & Liburd, 2005). Furthermore, the efficiency of the mulch treatment in reducing pest numbers is enhanced by reduced weed occurrence in mulched plots. Weeds, if left to grow, can serve as alternative hosts to plant pests.

Significant leaf miner (*Liriomyza spp*) (Plate 7) infestation was observed mostly during the normal season crop. Establishment of this pest occurred soon after transplanting and in all treatments except for the crop subjected to IPM and grower standard practice. Infestation under these two treatments was the least, attaining a maximum of only 20% i at 35 DAT (Fig. 3). Tomatoes subjected to the fertilizer treatment were totally infested throughout the sampling periods. Infestation levels for tomato under mulch, cowpea or spider plant intercrop or left untreated (check) were lower but not significantly different from the fertilizer treatment.

Plate 6: Tomato fruit damage due to bollworm

Plate 7: Leaf minor infestation

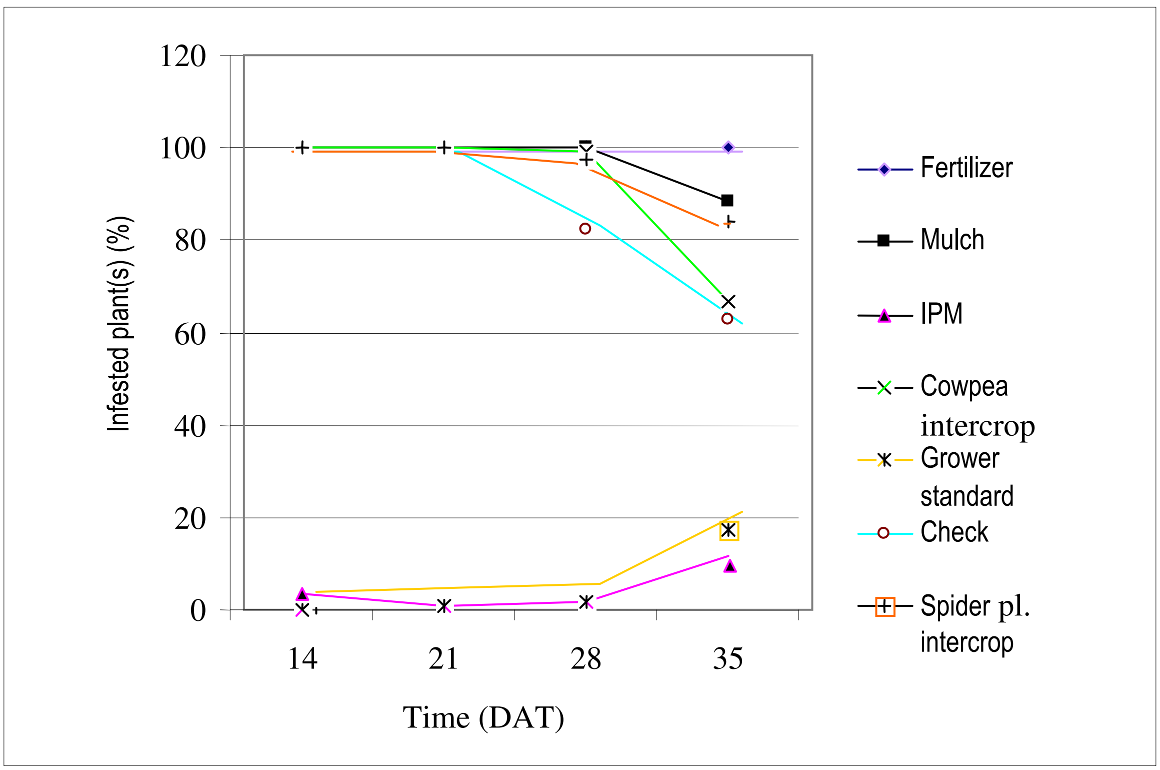

Figure 3: Mean incidence of Leaf miner over time on tomato cultivars CAL-J and Tanya under different pest management practices.

4.2 Beneficial organisms: Intercropping increased plant diversity, ground cover and created a relatively cooler micro-climate. The tomato-spider plant (*Gynandra gynandra*) intercrop had higher spider (*Stethorus punctillum*) and stinkbug (*Nezara viridula*) (Plate 8) populations averaging 13 and 3 insects per plant, respectively. Spider plants grew to a height taller than a meter and also flowered profusely attracting bees and butterflies. Both bees (*Apis mellifera*) and butterflies (*Lepidoptera spp*) were observed from 21 DAT on the spider plant intercrop plants. However, both bees and butterflies are much more mobile compared to the other beneficial insects, hence, it was not easy to obtain reliable counts. Ladybird beetles (*Cheilomenes sulphurea*) (Plate 9) preferred tomato plots that were mulched compared to other treatments. Mulch and intercrops provide suitable habitats for breeding

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and resting of natural enemies (Frank & Liburd, 2005). This supports the Natural Enemy hypothesis proposed by Root (1973), that increased plant diversity leads to increased densities of the former. The high prevalence of ladybird beetles in mulched plots also accounts for the reduced aphid infestation on this treatment. None of the beneficial predators/insects reported were recorded in plots subjected to the current farmer practice.

Plate 8: The Stink bug on tomato leaves

Plate 9: The Lady bird bettle on a tomato leaf

4.3 Diseases: Prevalent diseases in the normal season were early blight (*Phytophthrora infestans*) and late blight (*Altenaria solani*) (Plate 10) and differences between varieties were significant (Table 3). In the off-season both early and late blights, leaf spot (*Septoria lycopersici*) and leaf curl viral infection were recorded. Differences in severity were significant (P=0.05) among management practices and leaf curl was the most serious particularly in tomato intercropped with cabbage which attained close to 50% infection (Table 3). Leaf spot severity was highest in the untreated check or tomato intercropped with cabbage or spider plant compared to all other treatments.

Table 3: Diseases' occurrence and severity – average of normal season and off-season crops

	[1]Disease rating			
Treatment	Early Blight	Late Blight	Leaf Spot	Leaf curl incidence
Varieties*				
Tanya	2.8 a[2]	2.0 b	-	-
Cal-J	1.2 b	3 a	-	-
Mean	2.0	2.5		
SE±	0.32	0.31		
Management Practices**				
Fertilizer application	1.0 a	1.3 c	1.7 bc	3.7 b
Mulching	1.0 a	1.3 c	1.5 cd	3.8 b
IPM	1.0 a	1.3 bc	1.4 cd	0.6 c
Cowpea intercrop	1.2 a	1.6 a	2.1 a	2.4 a
Intercrop with spider plant	1.1 a	1.6 ab	2.1 ab	1.9 c
Spider plant intercrop	1. 0 a	1.1 c	1.2 d	0.4 c
Untreated check	1.0 a	1.7 a	2.4 a	0.6 c
Mean	1.0	1.4	1.8	3.9
Se ±	0.39	0.63	0.92	6.25

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[1]Rating scale of 1-4 where; 1=0% (no damage); 2= < 10% damage (low, a few spots); 3 = 10-50% (medium damage) and 4= > 50% (high damage); [2]Means in the same column for varieties and management practices, followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test. *Differences between varieties were significant only during the normal season (May-September); ** Differences between management practices were significant only for the off-season experiment (October-February).


Plate 10: Damage due to late blight

Generally, tomato plants were able to grow through the early blight infection. However, late blight infection which coincided with the beginning of the reproductive phase was observed to affect crop productivity. Severity of late blight and leaf spot were significantly ($P \leq 0.05$) higher in the intercropped treatments than in current farmer practice, mulch and fertilizer treatments. The results for the current farmer practice were expected. Fontem *et al.* (2003) similarly reported decreased severity of late blight on potato with increased number of fungicide applications. On the other hand, the low disease severity in plots treated with mulch is attributed to reduced rains/water splash which can enhance movement of spores from the soil back to the leaves as the water splashes on the soil. Similar effects would also arise from increased vegetative growth of plants as a result of higher nutrition due to fertilization. For mulch and fertilizer treatments, tomato growth was vigorous and less pre-disposed to infection. Our results are not in agreement with the findings by Fontem *et al.* (2003) who noted that unsprayed plots had higher disease infections than sprayed plots, regardless of the nutrition status.

4.5 Nematode incidence: The detection of nematodes in all treatments implies that nematodes are widespread at the study site. Nematode infection levels were relatively higher in the off season compared to the normal season crop (Table 4). In the off season differences between management practices were not significant while in the normal season nematode incidence was significantly higher with standard farmer practice treatment ($P \leq 0.05$) than in all other management practices. However, the widespread occurrence of nematodes suggests that nematode infection is another major constraint to tomato production that requires attention. Assessment of nematode occurrence and severity was only exploratory, done to determine the role of the pest in tomato production in the Morogoro area.

4.6 Weed prevalence: The most frequently observed weeds were sedges and broad leaf types (Table 5). The most dominant weed species were *Cyperus spp* (water sedge), *Amaranthus spp* (pigweed) and *Boerhaavia erecta* (spreading hog-weed). Weed counts were generally lowest when tomatoes were mulched for all weed species recorded. Mulches act as a barrier to the growth of many weeds but sedges and a few broad leaf weeds were able to grow through the mulch though at a much more reduced population. Weed biomass followed a similar trend (Table 5). In both seasons, the IPM treatment included a pre-transplanting treatment with Round-up and minimum soil disturbance which helped to keep the water sedge population low but not the annual broadleaf or grass weeds which subsequently re-established from seed around the tomato stand and made it necessary to do supplementary hand weeding. Tomatoes were regularly watered by surface irrigation hence water was equally available to weeds particularly those adapted to moist conditions such as sedges. Most weeds have higher water use efficiency than crop plants and tend to accumulate dry biomass at the expense of crops (Holm *et al.*, 1991). Given the difficulties associated with the control of sedges, the dominance of these weeds and their ability to re-grow through mulch and around tomato plant hills where irrigation water is applied implies that a supplementary weeding may be necessary by the time the tomato crop reaches fruit setting stage.

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Table 4: Nematode incidence (% infected plants)

Treatment	Infected plants (%) –off season	Infected plants (%) – Normal season
Fertilizer application	38.2 a	15 b
Mulching	39.9 a	13 b
IPM	21.7 a	13 b
Cowpea intercrop	32.5 a	18 b
Current farmer practice	26.6 a	26 a
Spider plant intercrop	47.7 a	15 b
Untreated check	29.4 a	10 b
Mean	32.71	16
SE±	6.61	3.02

Off season = October-February; Normal season = May-August. Means within the same column followed by the same letter(s) are not significantly different at P≤0.05 according to Duncan's Multiple Range Test (DMRT).

Table 5: Mean weed counts and dry biomass (normal season)

Treatment	Number of weeds/m²			Weed dry biomass (g/m²)		
	Grass weeds	Broadleaf weeds	Sedges	Grasses	Broadleaf weeds	Sedges
Fertilizer application	1.1c[1]	17 b	244.4ab	0.27bc	2.45c	30.58a
Mulching	0.0c	1.0c	2.3d	0.00c	6.63c	0.12c
IPM	11.0a	120a	54.4c	5.01a	29.87b	9.33b
Cowpea intercrop	2.0bc	41.6b	215.0b	0.94abc	6.68c	33.75a
Current farmer practice	1.6bc	20.6b	205.0b	0.71abc	2.19c	27.65a
Spider plant intercrop	2.5bc	19.1b	302.8a	0.66bc	2.85c	36.51a
Untreated check	5.8ab	110.9a	263.8ab	2.73ab	52.30a	36.85a
Mean	3.43	47.07	183.93	1.48	14.71	24.97
Se ±	0.34	0.95	0.91	0.27	0.57	0.38

[1]Means within the same column followed by the same letter(s) are not significantly different at P≤0.05 according to Duncan's Multiple Range Test (DMRT).

4.7 Tomato fruit yields: The majority of the tomato growers (98%) who evaluated the treatments prior to start of harvest selected the current farmer practice, mulch, and IPM, in that order, as the best three treatments based on the general appearance of the tomato plants and expected yields. Differences in tomato fruit yields between varieties were not significant (P≤0.05) in both the normal and off season crops (Table 6) though yields were generally higher in the normal season and consistently higher for Tanya than for Cal-J Mean marketable tomato yields, across varieties further indicated that during the normal season crop, tomato yields were significantly (P≤0.05) highest for current farmer practice, compared to the check (but similar (P≤0.05) to all other management practices. In the off season, mean marketable fruit yields across varieties were significantly highest) and similar (P≤0.05) in the mulch and current farmer practice (4.8 t/ha) compared to all other management practices. However, among the other management practices, yields for IPM (3.4 t/ha) and fertilizer (3 t/ha) were much higher compared to the spider plant and cowpea intercrops and the check, all of which gave marketable yields which were less than 50% of the

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yield levels for mulch and current farmer practice (Table 6). The high marketable yields in the current farmer practice were attributed to the regular control of insects and diseases through regular pesticide sprays. On the other hand, mulching contributed to a reduction in disease severity by minimizing chances of disease spores lying on the ground from being splashed back to the lower leaves posing the possibility of re-infecting the plant. In the mulched plots, weed growth was also reduced thereby reducing competition with the tomato plant.

The positive comparability of yield levels of current farmer practice, IPM and mulch are significant considering the fact that the IPM treatment required only 3 sprays compared to the 10 sprays that were applied to the plots that received the current standard farmer practice. It is evident from these results that the IPM and mulch management practices offer alternatives to the current farmer practice of routine pesticide application.

Table 6: Marketable fruit yields of tomato (t/ha)

Management practices	Normal season (May-September, 2007)			Off-season (October '07 – February '08)		
	Variety			Variety		
	Tanya	Cal-J	MEAN	Tanya	Cal-J	MEAN
Fertilizer (NPK)	9.8	5.9	7.9 ab[1]	4.0	2.0	3.0 c[2]
Mulch	15.0	13.1	14.0 ab	5.2	4.3	4.8 a
IPM	15.1	9.2	12.1 ab	4.2	2.7	3.4 b
Cowpea intercrop	7.6	8.1	7.9 ab	1.8	2.6	2.2 e
Spider plant intercrop	5.5	9.1	7.3 ab	1.3	0.5	0.9 f
Current farmer practice	18.0	19.0	18.5 a	4.8	4.8	4.8 a
Check	3.7	3.4	3.7 b	2.0	2.6	2.3 d
MEAN	10.7	9.7		3.4	2.8	
SE±	4.0			1.3		
CV (%)	75.8			67.1		

[1]Means in the same column followed by the same letter are not significantly different at P= 0.05 for Duncan's Multiple Range Test.

Yields were consistently lowest in the untreated check plots in both seasons. Uncontrolled weeds in the check plots smothered the tomato plants significantly reducing plant survival to less than 5% of the expected population. At the peak harvest period, damage by bollworms was the single most important source of loss of yield, accounting for an average of 52% of the unmarketable yield. The untreated plants also had the highest insect damaged fruits (64%) followed by intercrops (48%) while the current farmer practice and IPM had the lowest insect damaged fruits at 25 and 28%, respectively. Gnawing by rats and birds rendered up to 28% of the yield unmarketable while losses due to blossom end rot and late blight were much lower (Fig. 4).

Further evaluation of the mulch and IPM treatments is being undertaken on farmers' fields, incorporating cost-benefit determinations. The challenge lies on demonstrating profitable tomato production using either mulch including an aspect of pesticide application, on the basis of need, or IPM so as to convince farmers to reduce dependence on pesticides.

Overall, the efficacy of mulch, IPM and standard farmer practice, on pest control and yield, were comparable for both cultivars 'Tanya' and 'CAL-J'. Insect pests particularly aphids, thrips and bollworms and the late blight and leaf curl diseases are a significant threat to tomato production in Morogoro. Effective control of these pests is inevitable for attaining reasonable yield levels. Amongst weeds, sedges are the single most troublesome weeds but pigweeds and wandering jew are equally important. The current farmer practice requires that pesticides be applied at least 10 times while the IPM package has shown that it is possible to reduce the sprays to 3.

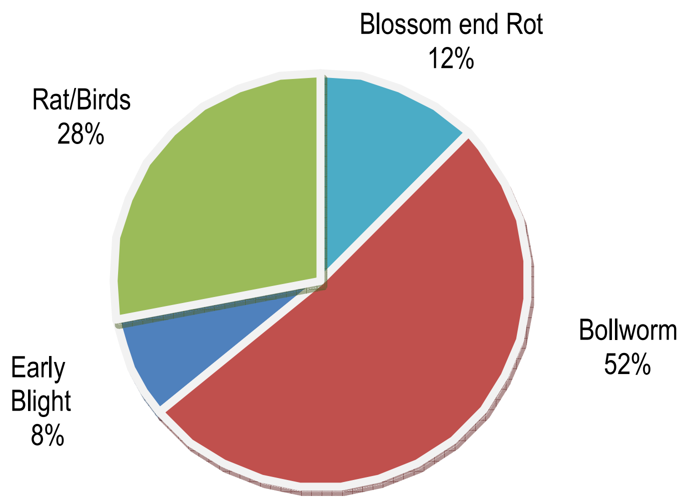

Figure 4: Causes of tomato fruit damage at peak harvest

As farmers are more likely to produce tomatoes during the normal season than during the off season, adopting the IPM package would provide an opportunity to produce tomatoes, using Tanya or Cal-J varieties, that have been subjected to reduced levels of pesticides without a significant reduction in yield compared to the current farmer practice. This is a significant reduction in the quantities of chemical pesticides used, and consequently, a reduction in input costs and health risks associated with pesticides' handling and use. The mulch and IPM treatments have been selected for further promotion and dissemination to tomato farmers in the study area.

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