ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF
AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 6 (2): 262-269, 2007
ISSN 1812-5379

Responses of NERICA Rice Varieties to Weed Interference in the Guinea Savannah Uplands

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Abstract: The objective of this study was to determine the critical period of weed infestation in two newly developed NERICA rice varieties for upland rice production to support their dissemination to farmers. Two experiments were conducted between June to November, 2005 to evaluate the responses of two NERICA rice varieties 1 (site 1) and 2 (site 2) developed by the West African Rice Development Association (WARDA) to weed interference in the uplands in the northern Guinea savannah ecological zone. The randomized complete block design was used with treatments in four replications. Gravimetric soil moisture fluctuated ($p<0.01$) at both locations but remained in the range of 9.7-27.0 and 11-19.6% at site 1 and 2, respectively. Generally in both experiments, weed infestation up to 6 weeks after planting (WAP) or more reduced plant height at 12 and 15 WAP, Leaf Area Index (LAI), tiller count m^{-2}, straw weight and grain yield. Keeping the varieties weed-free up to 6 WAP or more enhanced plant height at 12 and 15 WAP, LAI, tiller count m^{-2}, straw weight and grain yield. In the present study, the critical period of weed infestation with the two varieties of NERICA in the upland ecology were similar and was between 3 and 6 WAP. This is an important guide for the NERICA rice dissemination programme in Ghana in particular and for medium maturity rice cropping in general for optimum timing of weed control to maximize yield components and grain yield. Season-long weed infestation resulted in 66 to 72% reduction in grain yield of the varieties, confirming the vulnerability of the varieties to weed infestation. The occurrence and composition of weeds at the two locations were similar with a mean of 66% broadleaves, 33% grasses and 11% sedges. The most dominant weeds were *Brachiaria lata*, *Celosia laxa*, *Cleome rutidosperma*, *Commelina africana*, *C. benghalensis*, *Cyperus* spp., *Digitaria horizontalis*, *Mitracarpus villosus*, *Mollugo nudicaulis*, *Paspalum scrobiculatum* and *Scoparia dulcis*.

Key words: NERICA, critical period of weed control, Guinea savannah, upland and yield

INTRODUCTION

The genus Oryza belongs to the family and sub-family Grammineae and Bambusoideae, respectively. There are two cultivated species of the genus of which, *O. sativa* is of Asian and *O. glaberrima* is of African origin (Clayton and Renvoize, 1986). Varieties of NERICA (New Rice for Africa) are interspecific hybrid progenies developed by WARDA (1999) by combining the hardness of *O. glaberrima* with the productivity of *O. sativa*. The African parent endows the new rice with resistance to drought, pests, diseases, weeds and problematic soils, while the Asian rice transfers high yielding characters.

Fageria *et al.* (1997) observed that upland or rainfed rice is rice grown on both flat and sloping fields that are prepared for seeding under dryland conditions and depend on rainfall for moisture. Upland rice culture occupies about 13% of the total rice area of the world and is particularly important in Tropical America and West Africa rice cropping systems. About 60% of the total rice area in West Africa is under upland (Hanfei, 1992). In Ghana, approximately 5% of land under rice cultivation is rainfed (MOFA, 2003); as such concerted efforts are being made to increase the contribution of upland rice cultivation to the food security needs of the country.

Under such environments, weeds constitute a major pest constraint to increasing rice productivity (Akobundu, 1987; Moody, 1994; Labrada, 2002). Weeds interfere with rice growth and development by competing for light, nutrient and water; and secrete toxic root exudates or leaf leachates which depress the normal growth of the crop; and serve as alternate hosts to other pests. FAO (1996) observed interference as a negative interaction among plants in a community and involves competition, parasitism and allelopathy. Rice varieties respond differently to competition such that tall, droopy and late maturing varieties are more productive under weed infestations than short stature and semi-dwarf early maturing ones (Johnson and Jones, 1993; IRRI, 1993).

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Weed control in rice is therefore a required management input for the crop to meet expected production goals. In developing countries, farmers may spend 25 to 120 day's hand-weeding a hectare of cropland (Akobundu, 1991) yet still lose a quarter of the potential rice yield to weed competition (Parker and Fryer, 1975). In Africa, Johnson (1996) reported 20-100% yield loss in rice fields depending on farmers timing and method of weed control. Moody and Mian (1979) reported that maximum yield could be obtained with dry seeded rice if weeding is done three times during the first eight weeks of crop growth in the lowland. A hand weeding beyond 15-25 days sharply reduced yields (De Datta, 1981). Usman *et al*. (2001) found that weeding at 3 and 6 weeks after planting produced significantly higher rice grain yield than at only 3 weeks after planting. The weed control treatments did not significantly affect tillering, or leaf area of any variety (Kehinde *et al*., 2001).

The current obligation for improved weed management is aimed at reducing labour inputs through the use of integrated weed management approach for enhanced crop production (Akobundu, 1991). One basic requirement for implementation of a sound integrated weed management is knowledge of the critical period of weed control (CPWC) which, Knezevic *et al*. (2002) stated as the period in the crop growth cycle during which weeds must be controlled to avoid yield losses. Knowledge of CPWC enables optimum timing of weed control interventions to reduce production cost, minimize pollution of the environment and free some labour for other lucrative work by farmers (Akobundu, 1991; FAO, 1996; Knezevic *et al*., 2002).

The objective of this study was to determine the critical period of weed infestation in two newly developed NERICA rice varieties for upland rice production to support their dissemination to farmers.

MATERIALS AND METHODS

Site description: The rainfed upland rice trials were conducted from June-November of 2005 cropping season on the experimental field of the Savannah Agricultural Research Institute (SARI) in the northern Guinea savannah ecological zone at Nyankpala near Tamale. The sites lie on altitude 183 m, latitude 09° 25 and longitude 0° 58 of the equator. They have a unimodal rainfall pattern with mean annual rainfall of 1000-1200 mm fairly distributed from April-November. Temperature distribution is uniform with mean monthly minimum of 23.4°C and maximum of 34.5°C. It has a minimum relative humidity of 46% and maximum of 76.8% (SARI Annual Report, 1997).

Experimental design and materials used: In the two experiments and in each case, 10 treatments were compared in a randomized complete block design in 4 replications. In one set of 4 treatments, plots were kept weed-free up to 3, 6, 9 and 12 weeks after planting (WAP) and subsequently left weed-infested until harvest. In the other set of 4 treatments weeds were allowed to interfere with the crop for periods up to 3, 6, 9 and 12 WAP and subsequently kept weed-free until harvest. Two control treatments were included as either full-season weed-infestation or season-long weed-free regimes. All weeding operations were done every 3 weeks, starting from the third week after planting with a small hand hoe. An experimental plot measuring 5×5 m, with 2 and 0.5 m alleys between replicates and plots, respectively were marked out. The rice varieties used were NERICA 1 and 2 in experiments 1 and 2, respectively.

Land preparation and planting: The fields were ploughed to a depth of 20 cm on 28th June, 2005. Harrowing, levelling and planting were done on 5th July, 2005. The drilling planter was used with a spacing of 20 cm between drills. The method of sowing in drills makes weeding and fertilizer application easier henceforth time saving.

Fertilizer applications: NPK-fertilizer at a rate of 60-60-30 kg ha^{-1} was given in two split applications. On the 26th July, 2005 (3 weeks after planting-WAP) a basal fertilizer at a rate of 30-60-30 kg ha^{-1} with NPK (15-15-15) and single super phosphate (P_2O_5) of 18% was applied. The rest of the nitrogen was applied on 20th August, 2005 with 46% urea nitrogen. The first fertilizer application was drilled between drills of rice plants, whereas the second application was broadcasted. The method of applying fertilizer in drills prevents the fertilizer from being eroded by rainfall.

Data collection

Gravimetric moisture content: Soil samples were taken every 2 weeks from the 4 replicates and oven dried at 105°C for 48 h to constant dry weight for gravimetric moisture content determination using the relation: gravimetric moisture content = (X-Y)/Y×100%, where X is the wet weight of soil sample and Y is the dry weight of the sample. The soil at the experimental site was deep freely drained sandy loam.

Plant height: Five plants per plot were tagged for plant height determination at every 3 weeks starting from the third week to ascertain the growth pattern of the crop.

Tiller count: The number of productive tillers per plot was recorded by the use of 1 m^2 quadrat at 50 days after planting.

Leaf area index (LAI): Five plants per plot were used for leaf area index determination. The length and width of the first, middle and last leaf were measured and their averages used for the calculation of leaf area index. The relationship LAI = L×W×N×0.72/A, where L = length of leaves, W = width of leaves, N = number of leaves per plant, A = area covered per plant and 0.72 = constant for the determination of leaf area index of rice was used (Watson, 1952). Leaf area index is obtained to determine the performance of rice plants against the weed-free and weed-infested plots.

Grain and straw yields: The grain and straw yields of the varieties were harvested from each net plot and weighed. Grain weight was adjusted for grain moisture content.

Statistical analysis: The data was subjected to analysis of variance (ANOVA) using the computer programme GENSTAT release 6.1 (Anonymous, 2002). Treatment means were compared using the least significant difference (LSD) where F-values were significant i.e., (F-value <0.05). The data on mean weed dominance was converted to percentage weed coverage.

Weed species and density: A 1 m^2 quadrat was used for weed identification and dominance data collection. The density and frequency were recorded for the calculation of summed dominance ratio (SDR) of weeds, determined by using the relationship: ½ (F/∑F+D/∑D), where F = frequency of occurrence of a weed species within the field, D = density of occurrence of a weed species on the scale of 0-4, where 0 = zero occurrence of a weed species per 1 m^2 and 4 = 20 stands of the weed species (Dangol, 1991).

RESULTS

Gravimetric moisture content: Gravimetric soil moisture content (%) varied to a greater extent (p<0.001) but was slightly higher at site 1 where NERICA 1 was planted than at site 2 (p<0.05) for NERICA 2; but soil moisture was generally higher than 10% between the period 2-14 WAP (Fig. 1 and 2, respectively). At site 1, gravimetric soil moisture content decreased from 17.7 to 9.7% between 2-10 WAP but increased to 27% at 12WAP but again decreased to 18.2% at 14 WAP giving a season mean of

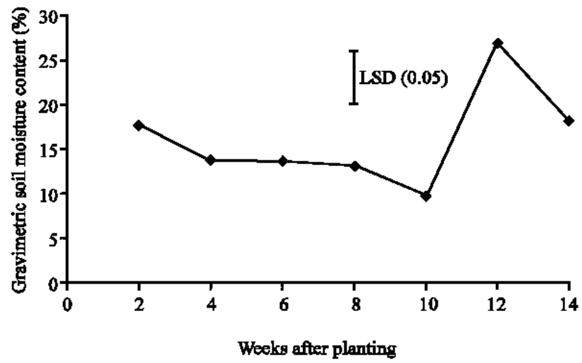

Fig. 1: Gravimetric soil moisture content (%) during 14 weeks of experimentation at site 1

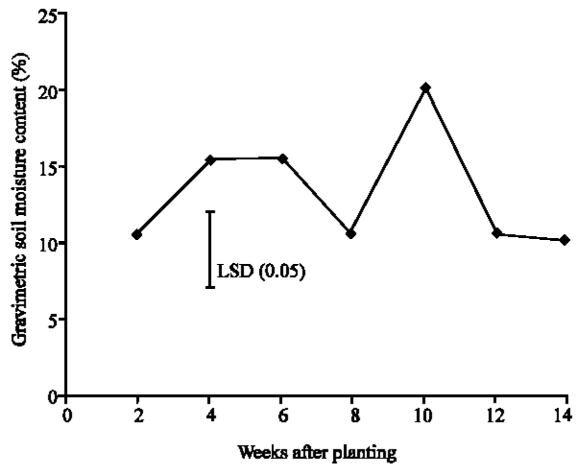

Fig. 2: Gravimetric soil moisture content (%) during 14 weeks experimentation at site 2

16.2%. At site 2 (Fig. 2), the moisture content remained relatively constant up to 8 WAP but increased over a two week period and then decreased to 11.3% at 12 WAP resulting in a trial mean of 14.5%.

Plant height: Plant height of the varieties did not vary (p>0.05) consistently at 3, 6 and 9 WAP, unlike at 12 and 15 WAP when the parameter showed significant differences in NERICA 1 (p<0.001) and 2 (p>0.05). At 12 and 15 WAP, varieties 1 and 2 kept weed-free for up to only 3 WAP and those weed-infested initially for more than 6 WAP produced shorter plants compared with the weed-free check (Fig. 3-6).

Leaf Area Index (LAI): Weeding regimes affected LAI of NERICA 1 (p<0.001) and NERICA 2 (p<0.05). Crops kept initially either weed-free or weed-infested until 3 and 6

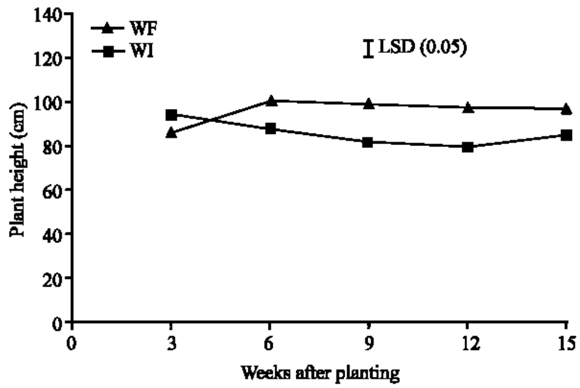

Fig. 3: Effect of period of weed interference on mean plant height at 12 weeks after planting of upland NERICA 1 rice at site 1

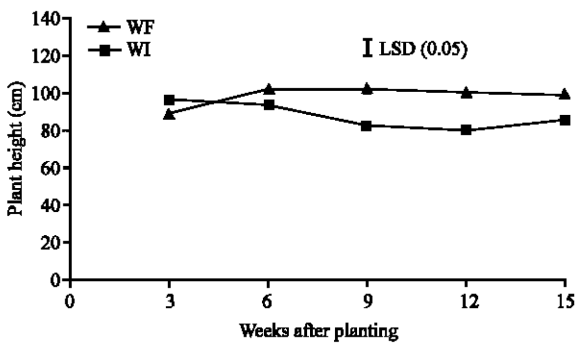

Fig. 4: Effect of period of weed interference on mean plant height at 15 weeks after planting of upland NERICA 1 rice at site 1

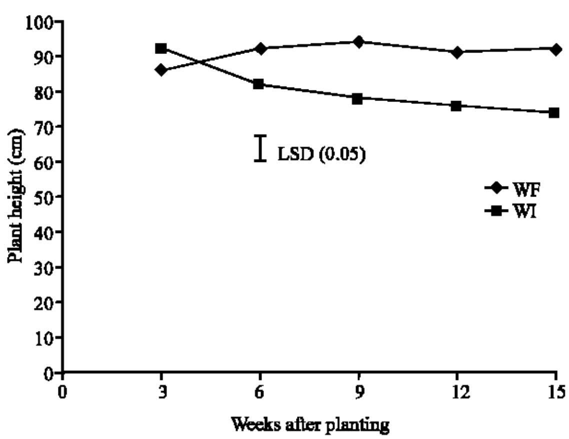

Fig. 5 Effect of period of weed interference on mean plant height at 12 weeks after planting of upland NERICA 2 rice at site 2

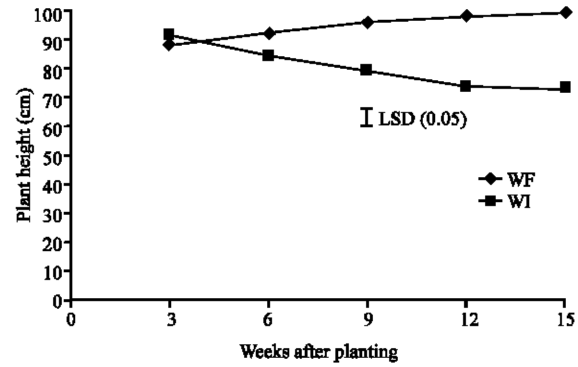

Fig. 6: Effect of period of weed interference on mean plant height at 15 weeks after planting of upland NERICA 2 rice at site 2

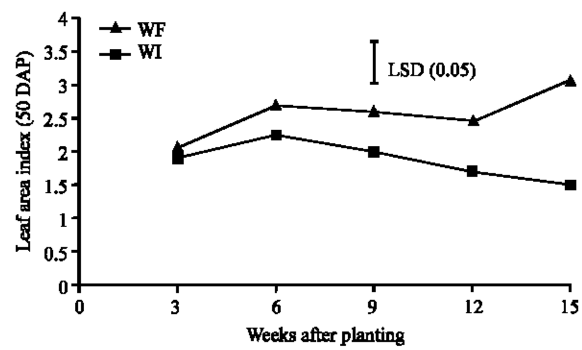

Fig. 7: Effect of period of weed interference on mean leaf area index (LAI) at 50 days after planting of upland NERICA 1 rice at site 1

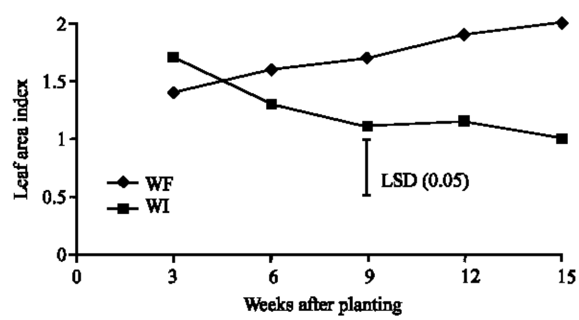

Fig. 8: Effect of period of weed interference on mean leaf area index (LAI) at 50 days after planting of upland NERICA 2 rice at site 2

WAP gave similar LAI but unrestricted weed infestation exceeding 6 WAP appreciably reduced LAI in NERICA 1 (Fig. 7) and NERICA 2 (Fig. 8).

Tiller count: Tiller count m^{-2} at 50 days after planting exhibited significant ($p<0.001$, NERICA 1 and $p<0.05$, NERICA 2) differences among treatments with generally plots kept weed infested for more than 9 WAP exhibiting less tillering ability compared with full season weed control (Fig. 9 and 10). Nevertheless, NERICA 1 showed

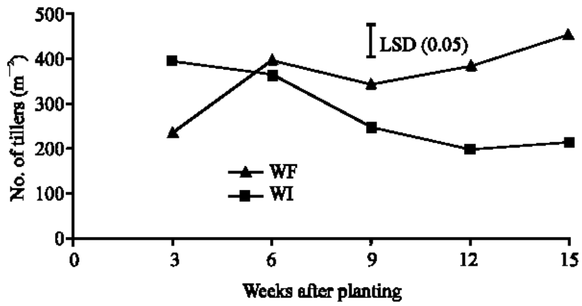

Fig. 9: Effect of period of weed interference on mean tiller count m^{-2} at 50 days after planting of upland NERICA 1 rice at site 1

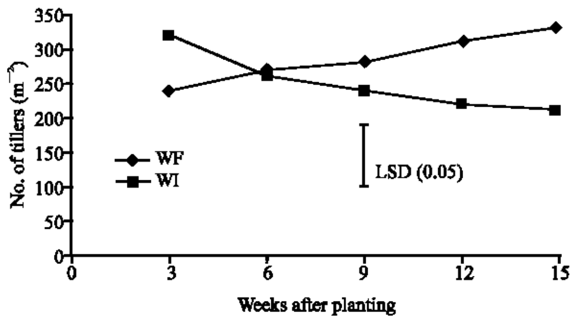

Fig. 10: Effect of period of weed interference on mean tiller count m^{-2} at 50 days after planting of upland NERICA 2 rice at Site 2

a slight departure from NERICA 2 in reaction to weed infestation as plants kept weed-free for only 3 WAP produced less tillers than the weed-free check (Fig. 9).

Straw yield: Straw yield of NERICA 1 kept either weed infested for more than 9 WAP or weed-free for only up to 9 WAP reduced ($p<0.05$) rice straw production below the maximum obtained with full-season weed-free check (Fig. 11). Straw weight data for NERICA 2 was not available.

Grain yield: Grain yield responses of both NERICA 1 and 2 to periods of weed infestation were similar and exhibited significant ($p<0.001$) changes. Keeping the rice entries either weed-free or weed infested for only up to 3 WAP did not reduce grain yields relative to weed-free check (Fig. 12 and 13). Grain yield however, decreased tremendously when plots were weed infested for more than 6 WAP and were comparable to full-season weed infestation. Notably, additional weed control after 6 WAP did not result in additional gain in grain yield of the NERICA entries relative to the weed-free check.

For the weed-free regimes, grain yield of NERICA 1 positively correlated with plant height at 3, 6, 9, 12 and 15

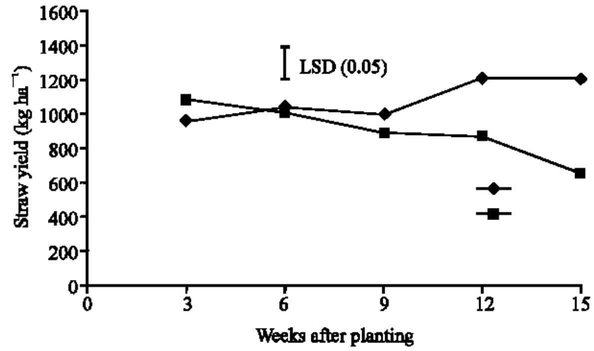

Fig. 11: Effect of period of weed interference on straw yield (kg ha^{-1}) of rainfed upland NERICA 1 rice during the 2005 cropping season at (SARI) Nyankpala

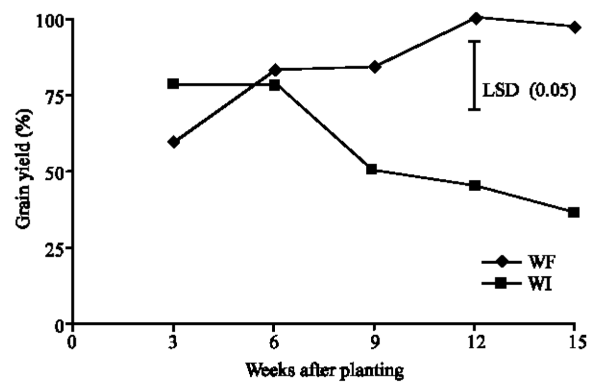

Fig. 12: Effect of period of weed interference on grain yields (% WF-Weed Free) of rainfed upland NERICA 1 rice during 2005 cropping season at (SARI) Nyankpala at site 1

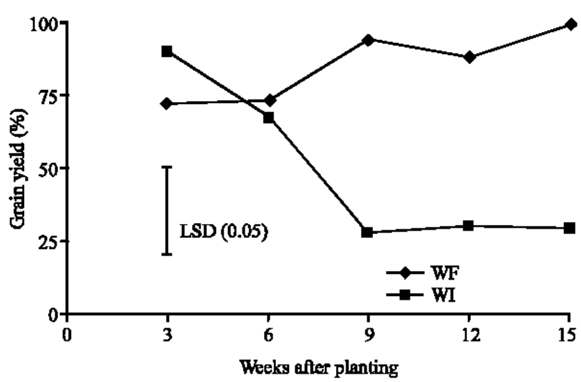

Fig. 13: Effect of period of weed interference on grain yields (% WF-Weed Free) of rainfed upland NERICA 2 rice during 2005 cropping season at (SARI) Nyankpala

Table 1: Relationship between growth parameters and grain yields of NERICA 1 and 2

	Correlation coefficient (r) of NERICA 1		Correlation coefficient (r) of NERICA 2	
Parameters	Weed-free	Weed-infested	Weed-free	Weed-infested
Plant height 3 WAP	0.555**	0.258NS	-0.044NS	0.179NS
Plant height 6 WAP	0.441*	0.650**	0.735**	0.485*
Plant height 9 WAP	0.622**	-0.397*	0.840**	0.680**
Plant height 12 WAP	0.588**	0.795**	0.833**	0.733**
Plant height 15 WAP	0.672**	0.865**	0.838**	0.622 **
Soil moisture content	0.690**	0.378*	-	-
Leaf area index	-0.086NS	0.586**	0.578**	0.718**
Tiller count m^{-2}	0.635**	0.688**	0.767**	0.296**
Straw weight	0.697**	0.760**	-	-

NS = Not significant, * = Significant, ** = Highly significant

Table 2: Weed species occurrence at experimental sites 1 and 2

	Coverage (%)		
Weed species	Site 1	Site 2	Life span[1]
a) Broadleaves			
Amaranthus spp.	-	4.2	A
Celosia laxa	1.3	6.8	A
Cleome rutidosperma	5.7	-	A
Commelina africana	-	5.6	A/P
Commelina benghalensis	10.0	8.4	A/P
Croton lobatus	-	1.6	A
Diodia scandens	-	3.3	P
Hyptis lanceolata	-	3.9	A
Hyptis suovelense	2.0	2.1	A
Ipomoea vagans	-	1.6	A
Ludwigia decureus	2.7	-	A
Mitracarpus villosns	7.3	12.0	A
Mollugo nudicaulis	5.7	10.2	A
Physalis angulata	-	2.1	A
Scoparia dulcis	34.8	-	A
b) Grasses			
Brachiaria lata	6.3	7.2	A
Dactyloctenum aegyptium	1.3	1.6	A/P
Digitaria horizoutalis	5.7	9.3	A
Paspalum scrobiculatum	7.0	6.0	P
Rottboellia cochinchineusis	-	2.1	A
c) Sedge			
Cyperus spp. (*C. esculeutns* and *C. rotundus*)	10.3	12	P

[1]A = Annual weeds, P = Perennial weeds, A/P = Annual and Perennial weeds

WAP, soil moisture content, tiller count m^{-2} and straw weight at harvest (Table 1); except LAI which was only at this instance negatively correlated but not important. For the weed infested NERICA 1 plots, all parameters measured except plant height at 3 WAP exhibited good correlation with the grain yield. Plant height at 9 WAP also showed a negative relationship. In NERICA 2 for both weed-free and weed infested plants, grain yield showed a good correlation with plant height at 6, 9, 12 and 15 WAP, LAI and tiller count.

Percentage weed occurrence at experimental site: The weed flora consisted dominantly of annuals most of which were broadleaves followed by grasses and then sedges irrespective of site of experimentation Table 2. At site 1, thirteen weed species were identified with the mean coverage of 69% broadleaves, 20% grasses and 10% sedges. At site 1, the most dominant weeds were *Cyperus* spp., *Commelina benghalensis*, *Mitracarpus villosus*, *Paspalum scrobiculatum*, *Brachiaria lata*, *Cleome rutidosperma*, *Mollugo nudicaulis*, *Scoparia dulcis* and *Digitaria horizontalis*. Species diversity was higher at site 2, with 18 flora consisting of 62% broadleaves, 26% grasses and 12% sedges. The most dominant weeds were *Cyperus* sp., *Celosia laxa*, *Commelina africana*, *Commelina benghalensis*, *Mitracarpus villosus*, *Mollugo nudicaulis*, *Brachiaria lata*, *Paspalum scrobiculatum* and *Digitaria horizontalis*.

DISCUSSION

The changes in gravimetric soil moisture content across the experimental fields of the savannah uplands could be attributable to the fluctuation in rainfall during the 2005 cropping season. Changes in soil moisture regime did not however, show any visual effect on both the vegetative and reproductive phases of the NERICA varieties. This might be due to an in-built ability of the NERICA varieties to withstand short periods of drought (WARDA, 1999).

At 12 and 15 WAP, the optimum mean plant height was observed with plots kept weed-free up to 6 WAP or more due probably to attainment of the maximum period of hand weed control required to produce the best plant height. Therefore weeding more than 6 WAP did not exhibit any further growth in height. Similarly, crops given continuous weeding up to 6 WAP or more, gave maximum LAI similar to weed-free check; indicating that restriction of weed interference within 6 WAP was enough for best LAI. Weed infestation of the NERICA exceeding 6 WAP timings (Fig. 7 and 8) resulted in poor LAI, suggesting that the crop is a poor competitor with weeds even at the later stages of development. The NERICAs have characteristics of wide, droopy lower leaves, which could smother out weeds (WARDA, 1999) but they appear to require at least 6 weeks of weed-free period for better initial canopy formation to enable late weed suppression. This concedes with the research result obtained by WARDA (1999) citing the need for early weed control. This was also in conformity with the report of Jennings and Herrera (1968) that, tall leafy and droopy-leaf rice plants tend to be more competitive for light and suppress weed growth resulting in high grain and straw production.

The results further indicated that crops kept weed-free up to 6 WAP and more, tillers more than those kept initially weed-infested for more than 6 WAP (Fig. 9 and 10). This could perhaps be attributed to the genetic tillering ability the crop exhibited with treatments which afforded the crop early weed-free regime (WARDA, 1999). Results of straw yield of NERICA 1 did not show a clear impact on CPWC in this study (Fig. 11).

However, the comparable grain yields produced by crops kept weed-free for up to 6 WAP with the weed-free check (Fig. 12 and 13) could be attributed to adequate elimination of weed interference during the period as reflected in plant height and tiller numbers. In effect, earlier weed removal especially at 3 and 6 WAP may obviate yield reduction due to the ability of the varieties to tiller and close up with sufficient canopy to prevent further growth of weeds. The apparent adverse effect of weeds on crops could be attributed to rapid weed growth causing nutrient and other growth resources falling short of the combined demand of both rice and weeds and better adaptation of weeds to dry environments (Akobundu, 1987; Labrada, 2002).

Usually the total leaf area index of rice is a factor closely related to grain yield because at flowering the parameter was reported to greatly affect the amount of photosynthates available to the panicle (Yoshida and Parao, 1976). In three out of four LAI measurements in this study, the parameter enhanced the production of grain yield (Table 2). Nevertheless, Fageria *et al.* (1997) showed that high leaf area index does not necessarily translate into higher grain yield.

The determination of critical period for weed competition is very important in planning an efficient weed control programme (Knezevic *et al*., 2002; Labrada, 2002). The results of this study indicate that the initial weed removal in rice crop for the first 6 WAP during the cropping season resulted in high grain yield comparable to continuous weeding until harvest. Hence, it is desirable to identify pre-emergence herbicide treatments which can keep the crop weed-free for the first 4 WAP; this may then be followed by one supplementary hoe-weeding or by the use of post-emergence herbicide treatments at 6 WAP. The post-emergence herbicides are particularly desirable in controlling broadleaved weeds which normally emerge later in the growing season and help to extend the period of weed control.

Weed flora at the experimental site was variable in composition but showed broadleaves (69.3%) as the most dominant flora in the uplands, followed by grasses (20.33%) and sedges (10.33%) (Table 1). The high broadleaf composition of the weed flora was attributed to favourable abiotic factors of temperature, rainfall, light and nutrient as well as cultivation practices, which provides ideal environmental conditions for weed growth (Akobundu, 1987). Despite the fewer number of grasses observed, they create serious physiological threats to upland rice and farm management practices. Grasses are very difficult to control in upland crop production systems, due to similarity of seedlings of weed and rice and their highly efficient mode of carbon fixation (Akobundu, 1987). Season-long weed infestation resulted in reduction in grain yield of 66 and 72% in NERICA 1 and NERICA 2, respectively, suggesting the vulnerability of the crop to weed infestation.

ACKNOWLEDGMENT

We thank the ARI of the African Rice Center, Cotonou. The NERICA rice Dissemination Project, Ghana. The Ghana Government through The Directorate of Crop Services of MoFA and The African Development for funding this research.

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