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Influence of tillage and cropping systems on field emergence, growth of weeds and yield of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.)

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Abstract

The effects of land tillage and cropping system on the pattern of weed seedling emergence, weed biomass production and yield of maize and cowpea were examined at Ilorin, in the southern Guinea savanna of Nigeria. Weed emergence occurred throughout the 2-12 weeks after planting (WAP) sampling period but peaked between 4 and 8 WAP. Tillage methods had limited effect on weed emergence, whereas cropping systems significantly affected weed emergence. A significantly ($p \leq 0.05$) lower number of weeds emerged in tractor ploughed, harrowed and ridged (PHR) plots compared with other tillage methods while higher weed densities and weed biomass were recorded in the sole maize and fallow plots than in the sole cowpea and maize/cowpea intercropped plots. While aggregate crop yields were significantly higher in the intercropped than in the sole plots, component crop yields were higher under the sole cropping than in the intercrop.

Keywords: Cropping system, intercropping, tillage method, weed growth, yield

Introduction

The need to provide food in the right quantity, quality and at affordable costs remains a priority in most of the developing world, where the bulk of agricultural production is largely in the hands of peasant farmers. Constraints faced by this category of farmers include the use of poor plant genetic materials and inadequate crop protection practices (Fadayomi, 1991). Weeds constitute a major pest with which farmers in West Africa must contend (Ayeni, 1991). In West Africa, uncontrolled weed growth has been reported to cause 40-90 % yield loss in cereals, 53-60 % loss in legumes, 50-53 % loss in oil seeds and 65-91 % loss in root and tuber crops (Ado, 2007). Farmers in this region spend more of their time weeding their crops, than in any other part of the world. Giampietro *et al.* (1992) estimated that about 70% of the farmer's labour is expended on weeding. It is also in this part of the world that high weed pressure on farmer's fields, inadequate and high cost of labour as well as the use of traditional hoe-weeding method by farmers, limit the farm size cultivated by farmers (Akobundu, 1996). In traditional agricultural systems, where herbicides are not used, most management practices are focused on the reduction of weed infestation (Derksen *et al.* 1996). For the development of improved weed management systems with a reduced dependence on herbicides, a quantitative insight of the population dynamics of weeds and their interaction with crops in needed (Labrada, 1996). Weed occurrence, composition and density are reflections of past and present agricultural practices (Froud-Williams *et al.* 1983). For example, the methods used for land preparation can cause damage to the soil and other land resources, which consequently affects the weed flora composition in the system. In the sub-humid tropics, conventional tillage involving disc ploughing, harrowing and ridging, is the predominant land preparation practice. The response of weed emergence to conventional, no-tillage and intensive farming system is well documented for temperate climates (Ekeleme *et al.* 2005). Shrestha *et al.* (2002) found that weed density was greater in conventionally tilled land than in no-tillage systems. These authors attributed the higher weed density to ploughing which could have brought weed seeds from lower soil profile to a depth that was favorable for germination and emergence. In West Africa, mixed and monoculture crop production are practiced extensively and weeds constitute a major constraint in both systems of production. Moody (1977) found that in Asia, crop associations of maize and groundnut, mung bean or sweet potato were excellent for reducing weed growth, yield losses and weeding time. He explained further that in a maize/sweet potato and maize/groundnut crop combination, weed growth was less than in sole cropped groundnut or sweet potato but higher than in sole maize. Researchers in CIAT (1979) reported that in intercropping systems involving cassava/beans, weed growth was reduced in Central America. They explained that with this result, frequent weeding of pure cassava was no more efficient in weed control than intercropping cassava with beans. Liebman and Dyck (1993) studied an intercrop system where a main crop was intersown with a 'smother' crop species and concluded that weed biomass in the intercrop was lower in 47 cases and higher in 4 cases than in the main crop grown alone. Ofosu-Anim and Limbani (2007) reported that intercropping okra with cucumber resulted in reduced weed infestation,

Table 1. Relative abundance of weed species encountered at the different study sites

Family	Weed species	LC	M	Relative	Abundance	
				Site I	Site II	Site III
Aizoaceae	*Trianthema portulacastrum* L.	A	B	-	-	0.006
Amaranthaceae	*Achyranthes aspera* L.	A	B	-	0.030	-
Asteraceae	*Aspilia africana* (Pers.) C.D. Adams	P	B	-	-	0.221
	Chromolaena odorata (L.) R.M.Kings	P	B	-	-	0.280
	Tridax procumbens L.	A	B	0.090	0.067	-
	Vernonia galamensis (Cass) Less.	A	B	0.136	0.065	0.084
Cleomaceae	*Cleome viscosa* L.	A	B	0.019	0.018	0.011
	C. rutidosperma DC	A	B	-	-	0.007
Commelinaceae	*Commelina benghalensis* L.	P	B	0.021	0.031	0.029
	C. diffusa Burm	A/P	B	-	0.018	-
	C. erecta L.	A/P	B	0.005	-	-
Convolvulaceae	*Ipomoea involucrata* P. Beauv	A/P	B	-	-	0.002
	I. vagans Bak	A	B	-	-	0.003
Cyperaceae	*Cyperus esculentus* L.	P	S	0.180	0.013	0.061
	C. rotundus L.	P	S	0.019	-	-
	C. tuberosus Rottb	P	S	0.006	0.209	0.095
	Fimbristylis littoralis Gaudet	A	S	0.016	0.025	-
	Mariscus alternifolius Vahl	P	S	-	0.002	0.147
	Pycerus lanceolatus (Poir). C.B. Cl	P	S	0.023	0.131	0.119
Euphorbiaceae	*Euphorbia heterophylla* L.	A	B	0.129	0.154	0.075
	E. hirta L.	A	B	0.052	-	-
	E. hyssopifolia L.	A	B	0.016	-	-
	Phyllantus amarus Sch. Thonn	A	B	0.030	0.018	0.015
	Croton lobatus L.	A	B	0.005	0.040	0.079
Fabaceae	*Crotalaria retusa* L.	A	B	-	0.001	0.001
	Desmodium salisifolium Poir	P	B	-	-	0.001
	Tephrosia bracleolata Guill & Per	A	B	-	-	0.013
Laminaceae	*Hyptis suaveolens* Poir	A	B	-	0.288	-
	H. lanceolata Poir	A	B	-	0.016	-
Loganiaceae	*Spigelia anthelmia* L.	A	B	-	-	0.001
Malvaceae	*Sida rhombifolia* L.	P	B	-	-	0.006
Nyctaginaceae	*Boerhavia coccinea* Mill	P	B	-	0.013	-
	B. diffusa L.	P	B	-	-	0.011
	B. erecta L.	A	B	0.002	-	-
Poaceae	*Brachiaria deflexa* (Schum.) C.E. Hubbard ex Robyns	A	G	0.127	0.152	0.173
	B. lata (Schum.) C.E. Hubbard.	A	G	-	0.127	0.578
	Cynodon dactylon (L.) Pers	P	G	-	0.215	-
	C. nlemfuensis (L.) Pers	P	G	-	0.251	-
	Dactylotenium aegyptium (L.) P.Beauv	A/P	G	0.066	0.140	-
	Eleusine indica Gaertn	A	G	0.035	0.335	0.287
	Imperata cylindrica Anders	P	G	-	0.129	0.406
	Paspalum conjugatum Berg	P	G	-	-	0.219
	P. orbiculare Forst	P	G	0.842	-	0.203
	P. vaginatum SW	P	G	0.003	0.181	-
	Rottboellia cochinchinensis (Lour) Clayton	A	G	0.023	0.271	0.305
	Setaria barbata (Lam) Kunth	A	G	-	0.006	-
	Digitaria horizontalis Willd	A	G	-	0.067	0.188
Rubiaceae	*Diodia scandens* SW	P	B	0.007	0.013	0.093
	Mitracapus villosus (SW) DC	A	B	0.187	0.137	0.008
	Oldelandia corymbosa L.	A	B	-	-	0.002
	Richardia brasilliensis Gomez	A	B	0.011	0.005	-

Table1. Continued						
Portulacaceae	*Portulaca oleracea* L.	A	B	-	-	0.081
	Talinum triangulare (Jacq) Willd	P	B	-	-	0.145
Solanaceae	*Physalis angulata* L.	A	B	0.005	-	-
Sterculiaceae	*Melochia corchorifolia* L.	P	B	-	-	0.001
Urticaceae	*Fleurya aestuans* (L.) ex Miq	A	B	-	-	0.002
	Pouzolzia guinensis Benth	A	B	-	0.002	-

LC = Life cycle, M= Morphological group, A = Annual, P = Perennial, S = Sedge, - = Absent

especially of broadleaf weeds in Ghana while Katsaruware and Manyanhaire (2009) in Zimbabwe reported that weed density and biomass were significantly lower when maize was intercropped with cowpeas than sole cowpeas. Therefore, adequate information on the pattern of weed emergence under both systems is important for making the best weed management decisions. The objective of this study is to ascertain if tillage methods and cropping systems significantly affect the time and pattern of field emergence of weeds, weed biomass production and yield of maize and cowpea in a southern Guinea savanna agro ecological zone of Nigeria.

Materials and methods

Site description

This study was conducted at the University of Ilorin Teaching and Research Farm during the late 2005 (June – October) and early 2006 (May – August) growing seasons. The farm is located at Bolorunduro, Ilorin, in the southern Guinea savanna ecological zone (9^0 29' N, 4^0 35' E) of Nigeria, and is 307 m above sea level. The area is characterized by a bimodal rainfall pattern with peaks in June and September and a dry spell between mid – July and August. The annual average rainfall of the area is 1,250 – 1500 mm and a mean temperature range of 19^0 – 33^0 C (Source: Geospatial Laboratory Database, IITA, Ibadan). The soil was a sandy clay loam, classified as a plinthustaffs with approximately 74.12 % sand, 5.54 % silt and 20.69 % clay, organic matter 2 % and pH 5.5.Three separate sites were used for this study. The site used in 2005 late cropping season (site I) was under continuous cropping between 2001 and 2004. Sites II and III were used for the 2006 trial. Site II, which was adjacent to site I, had been under continuous cropping from 2000 till the commencement of this study. Site III was located about 2 km down slope from sites I and II and was under natural fallow between 2000 and 2006.

Experimental layout

The experiment was laid out in a randomized complete block design (RCBD) with a split-plot arrangement and three replications. The main plots consisted of three tillage methods, which include: (i) tractor ploughed, harrowed and ridged, (PHR); (ii) tractor ploughed and harrowed (PH) and (iii) hand tillage with simple hoe (HT). The subplots consisted of four cropping systems, made up of a maize and cowpea intercrop (MZCP), a sole crop of maize (SMZ), a sole crop of cowpea (SCP) and a no- cropping (NCRP) treatment.

Field establishment

The vegetation cover of the experimental sites was slashed to ground level prior to carrying out the tillage operations. Thereafter, the appropriate plots were disc ploughed on 29th June 2005, harrowed and ridged on 8th July, 2005, while the hand tillage plots were cultivated on 7th July, 2005. In 2006, the plots were disc ploughed on 29th May (site II) and 6th June 2006 (sites III) while harrowing, ridging and hand tillage were done one week later, at each site. Maize (*Zea mays* L. variety, DMR SR), was sown, three seeds per hole at a spacing of 1.3 m x 0.3 m, on the ridges and 1.0 m x 0.3 m on the flat and later thinned to two plants per stand. Cowpea (*Vigna unguiculata* (L) Walp. variety, IAR 48) was sown, three seeds per hole at a spacing of 1.3 m x 0.25 m and 1.0 m x 0.25 m on the ridges and flat, respectively and later thinned to two plants per stand. Hoe-weeding was done at 3 and 8 weeks after planting (WAP), no fertilizer was applied to any of the crops in 2005, while NPK (20:10:10) fertilizer was applied in splits at the rate of 200 kg ha^{-1} at 3 WAP and 100 kg ha^{-1} at 7 – 8 WAP. The cowpea plants were sprayed with 1.2 kg ha^{-1} Karate® (cypermethrin 10 % EC) at weekly intervals for three weeks after commencement of flowering, to control foliage and pod insect infestations.

Data collection

Data on weed density and weed biomass were collected at 2, 4, 6,8,10 and 12 WAP. Weed seedling emergence was monitored in two scenarios. In one scenario, weed seedling emergence was monitored in the same fixed quadrats at each assessment in each sub plot, hereafter referred to as continuous emergence. In the second scenario, weed seedling emergence was monitored in different fixed quadrats at each assessment in each sub plot, hereafter referred to as discreet emergence. In both scenarios seedling emergence was assessed in two fixed 0.5 m^2 quadrats per sub plot. Weed seedlings in each quadrat were counted, pulled out and then separated into broadleaves, grasses and sedges. Thereafter, the number of weeds within each category was enumerated. The weed types were further identified to the species level using the weed identification manual of Akobundu and Agyakwa, (1987). Dry matter production by the weeds was determined from the harvested weeds within each quadrat, during each of the sampling periods. Samples from the same plot were bulked and oven-dried for 24 hours at 80^0C to a constant weight.

Data analysis

Data on weed density, weed biomass and weed types, were subjected to analysis of variance, and where F – ratios were significant ($P < 0.05$); means were separated using the Fisher's protected least significant difference. The composition of the weed flora was analysed by calculating the relative abundance (RA) of each species within each experimental unit as follows: RA = (RD + RF) / 2, where RD (relative density) = number of a weed species per unit area (within a quadrat) in the plot divided by the total number of weed species within the same

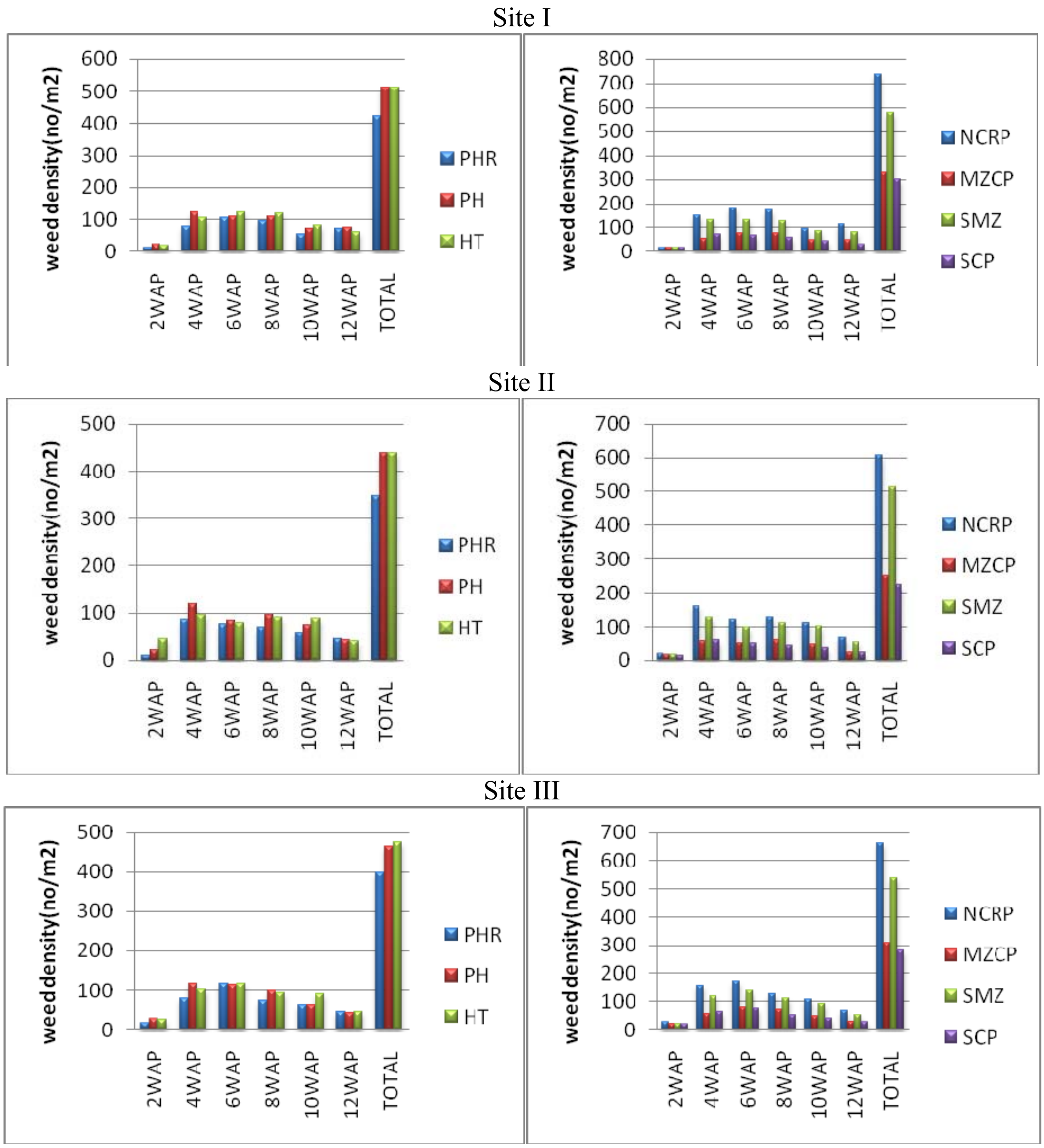


Fig 1. Effect of tillage and cropping system on weed seedling population in the continuously sampled quadrats

unit area (quadrat); and RF (relative frequency) = proportion of quadrat in which the species was present per experimental unit divided by the total frequency of all species in the experimental unit (Okore *et al.* 2001).

Results

Weed Species Composition

A total of 57 weed species, belonging to 42 genera, within 20 families, were identified throughout the study period (Table 1). About 48% of all the genera observed at the various sites belonged to the families of *Poaceae* (9), *Cyperaceae* (4), *Euphorbiaceae* (3) and *Rubiaceae* (4). Fourteen species, representing 25% of the total weed species were found at the three trial sites whereas 11 species (19%) and 32 species (56%) of the total occurred in two trials sites and one trial site, respectively. *Paspalum orbiculare, Mitracarpus villosus, Vernonia galamensis, Euphorbia heterophylla and Brachiaria deflexa* had the highest relative abundance in the 2005 trial (site I), while *Eleusine indica, Hyptis suaveolens, Rottboellia cochinchinensis and Cynodon* spp. had the highest relative

Table 2. Crop biomass and grain yield for sole stands and intercrop of maize and cowpea

Cropping system	Site	Crop Maize	Biomass Cowpea	(gm^{-2}) Total	Grain Maize	Yield Cowpea	(tha^{-1}) Total
	I						
Sole maize		47.81	-	47.81	1.17	-	1.17
Sole cowpea		-	68.23	68.23	-	1.31	1.31
Maize/cowpea		36.66	68.03	104.74	0.57	1.07	1.64
LSD(0.05)		12.83	NS	6.36	0.089	0.358	0.151
	II						
Sole maize		77.02	-	77.02	1.59	-	1.59
Sole cowpea		-	170.06	170.06	-	1.79	1.79
Maize/cowpea		57.87	122.96	180.83	0.88	1.21	2.09
LSD(0.05)		11.48	3.23	8.39	0.117	0.115	0.078
	III						
Sole maize		66.86	-	66.86	1.60	-	1.60
Sole cowpea		-	124.27	124.27	-	2.49	2.49
Maize/cowpea		66.01	78.75	144.76	1.42	1.25	2.67
LSD(0.05)		NS	17.15	10.86	0.086	0.338	0.149

abundance on site II and *Brachiaria lata, Imperata cylindrica, Rottboellia cochinchinensis, Chromolaena odorata and Eleusine indica* recorded the highest relative abundance on site III. There was a higher number of weed species in site III which was cultivated after 6-years natural fallow compared to sites I and II which were cultivated after 4 and 5 years continuous cropping respectively. In addition, broadleaf weeds were more abundant than grasses in all of the trial locations.

Weed Seedling Emergence

Tillage Effects on Weed Emergence

For continuously sampled quadrats, there was no significant effect of tillage system on weed emergence except at 4 WAP in site I, 8 WAP in site II and 2 & 8 WAP in site III. In all situations where tillage systems significantly affected weed seedling population, PH plots had 35-36 % of total weed seedlings emerged, which were similar to those obtained in HT plots and significantly higher than 28–30 % obtained in the PHR plots (Fig.1). For the discreet sampled plots, tillage method had no significant effect on the weed seedling population at any of the sampling periods (Fig. 2). In the continuously sampled quadrats, weed emergence increased from 2 WAP and peaked at either 4 WAP (site II) or 6 WAP (sites I and III), and decreased gradually thereafter. In the discreet sampled quadrats, weed seedling emergence peaked at 4 WAP and remained almost the same until 8 WAP(Fig.3).

Cropping System Effects on Weed Emergence

Weed seedling emergence was significantly affected by cropping system in all of the trial sites, except at 2 WAP in site II for the continuously sampled quadrats and sites II and III for the discreetly sampled quadrats (Fig.1, 2). In the continuously sampled quadrats, the uncropped plots (NCRP) had 37-38 % of the total weed seedling emergence at all sampling periods and trial sites while plots cropped to sole maize (SMZ) recorded 30-32 % of weed seedlings emerged. The number of weed seedlings recorded under maize/cowpea (MZCP) and sole cowpea (SCP) cropping system were similar and significantly lower than those in the uncropped and sole maize cropping systems.

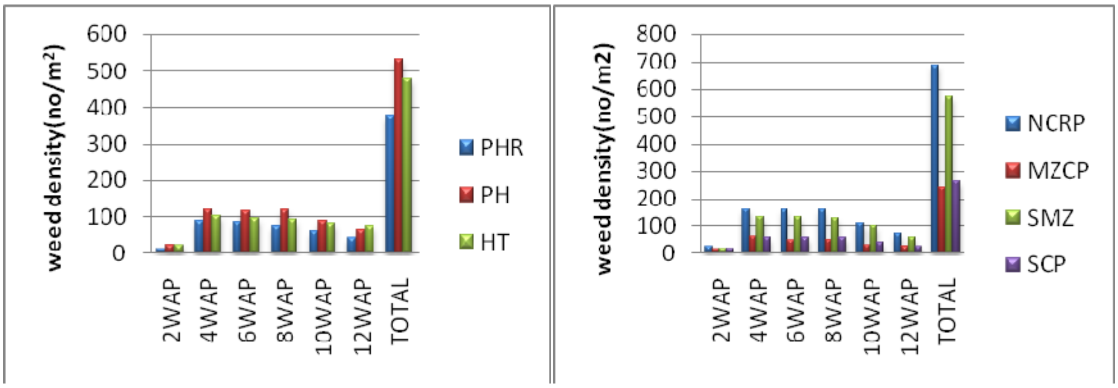
Tillage and Cropping System Effects on Weed Biomass and Crops Yield

The tillage operation had no significant effect on weed dry weight except at 8, 10 & 12 WAP in site II and at 6 & 8 WAP in site III. The highest total weed biomass (37-48 %) was obtained from the PH plots, across the trial locations, except in site I where PHR plots had 39 % of the total dry matter production. The cumulative weed dry weight in PHR and HT plots did not significantly differ from each other in site III. The cropping systems had significant effects on weed dry weight, except at 2,6,10 & 12 WAP in site I, 2 & 4 WAP in sites II and 2WAP in site III (Fig. 3). The uncropped plots (NCRP) had the highest ($P\geq 0.05$) cumulative weed dry weight in all the trial sites while plots cropped to sole maize (SMZ) recorded the next highest cumulative weed dry matter production. Sole maize and sole cowpea grain yields were not significantly different from their respective yields in the intercropped plots in site I while sites II & III recorded significantly better yields of these crops in the sole cropping plots than in the intercropped plots. The aggregate crop yields were, however, significantly higher in the intercropped plots than in the sole crop plots (Table 2).

Discussion

Weed composition slightly differed with trial site but was not specific to any type of tillage method and cropping system. The higher densities of emerged weed species recorded in sites I and II compared to site III, may be attributed to the fact that sites I & II had been under continuous cultivation for 4 or 5 years prior to their use for this study whereas site III was under natural fallow for 6 years prior to its use for the study. Our findings agree with the report of Ekeleme *et al.* (2004), which showed that weed emergence was greater in continuously cultivated plots and plots that were cropped every other year than plots that were cropped once and then left to fallow for 2-3 years. The higher densities of weed seedlings in sites I and II confirms the potential of the continuous cropping of a field to replenish soil weed seed bank, especially of those species adapted to the cultural practices employed for the cultivated

Site II



Site III

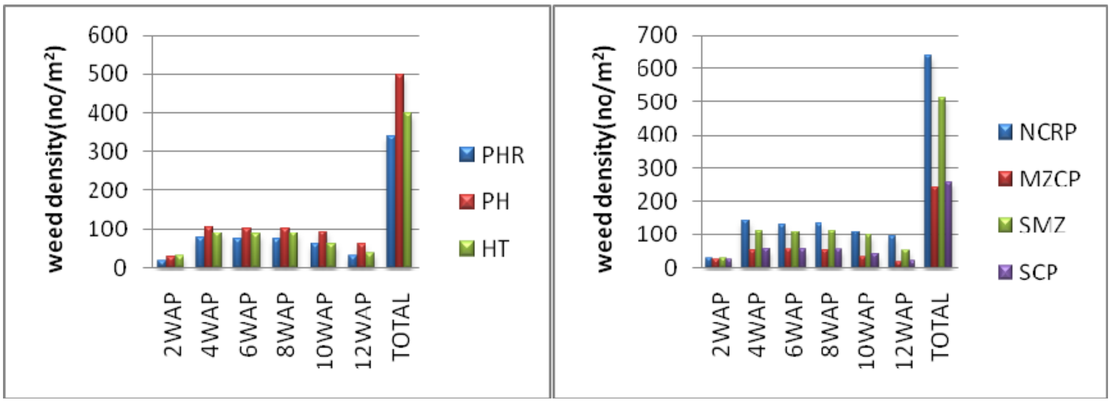


Fig 2. Effect of tillage and cropping system on weed density in the discreetly sampled quadrat

crops. This could have led to shift in weed species that mimic the cultivated crops. Conversely, the six years fallow period in site III, might have led to the depletion of the soil weed seed bank through decay of weed seeds during the fallow period. On the other hand, the increased in number of weed families /species (which were mainly perennials) encountered in this site (previously fallowed plot) might be due to the relative ability of the weed species in the soil seed bank to germinate and compete with each other for survival during the fallow period, in the absence of crop cultural practices, as indicated above, that could have limited the number/ type of persisting species. Soil disturbance, such as ploughing, is known to bury litter and humus covering the weed seeds in soils. This may lead to variation in weed seed germination. The method, intensity and frequency of the tillage method create difference in seed pools. The higher number of weed species emerged on the PH plots compared to other tillage methods could be attributed to the exposure of the weed seeds to conditions conducive for germination on the soil surface and deep burial down the soil profile. The results of this study are in agreement with the findings of Baldoni *et al.* (1999) who reported that tillage systems, which involved extensive turning over of the soil, reduce the soil weed seed bank more than those involving minimum tillage. The PHR tillage system entailed a greater turning over of the top soil than the PH and HT tillage systems. In the PHR plots, weed seeds that would have been on or near the soil surface are buried inside the ridges where they might have been deprived of the necessary stimuli required for germination. The reduced number of weed species emergence in the HT plots compared to PH plots could also be partly due to the above reasons. The majority of the weed species encountered in this study had their highest emergence between 4 and 8 WAP. These results are in agreement with the reports of previous workers. Marks (1983) working in the rain forest ecological zone of south Eastern Nigeria, reported that approximately 70 % of weeds emerged within the first six weeks of the wet season. In the Sudan savanna zone of northern Nigeria, Fadayomi *et al.* (1992) reported that the period of highest weed emergence falls between three and eight weeks after the planting of most early arable crops. The relatively high seedling population at 6 and 8 WAP in the continuously sampled quadrats must be due to fresh weed germination and emergence possibly stimulated by the soil disturbance caused by the hand pulling of emerged weeds during each of the previous sampling periods. This soil disturbance might have moved weed seeds near the soil surface, thus enhancing their germination. The almost constant population of weed seedlings between 4 and 8 WAP in the discreet sampled quadrats suggests that the micro-environment in the quadrats had reached their carrying capacities, thus additional seedlings are destroyed through allelopathy, competition (self – thinning), prevention of germination due to the shading provided by the previously emerged weeds, or any combination of the above factors. The crop canopy formed under the MZCP and SCP cropping system must have been responsible for the reduced weed emergence under those cropping systems. Teasdale and

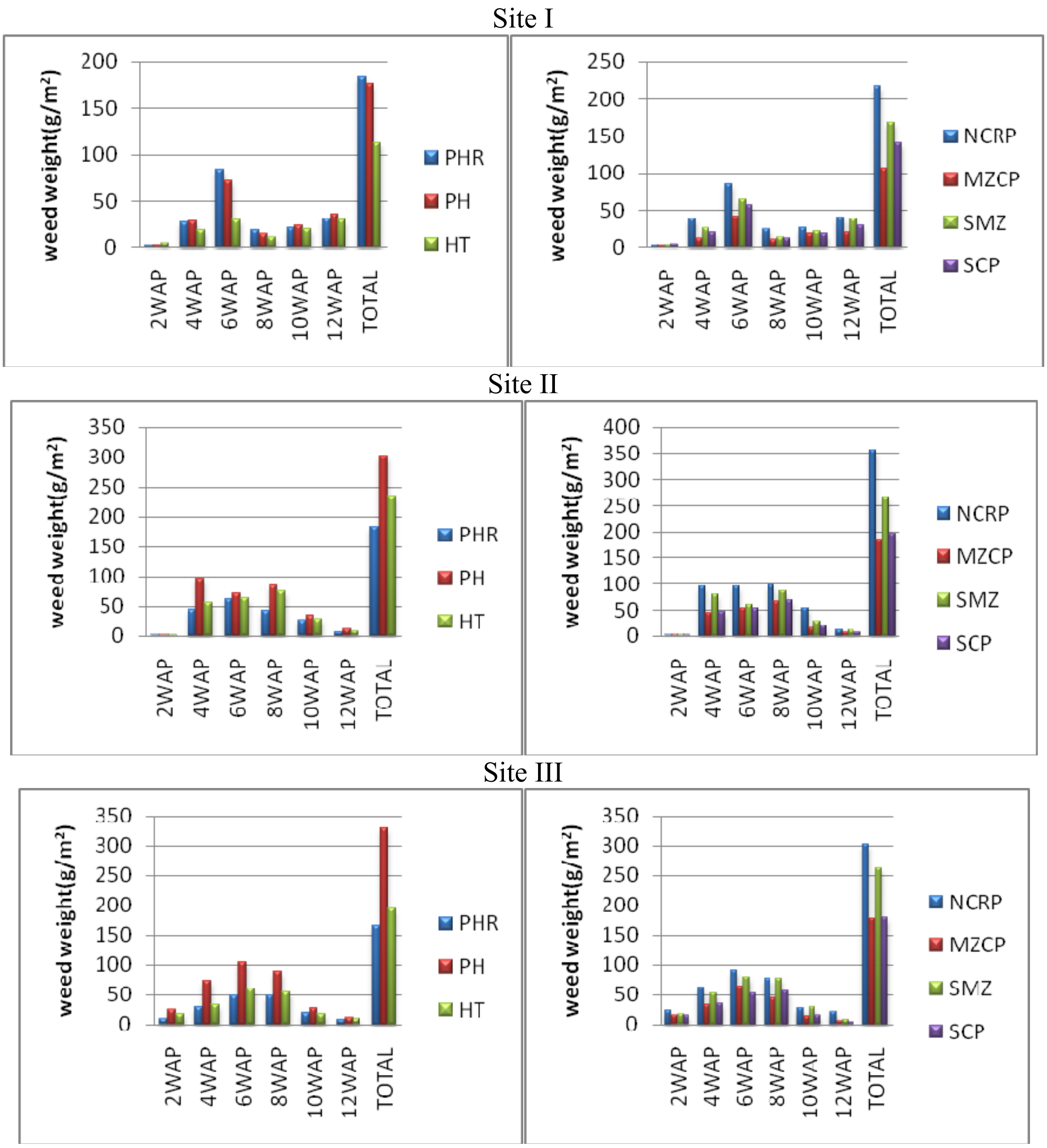


Fig 3. Effect of tillage and cropping systems on weed dry weight in the continuously sampled

Mohler (1993) reported that most small seeded weeds require light for germination while Nwagwu *et al*. (2000) noted that the cropping system influences the quantity and quality of light required for germination of weed seeds. These results are similar to those reported by Ayeni *et al.* (1984 a, b). This study revealed that maize-cowpea intercrop and sole cowpea can reduce weed establishment and biomass production. The crop canopy formed under the MZCP and SCP cropping system must have been responsible for the reduced weed density and dry matter production. Conversely, weed density and biomass in the SMZ plots were higher, possibly due to greater space for light penetration. Nwagwu *et al.* (2000) noted that the cropping system influenced the quantity and quality of light required for germination of weed seeds while Kruidholf *et al.* (2008) concluded that competitiveness under different cropping systems is strongly correlated to early light interception. The sole cropping plots had a better yield than their intercropped components although the aggregate crop yield was significantly higher in the intercropped plots than the sole crop plot.

Conclusion

Based on the above results, it could be concluded that tillage method had limited influence on weed emergence on the field. However, plots subjected to the full complement of tillage activities; ploughing, harrowing and ridging (PHR) supported a relatively lower density of emerged weeds while PH plots supported the highest number of emerged weeds. The period of high emergence of weed seedlings was between 4 and 8 WAP of crops. For small holders and/or resource limited farmers in West Africa, timing of hoe-weeding is one of the most important factors influencing the effectiveness of manual weed control activities. To be effective, such intervention should coincide with the period of peak field emergence of the weeds. As indicated above, this period was found to be between 4 and 8 WAP in this study in the southern Guinea savanna (SGS) of Nigeria. Two hoe weedings (at 2-3 and 6-7 WAP) are prescribed for weed control in most arable crops in this region (NACWC, 1994). This prescription is expected to reduce the level of weed infestation between 4 and 8 WAP which represent the period of highest weed emergence in this study. In the event of scarcity of labour or resources for two hoe-weedings, a single hoe weeding between 4 and 6 WAP might eliminate the bulk of weed infestation in the crop. There is however, the need for further studies to determine the influence of weed management practices on weed emergence and interference with cultivated crops during the cropping season

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