Resource and Crop Management Research Monograph No. 20

Weeds in Intensive Cereal-based Cropping Systems of the Northern Guinea Savanna

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International Institute of Tropical Agriculture

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Preface

The Resource and Crop Management Research Monograph series is designed for the wide dissemination of results of research about the resource and crop management problems of smallholder farmers in sub-Saharan Africa, including socioeconomic and policy-related issues. The range of subject matter is intended to contribute to existing knowledge on improved agricultural principles and policies and the effect they have on the sustainability of small-scale food production systems. These monographs summarize results of studies by IITA researchers and their collaborators in the IITA Resource and Crop Management Division (RCMD). They are generally more substantial in content than journal articles.

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I

Introduction

In the West African savannas, the bulk of the agricultural production is undertaken by small-scale farmers whose labor force, management, and capital originate from the household. Cereals are the major staple food crops with sorghum (*Sorghum bicolor* (L) Moench) and millet (*Pennisetum americanum* [L.] Leeke) being traditional. Because of improved access to fertilizer and the development of improved varieties, maize (*Zea mays* L.) and upland rice (*Oryza sativa* L.) are becoming more prominent, particularly in the northern Guinea savanna (NGS). Other traditional major crops include groundnut (*Arachis hypogeae* L.), cotton (*Gossypium* spp.), and cowpea (*Vigna unguiculata* [L.] Verdc.) while crops such as tomato (*Lycopersicum* spp.), yam (*Dioscorea* spp.), and cassava (*Manihot esculenta* Crantz.) are minor.

Cereal-based cropping systems are predominant with one or several other crops in mixture or rotation with the cereals. Various constraints limit production in these cereal-based systems and the constraints may increase or decrease in importance as farmers change their management practices. Results presented in this monograph are part of a collaborative study between the Institute for Agricultural Research (IAR), Samaru, and IITA, Ibadan, on intensifying cereal-based systems. During this study, nematodes, *Striga*, and weed infestations were analyzed. The present document reports the results for weeds. Results on nematodes and *Striga* were summarized in separate monographs (Weber et al. 1995 (a,b).

Weeds in intensive cropping systems

Agricultural production tries to favor desirable crop plants through the suppression of undesirable plants, commonly called weeds. Diverse natural plant communities are shifted towards crop associations or pure crops which optimize the farmer's use of available resources for enhanced productivity.

Since changes in plant communities are influenced by environmental conditions, the composition of weed communities is usually a function of the agroecological conditions in a field. Cropping systems across the African savannas are currently experiencing rapid changes leading towards intensive land use, reduction of fallow periods, and changing crop preferences and cropping patterns. Species such as *Imperata cylindrica* are well adapted to intensive land use and often increase to become noxious weeds and major production constraints in the derived savanna and the southern Guinea savanna (SGS). In spite of the recent development of highly intensive cereal-based production systems in the NGS, little is known about the relationship between weed communities and the intensification process in this ecozone.

The general objective of a collaborative project between the Farming Systems Research Program at IAR, Samaru, and the Resource and Crop Management Division at IITA was to analyze the system dynamics and the sustainability of maize-based systems in the NGS. The specific objective was the identification and classification of weed problems and management practices at the farm-level. Changes in weed communities were monitored in order to identify those well adapted to different production systems and likely to become noxious weeds and major production constraints.

Research approach

The study of weed communities was part of an overall intensive field monitoring effort in 1990 in five villages of the NGS. Details of the production systems in these villages are summarized in table 1. Villages were selected based on a survey by Smith et al. (1994) and include different cropping systems within a zone of high land-use intensity and intensive cereal cropping in Kaduna and Katsina states of Nigeria. However, large differences exist among individual farmers and the fields within villages, as some farmers had started to adopt new maize production technologies up to 15 years ago whereas some fields were planted to maize for the first time in 1990. Between 10 and 15 fields were selected in each village and all the farmers' management practices were recorded without interference in any way. Soil samples were taken at the beginning of the season and crop performance was evaluated including stand counts, pest incidence, and crop yields. Details of the methodology for field monitoring have been presented elsewhere (Weber et al. 1992).

Percentage weed cover was estimated with a frame of 80 cm x 40 cm in 68 maize fields with sole or mixed cropping at 4 and 8 weeks after planting (WAP) at 12 evaluation points across the field diagonals. Weed species were analyzed from 59 fields at 10 to 14 WAP, i.e., several weeks after final field operations had been completed but 3 to 6 weeks before maize harvest. Ten sample points, each occupying the area 2 m long between adjacent rows, were evaluated along the field diagonals for all weed species present. Weed specimens were identified with assistance from the Soil Survey Unit of the Department of Soil Science, IAR, Ahmadu Bello University, using available keys (Rains 1968; Kranz et al. 1979; Akobundu and Agyakwa 1987; Terry and Michieka 1987) and were later confirmed at the herbarium of the National Animal Production Research Institute, Shika. As identification at the species level was difficult in some cases where the weeds were not yet flowering, all analysis has been done for the genus level. Variables measured in the field and used for analysis are presented in table 2.

Frequency of occurrence was calculated as the percentage of fields where a certain weed species was present. Within-field incidence is expressed for each field as the proportion of the 10 samples which contained the weed species in this field. It varies between 0 (no sample contained the weed) and 1 (all samples contained the weed). Only those genera with an incidence of 0.5 or above in at least one field were used for the subsequent analysis, as the other genera were considered to be of minor importance in all fields. Genera were grouped into weed associations by clustering those weeds which had a similar pattern of incidence across fields. For weed associations, a new mean incidence was calculated from the incidences of all genera in the group.

Table 1. Major cropping systems, the role of livestock, and market access in the five study villages in Kaduna and Katsina states of the northern Guinea savanna in Nigeria, 1990

Study village	Major cropping system	Role of[a] livestock	Access to[b] market
Katsina state			
Barde	sorghum/maize sorghum/cowpea maize/cowpea sorghum/cotton	oxen traction some cattle small ruminants	moderate
Borin Dawa	sorghum sole crop sorghum/cotton sorghum/maize sorghum/cowpea maize/cowpea	oxen traction some cattle small ruminants	good
Kaduna state			
Gwanki	maize sole crop maize/vegetable maize/sorghum sorghum/groundnut maize/cowpea	small ruminants	good
Kaya	maize sole crop maize/sorghum soybean sole crop yam sole crop	oxen traction some cattle small ruminants	good
Tsibiri	sorghum/millet sorghum/maize small ruminants maize/cotton sorghum/maize/cowpea maize/vegetable	some oxen traction	moderate

Notes

a Most farmers keep small ruminants at their houses; richer farmers keep cattle in some villages; oxen traction is present only in some villages, the animals and plows are owned by a few richer farmers, but are rented out to many others

b Market access is defined by distances from all-weather roads: good (not more than 2 km), moderate (not more than 5 km)

Table 2. Variables being used for the analysis and their definitions

Variable	Definition
% silt	% silt in soil at 0 to 15 cm depth
% clay	% clay in soil at 0 to 15 cm depth
Phosphorus	ppm P in soil analyzed as P-Bray-1
Potassium	meq K per 100 g of soil
% OC	% organic carbon content at 0 to 15 cm depth
% TN	% total nitrogen content at 0 to 15 cm depth
pH	soil pH in water
CEC	cation exchange capacity in meq/100 g of soil
Soil depth	cm soil depth as measured by penetrometer
Frequency of occurrence	% fields with presence of weed genus
Within field incidence	Proportion of samples of 2 m interrow space with presence of the weed genus
Weed cover	% soil surface covered by weeds at 4 and 8 WAP
Fertilization N	Amount of nitrogen applied as inorganic fertilizer in kg/ha
Time since first maize cropping	number of years since maize had first been planted in the field as a major crop
Frequency of cereal cropping	frequency of cereal planting in the field during the last three years expressed as a proportion of 1 (all three years)
Frequency of noncereal cropping	frequency of noncereal planting in the field during the last three years expressed as a proportion of 1 (all three years)
Crop density	number of maize plants grain yield (kg/ha)
Grain yield	at 13% grain moisture

Subsequently, weed communities were formed by clustering fields according to the similarity in the pattern of incidence of weed associations within the fields. Thus, weed associations represent weed genera which have similar incidences across all fields, whereas weed communities are combinations of weed associations according to the specific conditions in the field. Ward's cluster procedure was used, allowing up to 10% of the data to be trimmed as outliers (Byth and Mungomery 1981; SAS 1985). Factors contributing to the differentiation of weed communities were analyzed using discriminant and multiple regression analysis (SAS 1985).

II

Importance of Weeds

Weed incidence and severity

Most fields had low levels of weed cover, especially during the early crop growth stages (table 3). Weed coverage continued to remain below 12% in most fields up to maize grain filling, although it tended to be higher at this period in some fields in Borin Dawa, Kaya, and Tsibiri. The intensification of land use in the study area has generally resulted in increased efforts by farmers towards maximizing the productivity of the most scarce resource, i. e., per unit area through intensive crop husbandry practices, maintaining weed cover at low levels.

Table 3. Percentage of monitored fields in Kaduna and Katsina states, 1990, with different weed infestations at 4 and 8 WAP

Village	n[a]	Weed cover at 4 WAP[b]				Weed cover at 8 WAP[b]			
		<5%	6 - 12%	13 - 25%	>25%	<5%	6 - 12%	13 - 25%	>25%
Barde	12	50	42	8	0	50	42	0	8
Borin Dawa	12	92	8	0	0	33	42	25	0
Gwanki	12	75	25	0	0	42	58	0	0
Kaya	15	53	33	14	0	27	47	19	7
Tsibiri	15	33	53	0	14	53	0	7	40
Average		60.6	32.2	4.4	2.8	41.0	37.8	10.2	11.0

Notes

a Number of fields monitored

b Percentage of fields with an average weed cover within the indicated range

Multiple stepwise regression did not reveal any significant, quantifiable factor explaining the variance in weed cover at 4 WAP. Most fields were fairly weed-free at 4 WAP, indicating the farmers' awareness of the need for early weed control. The conditions for weed germination and development become more conducive as the season advances, with more reliable rainfall and appropriate temperature and relative humidity. Therefore, the weed infestation increases at 8 WAP (table 3). Weed cover at 8 WAP was associated with soil organic carbon content, nitrogen application, and the frequency of noncereal cropping during the last three years (table 4). The amount of nitrogen fertilizer used by farmers was negatively correlated with weed cover at 8 WAP, as the farmers' method of placing fertilizer on each crop stand favors the crop against the weeds. The availability of sufficient nitrogen also facilitated rapid growth and adequate crop cover to smother weeds. The negative correlation with noncereal cropping over the last three years indicates the advantage of crop rotation in weed suppression. Other factors influencing variability in weed cover can hardly be quantified. These include type of labor or rainfall intensity after weeding. For example, hired laborers tend to do a less thorough weeding than farmers themselves, as payment is made according to the area weeded not to the time used in weeding; a heavy rainfall after weeding allows many weeds to recover and reestablish themselves more easily, especially if the soil has not been carefully shaken off the roots.

Table 4. Multiple regression analysis of factors associated with weed cover at 8 WAP in monitored fields, 1990

Independent variable	Estimates for independent variable	Partial R-square	F-value	Probability
Intercept	19.294	-	6.29	0.015
Organic carbon (%)	22.407	0.14	11.99	0.001
N fertilization (kg/ha)	-0.126	0.25	16.91	0.001
Frequency of non-cereal cropping	-13.618	0.05	4.17	0.050

Maize yield is associated with weed cover at 4 and 8 WAP, although these variables explain only 8% of the overall variance of maize grain yields in farmers' fields (table 5). Even this association has to be interpreted with care, as farmers tend to reduce weeding activities on those fields which have low yield expectations for any other reason such as nematode attack, *Striga*, lack of fertilizer, or water logging. Thus, the yield losses observed in farmers' fields may not be completely due to the weed infestation, as other constraints may have caused the farmers to minimize crop management or to abandon the field.

Table 5. Multiple regression analysis of the contribution of weed cover to maize grain yield in monitored fields, 1990

Independent variable	Estimates for independent variable	Partial R-square	F-value	Probability
Intercept	-355.276	-	1.44	0.230
Plants/ha	0.076	0.54	68.83	0.001
Soil CEC	88.037	0.06	9.52	0.003
Weed cover at 4 WAP (%)	-24.721	0.03	4.90	0.031
Weed cover at 8 WAP (%)	-14.567	0.05	7.52	0.008

Weed management by farmers

There are four different weed management (WM) strategies in the area. They include practices of land preparation, planting, first and second weedings, and remoulding. Details of the operations in each WM are indicated in table 6. WM1 is based on no-tillage planting into the old furrow with thorough ridging towards the row at first and second weedings. It is a strategy whereby farmers try to use the first rains for planting and give the crop a considerable advantage in establishment over the weeds. This weeding practice is common in the *gicci* system as described by Elemo et al. (1990).

All other methods are based on intensive land preparation and ridging with the first rains, and subsequent planting with additional rains. The first weeding in WM1, WM2, and WM3 involves weed removal and thorough soil cultivation with hand-hoes, while in WM4 quick weed removal is done by hand with minor soil cultivation in order to save labor. It is followed in WM4 by reridging with oxen 1 to 2 weeks later. The second weeding is combined with reridging of rows in WM1, WM2, and WM4, whereas the reridging is an additional subsequent activity in WM3.

Table 6. Land preparation and weeding methods used by farmers in monitored fields in Kaduna and Katsina states, 1990

Weeding method	Land preparation	Planting	First weeding	Second weeding	Remoulding
1	none	in old furrow with first rain	from old ridge to the row	ridging to the row	may be done
2	ridging with first rain	on ridges	from ridge to the furrow	reridging to the row	may be done
3	ridging with first rain	on ridges	from ridge to the furrow	away from the row	reridging and remoulding
4	ridging with first rain	on ridges	reridging to the row	reridging to the row (some)	none

The use of the different weeding methods was similar across the villages, with a preference for WM2 and WM3. Farmers in Gwanki preferred WM1 because they have no access to animal traction and try to reduce labor-requirements for land preparation through no-tillage (table 7).

Table 7. Use of weeding methods (WM) by farmers in five study villages in Kaduna and Katsina states, 1990

Village	WM1	WM2	WM3	WM4
Barde	0	67	25	0
Borin Dawa	0	76	24	0
Gwanki	75	17	0	0
Kaya	0	47	33	20
Tsibiri	0	66	8	26

Note
For definition of weeding methods, see table 4

The first weeding was done within two weeks of emergence by all farmers, whereas the timing of late remoulding of ridges varied widely (table 8). Farmers in Barde and Kaya tended to cultivate larger fields and carried out most of their second weeding and reridging by oxen (table 1). They did not practice an additional late remoulding, as the available ridging implements do not allow oxen to enter the field later than 5 to 6 WAP.

Table 8. Timing of first weeding and last remoulding of ridges in monitored maize fields in Kaduna and Katsina states, 1990

Village	n[a]	Firstweeding[b]			Last remoulding of ridges[b]			
		<2 WAP	<3WAP	none	<6WAP	6 WAP	7 WAP	>7WAP
Barde	40	7.5	92.5	22.5	30.0	47.5	0	0
Borin Dawa	39	7.7	92.3	0	10.3	25.6	12.9	51.3
Gwanki	35	45.7	54.3	2.9	0	0	31.4	60.1
Kaya	31	0	100.0	0	80.7	12.9	6.5	0
Tsibiri	40	74.9	25.1	25.1	25.1	6.3	37.6	6.3

Note
a n = number of fields analyzed;
b % of fields with activity at indicated period in weeks after planting

The major difference among farmers' weeding methods at the first and second weedings is the direction of weeding: away from the maize row (towards the furrow) or from the furrow towards the row. The first-mentioned method requires a subsequent reridging towards the row; the second method combines the weeding with a reridging. Farmers based their preference for any method on agronomic reasons relating to soil water retention, prevention of lodging, efficiency of weed control, and effective fertilizer incorporation, as well as on economic reasons such as a reduction in labor requirements (table 9). The final choice is determined by farmers' resource endowments (labor, fertilizer) and biophysical conditions in the field (risk of drought, incidence of grassy weeds).

Table 9. Percentage of farmers indicating reason for weeding method practiced on their field

Weeding method	No. of farmers responding	Reasons indicated by farmers for weeding method					
		Cover roots, prevent lodging, reduce erosion	Reduced labor for remolding thinning, planting	Better water retnetion near plant base	Better weed control especially grasses	Fetilizer incorporation	Other reasons
First weeding to the row	34	65	12	3	9	6	5
First weeding to the furrow	33	0	52	24	12	6	6
Second weeding to the row	6	67	0	0	0	33	0
Second weeding to the furrow	37	5	27	0	47	11	10

III

Analysis of Weed Communities

In the field, 74 species belonging to 60 genera within 20 families were identified (table 10). About 40% of all genera observed at the locations belonged to the families of *Asteraceae* (10 genera) and *Poaceae* (14 genera). Six genera constituting 10% of the total *(Commelina, Ipomea, Kyllinga, Leucas, Dactyloctenium, and Digitaria)* were found in more than 80% of the fields and 13 genera *(Ageratum, Vernonia, Celosia, Commelina, Ipomoea, Fimbristylis, Kyllinga, Mariscus, Acalypha, Leucas, Dactyloctenium, Digitaria, Oldenlandia)* or 22% in more than 50% of the fields. Five species of *Eragrotis*, three species each of *Vernonia* and *Ipomoea*, and two species of *Commelina, Mariscus, Cyperus, Cassia, Chloris, Setaria, Hyphis, Physalis*, and *Oldenlandia* were identified in the fields, while only one species each was observed for the other genera. Identification of all plants to the species level was not possible as many had not yet reached the flowering stage at the time of observation. Therefore, the analysis is limited to the genus level.

Hussain and Karatela (1989) observed 275 plant species around Kano town which belong to 43 out of the 60 genera found in Kaduna and Katsina states in this study. The study in Kano did not provide information on frequency of occurrence and within-field incidence of the weed species, therefore further comparisons between the two studies are not possible. A study by Okafor and Adegbite (1991) in cowpea fields in the Bauchi area reports 21 weed genera which were all found also in the study villages in Kaduna and Katsina states. *Commelina* spp. and *Digitaria* sp. were among the most commonly found weeds in the Bauchi and Zaria studies.

Out of 38 genera occurring in at least one field at a within-field incidence greater than 0.5, only four, *Commelina, Kyllinga, Leucas, Digitaria*, have a mean incidence across fields above 0.5. The analysis of variance indicated a 53% contribution of weed x field interactions to the total variance (table 11). Thus, differences in incidence between fields are partly genera-specific, and the composition of weed populations varies significantly across fields. The subsequent classification included only those genera with an incidence above 0.5 in at least one field.

Classification of weeds

Weed genera which have a similar pattern of incidence across fields were grouped together and classified into weed associations (WA). Ten such associations were initially identified, based on the cluster analysis (figure 1). *Ipomoea, Eleusine, Dactyloctenium*, and *Leucas* had a unique pattern as visible in the dendrogram and were treated as single-genera "associations" in the subsequent analysis, while (for example) *Striga hermonthica* was associated with *Porphyrostemma, Alysicarpus*, and *Acalypha*, all of which are common weeds in the savannas.

Table 10. Weed species found and frequency of occurrence (% fields infested) as well as within-field incidence for each genus in monitored fields in Kaduna and Katsina states, 1990

Family	Genus	Species found	% fields infested	Within-field incidence[a] Mean	Max
Amaranthaceae	*Amaranthus*	*spinosus*	16.9	0.032	0.45
	Achyranthes	*aspera*	8.5	0.022	0.50
	Celosia	*laxa*	50.8	0.224	1.00
Asteraceae	*Acanthospermum*	*hispidum*	30.5	0.106	0.87
	Ageratum	*conyzoides*	74.6	0.442	1.00
	Chrysanthemum	*americanum*	5.1	0.015	0.38
	Ethulia	*conyzoides*	11.8	0.041	0.83
	Eclipta	*prostrata*	35.6	0.228	1.00
	Melanthera	*africana*	6.8	0.024	0.58
	Porphyrostemma	*chevalieri*	42.4	0.138	0.88
	Vernonia	*(galamensis ambigua nestor)*	61	0.279	1.00
	Synedrella	*nodiflora*	3.4	0.012	0.45
	Tridax	*procumbens*	6.8	0.011	0.25
Caesalpiniaceae	*Cassia*	*(obtusifolia nigricans)*	15.3	0.041	0.91
	Daniellia	*oliveri*	1.7	0.002	0.11
	Piliostigma	*thonningii*	3.4	0.003	0.10
	Sesbania	*sesban*	3.4	0.004	0.14
Cleomaceae	*Cleome*	*acilata*	1.7	0.008	0.45
Commelinaceae	*Commelina*	*(benghalensis capitata)*	96.6	0.733	1.00
Convolvulaceae	*Ipomoea*	*(aquatica, eriocarpa,* spp.)	84.8	0.425	1.00
Cyperaceae	*Cyperus*	*(esculentus, tuberosus)*	22	0.073	0.88
	Fimbristylis	*hispidula*	52.5	0.326	1.00
	Kyllinga	*squamulata*	100	0.893	1.00
	Mariscus	*(alternifolius, flabelliformis)*	72.9	0.416	1.00
Euphorbiaceae	*Acalypha*	*segetalis*	59.3	0.214	0.90
	Euphorbia	*hirta*	6.8	0.010	0.25
Labiatae	*Hyptis*	*(spaegera* spp.)	8.5	.040	0.80
	Leucas	*martinicensis*	91.5	0.685	1.00

Table 10. Contd.

Family	Genus	Species found	% fields infested	Within-field incidence[a] Mean	Max
Lytharaceae	*Ammania*	*baccifera*	3.4	0.009	0.80
Malvaceae	*Sida*	*rhombifolia*	3.4	0.006	0.22
Mimosaceae	*Leucaena*	*leucocephala*	5.1	0.007	0.20
Onagraceae	*Ludwigia*	*hyssopifolia*	35.6	0.154	1.00
Papilionaceae	*Alysicarpus*	*glumacus*	35.6	0.135	0.90
	Desmodium	*tortuosum*	1.7	0.002	0.12
	Indigofera	*priurena*	1.7	0.004	0.25
	Mucuna	*pruriens*	13.6	0.031	0.45
	Vigna	*racemosa*	37.2	0.086	0.62
Poaceae	*Brachiaria*	*stigmatisata*	1.7	0.006	0.20
	Chloris	*(pilosa,* spp.)	15.3	0.026	0.58
	Dactyloctenium	*aegyptium*	84.7	0.333	1.00
	Digitaria	*ciliaris*	98.3	0.837	1.00
	Eragrotis	*(pilosa, turgida, tenella, tremula, ciliaris)*	25.4	0.068	0.91
	Eleusine	*indica*	44.1	0.221	1.00
	Echinochloa	*colonum*	3.4	0.009	0.33
	Hackelochloa	*granularis*	5.1	0.007	0.20
	Paspalum	*orbiculare*	3.4	0.004	0.14
	Pennisetum	*pedicellatum*	5.1	0.009	0.37
	Setaria	*barbata*	37.3	0.077	0.50
	Cynodon	*dactylon*	11.9	0.061	1.00
	Rottboellia	*cochinchinensis*	15.3	0.027	0.50
	Andropogon	*gayanus*	8.5	0.026	1.00
Portulaceceae	*Portulaca*	*oleracea*	3.4	0.004	0.12
Rubiaceae	*Gardenia*	*erubescence*	15.1	0.007	0.25
	Mitracarpus	*villosus*	13.6	0.043	1.00
	Oldenlandia	*corymbosa*	71.2	0.473	1.00
	Spermacoce	*verticilliata*	28.8	0.378	1.00
Scrophulariaceae	*Striga*	*hermonthica*	47.5	0.151	0.91
Solanaceae	*Physalis*	*angulata*	32.2	0.080	0.58
	Schwenkia	*americana*	1.7	0.010	0.60
Tiliaceae	*Corchorus*	*tridens*	20.3	0.056	0.75

Note

a proportion of sampling points with presence of weed

Table 11. Analysis of variance for the incidence of 60 weed genera in 59 fields in Kaduna and Katsina states of the NGS of Nigeria, 1990

Source of variance	Sum of squares (ss)	% of total ss
Fields	8.823	3.2
Weeds	121.593	43.9
Weeds x fields	146.571	52.9

Fields were clustered based on weed associations in order to form weed communities (WC) (figure 2). Four weed communities could be identified. Significant differences existed among these four in the incidence of weed associations (table 12): WC4 had the lowest incidence of *Dactyloctenium*, WA13 *(Oldenlandia, Spermacoce)*, WA15 *(Ludwigia, Celosia, Eleusine,* and *Ipomoea)*. WC5 had the highest incidence of WA11 *(Vernonia, Eclipta)*. It also had a higher incidence of WA14 *(Kyllinga, Commelina, Leucas)* and WA15 *(Ludwigia, Celosia)* than WC4 and WC7 and a lower incidence of *Eleusine* than WC8. WC7 had the highest incidence of *Dactyloctenium*. WC8 was characterized by the highest incidence of WA13 *(Oldenlandia, Spermacoce*, and *Eleusine)*.

WC 4 was most common (49.2% of all fields) while WC5 occurred in 22%, and WC8 in 19% of the fields. WC7 was found in only 10% of the fields.

Determinants of weed communities

An attempt was made to identify factors which best differentiate fields with different weed communities. Variables describing soil characteristics, field management, cropping systems and history were used in a stepwise discriminant analysis in order to identify the most significant contribution. Five variables describing soil fertility status and cropping history were finally used in a nonparametric discriminant analysis. These were percentage soil organic carbon, meq/100g cation exchange capacity, frequency of cereal cropping during the last three years, frequency of noncereal cropping during the last three years, and time since maize production technologies were first introduced into the field. Soil organic carbon content and the frequency of cereal cropping were the most important parameters for differentiating weed associations, followed by the frequency of noncereal cropping and soil cation exchange capacity (table 13). None of the crop management practices in the year of study contributed significantly to the differentiation of weed communities. These included planting time, weeding time, fertilization amount and time, and cropping density and pattern.

The predictive power of the discriminant model was tested by evaluating whether the original grouping of fields with similar weed communities based on clustering coincided with the new assignment of fields according to the discriminant model (table 14). While WC7 was well differentiated from WC5, and WC8 was well separated from WC4 and WC5, 30% of the fields belonging to WC8 were wrongly classified into WC7. WC 4 could be well differentiated from WC5 and WC7, but 38% of its members were wrongly classified into WC8. No further improvements in the classification were found possible with the available data.

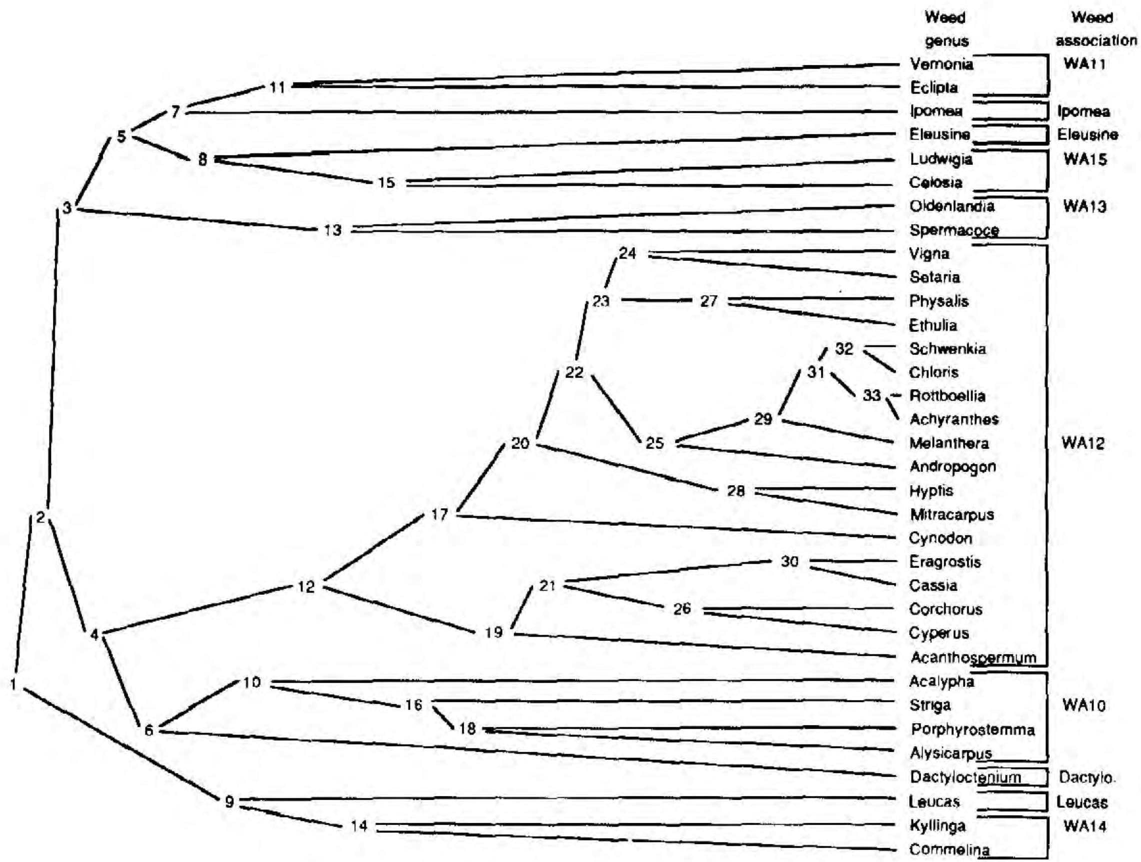

Figure 1. Dendrogram of clustering weed genera into weed associations according to their within-field incidence in 59 fields, research area NGS, 1990

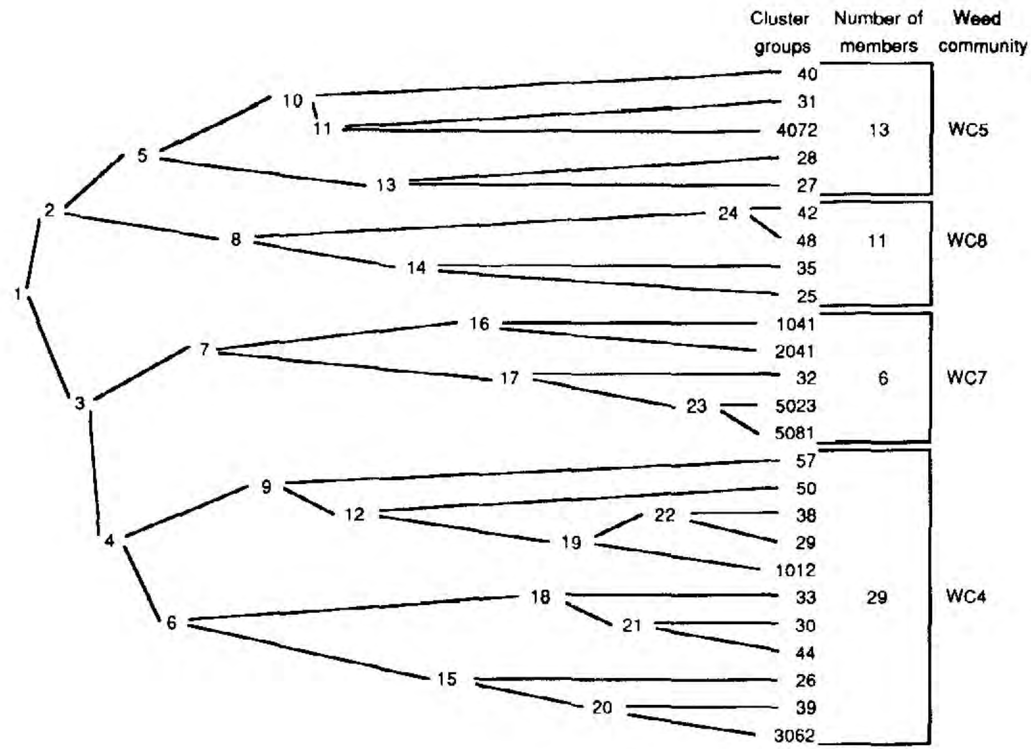

Figure 2. **Dendrogram of weed communities formed through clustering of fields with similar composition of weed associations across 59 farmers' fields in the NGS 1990; 4 weed communities (WC) were formed**

Table 12. Comparison of weed associations in weed communities for monitored fields in Kaduna and Katsina states, 1990

Weed association (WA)	Weed communities formed through field clustering												
	Weed community 4			Weed community 5			Weed community 7			Weed community 8			F-value
	Mean		SD	Mean		SD	Mean		SD	Mean		SD	
WA14	0.79	b	0.19	0.87	ab	0.10	0.59	c	0.37	0.93	a	0.07	xxx
Leucas	0.55	b	0.32	0.88	a	0.19	0.41	b	0.33	0.97	a	0.06	xxx
Dactyloctenium	0.22	b	0.19	0.32	b	0.30	0.95	a	0.08	0.29	b	0.21	xxx
WA10	0.17	a	0.17	0.17	a	0.13	0.22	a	0.12	0.07	b	0.07	o
WA12	0.04	a	0.04	0.05	a	0.04	0.05	a	0.05	0.07	a	0.04	n.s.
WA13	0.21	c	0.29	0.58	b	0.26	0.22	c	0.20	0.93	a	0.09	xxx
WA15	0.07	c	0.10	0.33	ab	0.31	0.14	bc	0.24	0.36	a	0.29	xxx
Eleusine	0.06	b	0.14	0.18	b	0.19	0.20	b	0.32	0.70	a	0.21	xxx
Ipomoea	0.25	b	0.22	0.68	a	0.22	0.37	b	0.30	0.62	a	0.25	xxx
WA11	0.09	b	0.13	0.73	a	0.22	0.16	b	0.23	0.17	b	0.14	xxx

Note
Values were transformed to arcsin for comparison. Different letters indicate significant differences between weed communities at $P<0.05$; o, xx, xxx indicates differences for $P<0.1$, 0.05, 0.01 for F-value

Table 13. Discriminant analysis of weed communities according to soil and field management characteristics in monitored fields, 1990

Parameter	Canonical coefficients for discriminant functions		Eigen value	Proportion explained[a]
	Function 1	Function 2		
Organic carbon (%)	1.128	-0.019	0.77	0.39
CEC (meq/100g)	-0.035	0.833	0.26	0.13
Frequency of cereal-cropping 1988–90	0.523	-0.259	0.42	0.21
Frequency of noncereal-cropping 1988–90	0.205	0.663	0.32	0.16
Years since first maize cropping 1988–90	0.265	0.068	0.19	0.09

Note

Function 1 and function 2 were developed through nonparametric discriminant analysis; function 1 and function 2 contribute 66.2% and 28.3% to the explained variance of the model

a Contribution of parameters to the explained variance of the model

Table 14. Comparison of original weed communities (WC) grouped according to cluster analysis with new grouping (NG) based on the discriminant model

Original community based on clustering	New groups based on discriminant model				Total
	NG 4	NG 5	NG 7	NG 8	
	% fields classified from WC into NG				
WC 4	47.6	9.5	4.8	38.1	100
WC 5	9.1	81.8	0	9.1	100
WC 7	0	0	100.0	0	100
WC 8	0	0	30.0	70.0	100
% error in classification	52.4	18.2	0	30.0	25.1

Additional factors which were not taken into account during this study may affect the frequency of occurrence and incidence of weeds. For example, the movement of cattle during the dry season, the frequency, amount, and type of manure applied during recent years or soil hydrological conditions affect weed distribution and incidence but were not measured in this study.

Mean values for the discriminant variables were compared in order to differentiate scenarios which determine the likely development of one or other weed community (table 15).

Table 15. Comparison of weed communities for discriminant variables

Weed community	n	% OC			CEC			CER 9088			N9088			M1st		
		Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD
WC4	21	0.52	b	0.14	5.10	b	1.34	1.29	a	0.38	0.32	a	0.30	9.62	a	5.22
WC5	11	0.71	a	0.17	7.23	a	3.98	1.56	a	0.37	0.21	a	0.27	10.36	a	7.55
WC7	4	0.53	b	0.05	8.03	a	3.73	0.80	b	0.51	0.47	a	0.38	8.75	a	7.63
WC8	10	0.44	b	0.09	5.64	ab	2.96	1.27	a	0.25	0.18	a	0.17	7.73	a	3.85

Notes
% OC = percentage organic carbon in soil; CEC = cation exchange capacity in meq/100g
CER 9088 = frequency of cereal cropping in last three years; N9088 = frequency of noncereal cropping in last three years
M1st = years since maize production was first introduced into the field n = number of fields in weed community
Mean = mean values; SD = standard deviation of mean
different letters indicate significant differences between means for $P<0.05$ based on a general linear modeling-procedure

- WC5, characterized by a high incidence of *Vernonia*, *Eclipta*, *Kyllinga*, and *Commelina*, was most common in fields with a long history of maize production technology and intensive maize/sorghum intercropping with a low frequency of noncereal crops during the last three years. Soils were moderately fertile.

- WC7 with a high incidence of *Dactyloctenium* was common in fields with a history of noncereal cropping in more than one out of three years. It was associated with soils of an increased cation exchange capacity and moderate levels of organic carbon.

- WC8 which was characterized by a high incidence of *Oldenlandia*, *Spermacoce*, and *Eleusine* was common in the most degraded fields of low organic carbon content and low cation exchange capacity. It occurred in cereal-dominated systems with a higher proportion of sorghum and a very low frequency of noncereal cropping.

- WC4 which was characterized by a generally reduced weed incidence occurred, like WC8, in rather degraded soils, but the cropping system included a higher proportion of non-cereal crops. The poor soil fertility and the smothering effect of noncereal crops is likely to contribute to weed suppression in these fields.

The analysis gave an insight into the development of different weed communities according to field conditions in the NGS. Maize-based systems with a high frequency of cereal cropping and low frequency of noncereal cropping tended to be dominated by weeds such as *Commelina* and *Kyllinga*. As soil fertility declined, *Vernonia* and *Eclipta* became more important. Increased frequency of noncereals in the cereal-dominated system was associated with reduced incidence of weeds such as *Leucas*, *Oldenlandia*, *Spermacoce*, *Ludwigia*, *Celosia*, and *Ipomoea*. Further diversification of cereal-based systems to obtain a reduced frequency of cereals would be likely to increase the incidence of *Dactyloctenium* in crop fields. The above analysis indicates likely weed communities for upland fields in intensified cereal-based systems of the NGS. Compound fields with the continuous application of manure and household residues as well as inland valley fields with different soils and hydrological conditions may have very different weed communities.

IV

Farmers' Perceptions

Most farmers in the study area practice mixed farming involving crops and livestock, although their major emphasis is on crop production. Hardly any land is devoted to fodder production, thus crop residues and other plants from the fields are used as fodder. The manure is returned to the fields. The more intensified a cropping system, the higher is the value of such fodder sources. As the use of weeds as fodder is common in the study area, and as farmers have to balance the value of weeds against their damaging effect on crop growth, farmers' perceptions of the importance and use of weeds were assessed.

Importance and control of weeds

Farmers in all villages were asked to bring those weeds from their fields which they consider to be important. Thirty weeds were brought and identified by farmers (table 16). Local names given by farmers in one village were cross-checked in other villages. In most cases, farmers differentiated weeds only up to the level of genera. Grasses were best differentiated as they are among the most commonly occurring weeds in intensified savanna farming systems. Most names were descriptive as (for example) *Bitche uta*, a hairy species, which causes itching on contact with human skin.

Eight genera were most frequently mentioned by farmers as being important and all of them were seen as increasing in incidence (table 17). Only *Eleusine indica* was mentioned by 33% of the farmers as a weed whose importance was decreasing. *Commelina* spp. were present at various levels of incidence in most fields, while *R. cochinchinensis* was found in only 15% of the fields, although it almost dominated one field totally. Okafor and Adegbite (1991) found *R. cochinchinensis* in the Bauchi area in only two out of 24 fields surveyed. *R. cochinchinensis* was mentioned by 40% of the farmers as a new weed on their fields. The species is indigenous to Asia and has been introduced into other continents where it tends to be a noxious weed in tropical savannas. It is also known as a weed of large-scale farms, where weeding is less intensive. Seeds are easily distributed by machinery and contaminated seed.

Farmers rated weeds using mainly two criteria of equal importance: (1) weeding and other crop management requirements, and (2) crop yield and quality. Of all the weeds identified as troublesome, *Kyllinga squamulata* was rated as least important for its effect on yield (table 18). Farmers observed some factors which contributed to the increasing importance of weeds (table 19). *Commelina* spp., *K. squamulata*, and *R. cochinchinensis* were observed to reestablish easily after weeding, if weeding was not done carefully or if adequate soil moisture after weeding allowed the plant to establish itself again. *Commelina* spp. and *K. squamulata* have vegetative propagules for reestablishment while *R. cochinchinensis* has plasticity for a renewed germination from seeds in the soil.

Table 16. Important weeds in the study villages in Kaduna and Katsina states and their names in Hausa, 1990

Hausa Name	Family Name	Genus	Species
Yao	Asteraceae	*Acanthospermum*	*hispidum*
Zarangode	Amaranthaceae	*Amaranthus*	*spinosus*
Balamsaya	Commelinaceae	*Commelina*	*benghalensis*
Yaryadi	Convolvulaceae	*Ipomoea*	*aquatica*
Yaryadi	"	*Ipomoea*	*eriocarpa*
Yaryadi	"	*Jacquemontia*	*tamnifolia*
Biiche uta	"	*Ipomoea*	sp.
Aya aya	Cyperaceae	*Cyperus*	*esculentus*
Aya aya	"	*Cyperus*	*tuberosus*
Aya aya	"	*Fimbristylis*	*hispidula*
Gyemu Kwadi	"	*Kyllinga*	*squamulata*
Tapasa	Caesalpiniaceae	*Cassia*	*obtusifolia*
Kai barawo	Labiatae	*Leucas*	*martinicensis*
Gidagi	Papilionaceae	*Alysicarpus*	*glumacus*
Wake gizogizo	Papilionaceae	*Mucuna*	*pruriens*
Kirikiri (Tsargo)	Poaceae	*Cynodon*	*dactylon*
Godegode	"	*Dactyloctenium*	*aegyptium*
Harkiya	"	*Digitaria*	*ciliaris*
Tuji	"	*Eleusine*	*indica*
Komaiya	"	*Eragrotis*	*tremula*
Kyasuwa	"	*Pennisetum*	*pedicellatum*
Dantania	"	*Setaria*	*barbata*
Gero tsunsun	"	*Setaria*	*pallidefusca*
Daudawa	"	*Rottboellia*	*cochinchinensis*
Sembia	"	*Andropogon*	*gayanus*
Tofa	"	*Imperata*	*cylindrica*
Anta Kuturu	Portulacaceae	*Portulaca*	*oleracea*
Monokuchia	Rubiaceae	*Spermacoce*	*verticilliata*
Dandana	Solanaceae	*Schwenkia*	*americana*
Lalo	Tiliaceae	*Corchorus*	*tridens*

Table 17. The most important weeds according to farmers' perceptions in the study villages in Kaduna and Katsina states, 1990

Weed species	Importance of the weed		Status of the weed		Trend of the weed	
	% responses positive	% villages positive	% responses old	new	% responses increase	decrease
Commelina spp.	15.9	100	65	35	90	10
Rottboellia cochinchinensis	15.2	80	60	40	84	16
Digitaria spp.	13.8	100	100	0	93	7
Eleusine indica	8.7	80	89	11	67	33
Cyperus spp.	8.0	80	100	0	100	0
Kyllinga squamulata	7.2	100	100	0	100	0

Table 18. Major reasons indicated by farmers for the importance of some weeds in the study villages in Kaduna and Katsina states, 1990

Weed species	Increased requirement for weeding (%)	Increased requirement for ridging, planting or harvest (%)	Reduced yield or harvest quality (%)
Commelina spp.	43	35	22
Rottboellia cochinchinensis	36	34	31
Digitaria spp.	31	38	31
Eleusine indica	35	35	29
Cyperus spp.	39	36	25
Kyllinga squamulata	59	41	0

Table 19. Percentage of farmers indicating reasons for increasing importance of weed species in the study villages in Kaduna and Katsina states, 1990

Weed species	Quick reestablishment after weeding (%)	Spreading with manure (%)	High seed production (%)	Not sure (%)
Commelina spp.	33	22	28	17
Rottboellia cochinchinensis	50	6	38	6
Digitaria ciliaris	21	50	14	14
Eleusine indica	17	17	33	33
Cyperus spp.	29	0	43	29
Kyllinga squamulata	38	25	25	13

Farmers associated the incidence of *Digitaria ciliaris*, which they frequently use for fodder, with the spreading of manure in the field. It also reestablishes through the stolons, but this is less important for farmers as they often remove the whole plant for fodder. The risk of spreading weed seeds with manure was confirmed by farmers in another interview on the effect of manure: all farmers interviewed associated an increased incidence of weeds with the application of manure (table 20).

Table 20. Percentage of farmers indicating the effect of manure on yield, drought risk, weed and termite incidence

Parameter	Number of responses	Farmers' response (%)	
		Increasing effect	Decreasing effect
Crop yield	51	100	0
Weed incidence	51	100	0
Drought risk	42	19	81
Termite incidence	46	80	20

Six methods were identified by farmers as efficient for weed control. Two of these, weeding with removal of weeds and weeding before seed shed, were mentioned as most important (table 21). Species of *Commelina*, *Digitaria*, *Kyllinga*, and *Cyperus* can easily reestablish themselves in the field through their vegetative propagules, which require to be removed from the field for complete control, whereas *Eleusine indica* relies only on seeds for its propagation. Thus, farmers considered weeding before seed shed to be more efficient for this species. However, most farmers did not have adequate resources to prevent weeds from flowering and seed shedding towards the later part of the season.

Six species were frequently mentioned by farmers as useful plants (table 22). The major use of all these plants was invariably for fodder. *Dactyloctenium aegyptium* was mentioned as having additional uses such as for mosquito-control and as construction material for houses.

In an open-ended, informal interview on soil fertility, more than half of the farmers recognized the incorporation of weeds into the soil during weeding and reridging as an important method for maintaining soil fertility whereas only 2% to 5% of farmers mentioned crop residue incorporation as an important method (table 23). The recognition of the incorporation of weeds as a method for soil fertility maintenance indicates that leguminous cover crops might be of interest to farmers. In addition to the weeds identified by farmers as being economically important in the study, we are aware that some of the identified weeds are also useful in the study villages. These include *Cyperus esculentus* for snack food, *Celosia laxa* and *Corchorus tridens* for vegetables, as well as *Mucuna pruriens* and *Cynodon* spp. for fodder. In the present study, however, these uses were not mentioned by farmers as important.

Table 21. Most efficient weed control for some major weeds as indicated by farmers for the study villages in Kaduna and Katsina states, 1990

Weed species	Plowing before planting	Weeding and taking weeds out of field	Incorporation of weeds in soil	Weeding before seed shed	Burning of residues	Planting of cover crops
Commelina spp.	0	48	0	43	5	5
Rottboellia cochinchinensis	25	40	5	25	5	0
Digitaria spp.	0	50	6	44	0	0
Eleusine indica	0	33	0	66	0	0
Cyperus spp.	0	56	0	33	11	0
Kyllinga squamulata	0	56	11	33	0	0

Note
Values indicate percentage farmers mentioning method of weed control as most efficient

Table 22. Weeds recognized as useful by farmers

Weed species	Considered as useful weed		% responses indicating a utilization of the weed			
	% responses	% villages	Medical use or deterrent for mosquitoes	Fodder for animals	Material for construction	Mulching
Digitaria spp.	29	100	0	97	3	0
Pennisetum pedicellatum	14	80	0	83	8	8
Commelina spp.	12	80	0	100	0	0
Alysicarpus glumacus	11	80	0	100	0	0
Eleusine indica	5	80	0	100	0	0
Dactyloctenium aegyptium	4	80	20	60	20	0

Table 23. Methods for soil fertility maintenance indicated by farmers in order of importance in study villages in Kaduna and Katsina states, 1990

Importance of method	Number of responses	Methods indicated by farmers					
		Use of fertilizers	Use of manure	Residue incorporation	Crop rotation	Weeding and weed incorporation	Other methods
First	66	47	35	5	6	3	4
Second	46	26	30	4	15	17	8
Third	40	23	15	2	15	45	0

Note
Information based on open-ended, informal interviews, when farmers were asked about the three most important methods for soil fertility maintenance in order of preference

V

Weeds in Intensified Cereal-Based Systems

Relevance for further research

The basic principles of integrated weed management have been well developed and described (see Akobundu 1987) although their application in practice needs greater emphasis. The present study contributes to the development and implementation of integrated weed management concepts for intensifying, cereal-based systems in the NGS. These production systems become increasingly important as land use intensifies across the savannas, with maize production expanding in many countries. The results of this study indicate a need for increased attention to the following findings.

1. Farmers in the study area differentiated up to 30 weed species and expressed clear perceptions about their importance and mechanisms of spread. Not all weeds are perceived as noxious plants. Some are considered to be useful components in the system. The higher the land-use intensity, the more farmers appreciate the contribution of weeds to fodder supply and soil fertility. Research on weeds and any companion plants such as cover crops should take into account the fact that farmers' perceptions about companion plants are partly a function of land-use intensity. For example, farmers appreciate many weeds as fodder plants, even important types such as *Digitaria* spp. and *Commelina* spp. This fact suggests that weed control methods which provide excellent, season-long weed control might not be acceptable to farmers in mixed farming systems, as long as no other fodder sources are available. Thus, cover crops which effectively suppress weeds without being a palatable fodder crop, might be rejected by farmers in mixed farming systems.

2. Ten weed associations and four weed communities could be differentiated in the study area. The incidence of the different weed communities was primarily determined by factors related to soil fertility and to cropping system and history. Weed communities become more specialized as land use intensifies, and as the cropping system becomes increasingly dominated by one crop or a few related crop species. Maize-based cropping systems with a long history since the introduction of maize production technologies, a high frequency of maize/sorghum intercropping, and a low frequency of noncereal cropping, tended to have a high incidence of weeds such as *Commelina* and *Kyllinga*. Both genera were rated by farmers as very important, in particular because they make weeding and reridging difficult and costly. As soil fertility declines, *Vernonia* and *Eclipta* become more important. An increased incorporation of noncereals into the cereal-

dominated system lowers the weed pressure at 8 WAP and reduces the importance of several species such as *Leucas, Oldenlandia, Spermacoce, Ludwigia, Celosia*, and *Ipomoea*. However, other species such as *Dactyloctenium aegyptium* are likely to increase in importance as noncereal crops increase in frequency against cereals. Several other species, especially *Ageratum, Fimbrystylis, Mariscus, Acalypha*, and *Digitaria* are widespread and belong to the common weed flora in most fields (table 24).

Table 24. Intensifying cropping systems, their general weed pressure and system-specific changes in weed community incidence and composition according to system characteristics

Cropping system	General weed pressure and major changes	Genera of high incidence
Intensifying cereal-based systems with a high land-use intensity	- grasses increase in incidence against broad-leaf weeds - annual weeds increase	*Digitaria* *Fimbristylis* *Mariscus* *Ageratum* *Acalypha*
Cereal-based cropping systems with a high frequency of noncereal crops	- moderate pressure - diverse weed community	*Dactyloctenium*
Intensified cereal-based systems with a high frequency of sorghum and maize cropping on soils of low fertility	- high pressure	*Vernonia* *Eclipta*
Intensified cereal-based systems with a long history of maize cropping and a high frequency of cereal cropping on soils of moderate fertility	- high pressure	*Commelina* *Kyllinga*

3. Farmers clearly recognize the need for intensive weeding and the prevention of seed shedding by weeds as the most important methods of weed control. Considerable efforts are devoted to achieve good weed control during the first 6 to 8 WAP. *Commelina* spp., *Rottboellia cochinchinensis, Digitaria* spp, *Eleusine indica, Cyperus* spp., and *Kyllinga squamulata* were recognized as the most important weeds, mainly because of the difficulty and additional cost which they pose for weeding and ridging rather than because of actual yield losses from these weeds. Farmers' rating is confirmed by the results of field monitoring which indicated excellent weed control in most fields and nil or minor yield losses caused by weeds.

However, farmers do not have the facilities to prevent weeds from flowering and seed shedding during the second half of the season as they devote their labor to maintenance, harvesting, and processing of crops. Weed control methods which prevent seed shedding of weeds after crop harvest and which are not highly labor-demanding are likely to be adoptable, as farmers are aware of the problem. The timing and method of weeding depend partly on the availability of animal traction. The presently available implements for weeding, the oxen-drawn ridger pulled by two animals, cannot be used in maize fields later than 5 WAP. The design of new implements which can overcome this constraint can make weeding more effective and increase the contribution of animal traction to farm work.

4. *Rottboellia cochinchinensis* was mentioned by farmers as a new and increasingly important weed. It can at present be found in only 15% of the fields. Its increase poses a serious problem to farmers and may lead to fields being abandoned. The control of the weed and efforts to prevent its spread with the movement of seed and livestock should be analyzed and transferred. It is unlikely that any relay-planted cover crops will be able to suppress aggressive grasses such as *R. cochinchinensis*. Such species will require special attention.

5. The analysis indicates a lower weed pressure and a reduced incidence of several species when more noncereals are integrated into the cereal-based cropping system. The replacement of cereal-dominated intercropping through crop rotations is likely to contribute to reduced weed incidence.

6. Weeds can serve as alternative hosts for pests of crop plants, but information on such relationships is scarce. *Setaria barbata*, which occurred in 37% of the fields, can be an alternative host for maize streak virus (Mesfin et al. 1992). The incidence of nematodes of the genus *Ditylenchus* is associated with the incidence of *Andropogon gayanus* in savanna fields (Weber et al. 1995a). Many other interactions, partly beneficial, occur between crops, weeds, and insects or diseases in the field. The integrated management of savanna systems will require an understanding of the major interactions in the ecosystem.

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