Original Research Article

Effects of Different Weed Control Measures on Leaf Area Index and Yield of Three Varieties of Rice Under Two Planting Methods

ABSTRACT

Field trials were conducted during the 2005, 2006 and 2007 rainy season at Irrigation Research Station, Kadawa situated in Sudan savannah agro – ecological zone, Kano state , Nigeria to investigate the effects of different weed control measures on leaf area index and yield of three varieties of lowland rice under two planting methods. The trials were laid out in split – plot design and replicated three times with factorial combination of two planting methods and three varieties in the main plots and weed control treatments in the subplots. The result revealed that transplanting of rice increased leaf area index in 2006,2007 and mean value for the three years 12WAS / T. Transplanting also resulted in higher paddy yield of than direct seeding in 2006 and mean value for the three years. FARO 52 rice variety had significantly higher leaf area index than FARO 50 and FARO 44 in 2005 cropping season. FARO 52 had higher yield in 2006 and the mean value for the three years compare to the other two varities .Application of pre – emergence oxadiazon at 1.0 Kg per hectare followed by post – emergence piperrrrrrrophos plus propanil at 1.5 Kg per hectare applied at 5 WAS / T gave the highest mean yield for the three years closely followed by handpulling weed control measures compared to the weedy check that gave the least mean paddy yield. .Application of pre – emergence oxadiazon at 1.0 Kg per hectare followed by post – emergence piperrrrrrrophos plus propanil at 1.5 Kg per hectare applied at 5 WAS / T in transplanted FARO 52 gave the highest mean yield of 5.5 tonnes per hectare for the three years than weedy check that gave the least mean paddy yield of 2.6 tonnes per hectare. It can be concluded that transplanting of FARO 52 rice variety and combined application of pre-emergence application of oxadiazon at 1.0 kg a.i.ha^{-1} followed by post-emergence piperophos plus propanil at 1.5 kg a.i.ha^{-1} is therefore recommended as the economically viable integrated package for lowland rice production in the sudan savanna agro-ecological zones.

Keywords : Effects, Weed control measures, Leaf area index, Yield, Rice varieties, Planting methods

1.0. INTRODUCTION

The FAO [1]report gave the world production of paddy rice in 2008 as 650 million metric tonnes on 150 million hectares of farmland, with Asia the leading contributor producing 590 million tonnes (90.7%) on 135 million hectares followed by Africa with 23 million tonnes (3.5%) from 7.7 million hectares, South America 21 million tonnes (3.2%) on 5.3 million hectares, USA 8.9 million tonnes (1.3%) on 1.2 million hectares, Europe 3.4 million tonnes (0.5%) on 0.1 million hectares and others 3.7 million tonnes (0.8%) on 0.7 million hectares. The leading world producers and the hectare produced are India, 141.1 million tonnes on 43 million hectares, followed by Indonesia 57 million tonnes on 11.7 million hectares, Bangladesh 43.5 million tonnes on 10.6 million hectares, Myanmar 32.6 million tonnes on 7 million hectare, Thailand 27.8 million tonnes on 10.0 million hectares. In Africa, Egypt is the highest producer with 6.6 million tonnes on 0.6 million hectare of land giving a mean yield of 10.0 tonnes per hectare, followed by Nigeria 4.6 million tonnes from 2.5 million hectares of land with an average low yield of 1.84 tonnes per hectare. The rice growing area of Nigeria occupies 6.7% of the total area of 31 million hectares devoted to various food crops [2].

Presently, the rice production systems in Nigeria are categorized into upland system, which accounts for about 30% of the national rice production area with average yield capacity of 1.7 tonnes per hectare. Rainfed lowland rice production accounts for 47% with yields of 2.2 tonnes per hectare, irrigated lowland rice fields about 16% with yield of 3.5 tonnes per hectare, while deep water floating production accounts for 2% with average yield of 1.3 tonnes per hectare and mangrove areas with less than 1.0% and 2.0 tonnes of yield per hectare [3] and [1]. Amongst these, the lowland rice represents the largest area of production, and highest yield per hectare is obtained from irrigated lowland.

In spite of the importance of rice as a staple food and industrial crop, in Nigeria the yields remain very low. While India, the leading world producer, is having a mean yield of 3.22 t ha^{-1} and Egypt the leading producer in Africa 10.0 t ha^{-1} per hectare, on the other hand, Nigeria has an average yield of only 1.8 t ha^{-1} per hectare [1]. In order to hasten production, the Federal Government of Nigeria came up with various initiatives on rice, one of which is the Presidential initiative on rice which involves the 11 River Basin Development Authorities and the 36 state Agricultural Development Project [4]. The Kadawa Irrigation Scheme under the Hadejia Ja'amare River Basin Development Authority one of the largest irrigation projects with an area of 22,000 hectare is fully involved in the rice production [5]. Although the yield potentials for rice in the scheme stands at 9.0 t ha^{-1} the actual yields obtained range from 1.5 to 3.5 t ha^{-1}. Problems militating against increase in production include, planting method, inefficient weed management, low yielding varieties, inadequate fertilization, pest and diseases, inadequate soil moisture and soil alkalinity [5] and [6]. Amongst these constraints, planting method, rice varieties and weed control are the major problems which if effectively taken care of will boost production and increase the short fall in supply. Weeds have been known to constitute an important constraint to increase in rice production. Weeds compete with crops for sunlight, nutrients, water and space [7]. Although yield losses due to weeds can be as high as 100% [8], these losses vary from one ecology to another. Several workers have reported on yield losses varying between 80-100% (JO Adeosun, ABU, Zaria, Nigeria, Unpublished PhD Thesis results). Various methods have been identified for controlling weeds in Nigeria, namely cultural, biological, chemical and physical [7].

At Kadawa, handpulling is the most common method in use by farmers and it is done 2-4 times before harvest [5]. This method is very laborious, expensive and time consuming, and it is only suitable for small scale rice production. However it causes injury to crop thereby reducing yield. In order to remove these constraints and improve rice yield, several workers have recommended the use of various pre-emergence and post-emergence herbicides. These include bifenox, avirosan, pedimenthalin, pyrazosulfuran, butachlor, oxadiazon, propanil [9] or post-emergence such as Benthiocarb + propanil, Cyperquat, MCPA + propanil, piperophos + propanil, Bentazon, 2, 4-D + propanil [9].

The common planting methods in rice production in Nigeria are direct seeding and transplanting. Planting methods have also been reported to have effect on weed infestation. In addition to planting method, the morphological characteristics of rice such as plant height, maturity period and yield component can be exploited to achieve suppression of weed germination and growth in various agro ecologies in the country.

Various rice varieties have been bred and released, identifying the suitable variety for a location as well as availability of enough seeds is crucial for rice production. Yet the availability of improved rice varieties and good quality seed have been cited as principal constraints to rice production [7];[5] and [3].

Thus, the rice production components such as planting methods rice varieties, weed control which have been studied separately could be integrated to achieve effective weed control and good crop yields.

The study aimed at investigating the effect of different weed control measures on the leaf area index and yield of three varieties of rice under two planting methods.

2.0. MATERIALS AND METHODS

2.1 Experimental Site

Field trials were conducted during the 2005, 2006 and 2007 wet seasons at the Irrigation Research Station, Kadawa (11º 39`N; 80º 02`E, 500 m altitude above sea level) of the Institute for Agricultural Research, Zaria, Nigeria. Kadawa is located in the Sudan savanna agro-ecological zone. Geomorphologically, the Kano region where Kadawa is located is in the Western African plains, with a flat to slightly undulating surface, bordering the Jos Plateau in the Southeast. The prominent weed species of the experimental sites were collected from 1.0m² areas at random within the plots and the weeds were identified at all sampling stages. The intensities of occurrence were also recorded at the sites of the trials,

2.2 Experimental Treatments

The three rice varieties used during the trial were Sipi 692033 (FARO 44), Wita 4 (FARO 52) and ITA 230 (FARO 50). The two planting methods were the direct seeding and transplanting, while the seven weed control treatments were as follows: Oxadiazon (Ronstar) 25 EC at 1.0 kg a.i.ha^{-1} pre-emergence (PE), oxadiazon (Ronstar) 25 EC at 1.0 kg a.i.ha^{-1} (PE) followed by (fb) hand pulling of weed at 6 weeks after sowing/transplanting (WAS/T), piperophos plus propanil (Rilof S) at 1.5 kg a.i.ha^{-1} applied post-emergence (POE) at 2 WAS/T, piperophos plus propanil (Rilof S) at 1.5 kg a.i.ha^{-1} applied POE at 2 WAS/T fb hand pulling at 6 WAS/T, oxadiazon (Ronstar) 25 EC at 1.0 kg a.i.ha^{-1} applied (PE) fb piperophos plus propanil (Rilof S) at 1.5 kg a.i.ha^{-1} applied POE at 5 WAS/T, Hand pulling of weeds at 3 and 6 WAS/T (control) and Weedy check.

2.3 Field Design and Layout

The experimental design was a split-plot, with the main plot consisting of factorial combination of three rice varieties (FARO 44, FARO 52, FARO 50) and two planting methods (direct seeding and transplanting), while seven weed control treatments were assigned to the subplots. The treatments were replicated three times, the gross plot size was 5.0 m long by 4.0 m wide (20 m²), while the net plot size was 4.0 m by 3.0 (12 m²). The border between each plot and replicate was 0.5 m and 1.5 m, respectively.

2.4 Cultural Practices

2.4.1 Soil sampling

A 100 g composite soil sample was obtained at the 3 different locations where the trials were conducted during the three year study period. Six samples were randomly collected across the field and diagonally from three different locations at 0-30 cm depth using an auger soil sampler, bulked together, analyzed for its physico-chemical properties in the Agronomy Departmental Laboratory. The results obtained are contained in Table I.

2.4.2 Nursery site preparation

The nursery plot was selected close to the experimental site and proximal to source of water. The soil was loosened and three plots of 2 m×2 m size (one for each variety) were demarcated during each of the three years. Two kilograms of seed of each variety were treated with Apron Star as seed dressing chemical at the rate of 1.0 g of metalaxy to 3.0 kg seed to prevent pest attack on the seed. The plots were watered before drilling the seed in the second week of June and first week of July during the three years period. Application of 20 g N.P.K. compound fertilizer was also done, immediately after sowing of seeds. Watering of plots was carried out on daily basis. The seedlings were left up to 4 weeks before transplanting.

2.4.3 Land preparation

Pre planting herbicide, glyphosate (Roundup) was applied to the experimental site at the rate of 2 kg a.i.ha^{-1} two weeks before land preparation during each year of the study in order to control the prevalent stubborn sedges that are often found on the field. The field was then ploughed, harrowed to ensure fine tilth of the soil and ridged at 75 cm apart. The ridges were levelled to form basins. The field was then marked out into the appropriate number of main plots and subplots according to earlier specified plot sizes.

2.4.4 Planting materials

FARO 44 and FARO 52 seeds of the three rice varieties were obtained from National Cereal Research Institute, Badeggi while FARO 50 was obtained at Kadawa Irrigation Research Station of the Institute for Agricultural Research, Ahmadu Bello University, Zaria.

Table 1: Physico–chemical characteristics of the soil sample (0 – 30cm) at the experimental site during the 2005, 2006 and 2007 rainfed seasons.

Soil composition	2005	2006	2007
Physical Characteristics			
Sand (%)	56	58	55
Silt (%)	30	28	30
Clay (%)	14	14	15
Textural class	sandy loam	sandy loam	sandy loam
Chemical characteristics			
P^H in H_20	7.87	7.97	7.83
P^H in 0.01M $cacl_2$ (1:25)	N/A	N/A	N/A
Organic carbon	3.02	1.87	3.34
Total Nitrogen (%)	0.78	0.67	0.85
Available P (Meq/kg)	6.244	7.532	7.00
Exchangeable cations (meq/kg)			
K	0.28	0.35	0.25
Mg	0.81	0.75	0.90
Ca	2.09	1.60	2.03
Na	1.50	1.70	1.65
CEC	11.50	5.00	7.83
Exchangeable Acidity H^+ and Al $^{3+}$ Meq/100g	0.4	0.2	0.3

Source: Soil sample analysis by Agronomy Department Laboratory A.B.U. Zaria

The notable characteristics of these varieties used in this study are given below:

FARO 44 (Sipi 692033): This variety originated from Asia (Taiwan) and it is cultivated under irrigated swamp condition. It grows to a plant height of 110-120cm (tall variety). It has a tillering capacity of 15-20*,* with a green stem base. The leaves are long, semi broad and lax. The leaf sheath is green, with fully exerted panicle, erect flag leaf and medium ligule. It matures within 110-120 days, and it has long grains[10]. The potential yield is 5,000-8,000 kg ha^{-1}.

FARO 52 (Wita 4)**:** This variety was developed by the International Institute of Tropical Agriculture (IITA), Nigeria; It is grown as lowland irrigated and shallow swamp rice. It has a plant height of 95-105 cm (medium stature), and tillering capacity of 12-18. The stem base is green with long leaves and green leaves sheath, with a panicle that is fully exerted, and erect flag leaves. The husk from unripe to mature seed is green to straw colour. The stigma is colourless, awnless and the ligule is of medium size. It matures within 125- 130 days and it has short grains [10]. The potential yield is 5,000-8,000 kg ha^{-1}.

FARO 50 (ITA 230): This variety was developed by IITA, Nigeria, as irrigated low land swamp rice. It grows to a height of 100–110 cm (tall variety). The stem base is green and the leaves are long with green leaf sheath. The panicle is fully exerted with erect flag leaf. The husk colour from unripe to matured seeds bears green straw coloration. The stigma is colourless, it is awnless and ligule is medium. It matures in 120 – 125 days and produces short grains [13]. The potential yield is 5,000-8,000 kg ha^{-1}.

2.4.5 Planting and transplanting operations

Transplanting and direct seeding by broadcast of the seed were done on 15 July in 2005, 2 August in 2006 and 7 August in 2007 respectively when the rains were fully established. In direct seeding, 100 kg ha^{-1} seed was broadcast and incorporated into the soil. The seedlings raised in the nursery were transplanted at four weeks of age at 2 seedlings per hill spaced at 20 cm both between and within rows.

2.4.6 Weed control treatments

Weed control treatments applied are as specified earlier. The pre-emergence herbicide was applied immediately after sowing in the direct seeding method before the emergence of the crop plant, and one day prior to transplanting operations. The CP 3 knapsack sprayer with the green deflector nozzle and spray shield to avoid drift was used and kept at a pressure of 2.1 kg m^{-2} to deliver 250 ha^{-1} was used to deliver the spray solution. The hand pulling treatment was carried out at 3 and 6 WAS/T depending on the treatment requirements on both direct seeded and transplanted plots.

2.4.7 Description of the herbicides used

Oxadiazon (Ronstar 25EC): Oxadiazon, first reported in 1969 and introduced by Rhone-poulenc, is primarily a pre-emergence herbicide (0.50-4.0 kg a.i.ha^{-1}), although it shows some post-emergence activity (0.5-2.0 kg a.i.ha^{-1}). It is used in rice, cotton, sugarcane, soybean, groundnut, onion and transplanted vegetables. It is particularly useful for controlling weeds that grow from bulbs, rhizomes and other deep-rooted plant propagules, including *Cynodon dactylon* (Linn.)*, Lolium perenne*, etc. It is effective against many annual and broad leaved and grass weeds such as *Oxalis* spp.*, Amaranthus* spp.*, Richardia scabra, Urtica* spp.*, Poa annua, Digitaria* spp.*, Mollago varticilata,, Eleusine indica* Gaertn.*, Setaria verticillata,* etc. At post, it is active during the early stage of application. It has average to long persistence, with a field half-life of 60 days. Oxadiazon, is readily absorbed by the shoots of emerging seedlings, but less so by the roots. It is translocated apoplastically and distributed in plant parts. When applied to foliage, it is readily absorbed by leaves. It accumulates in older plant parts and also in roots, rhizomes and buds with little movement to growing points [11].

Piperophos plus propanil (Rilof S): This product is usually formulated as emulsifiable concentrate for the control of annual grasses and sedges as well as, dry-sown rainfed upland rice. The active ingredient content consists of piperophos and propanil. With propanil, its mode of action is through the leaves and stems to the plant, thereby exhibiting contact action while piperophos is through the roots to the weeds. It can also be taken up through cotyledons, coleoptiles and leaves of emerging per growing plants. Rilof S is specifically active against annual grasses, sedges and some broadleaved weeds. Typical weeds controlled are susceptible species such as *Ageratum conyzoides* Linn.*, Cyperus* spp.*, Echinochloa crus-ghalli, Echinochloa colona* (Linn.) Link, *Eleusine indica* Gaertn*.*

2.4.8 Fertilizer application

The recommended fertilizer rate of 120 kg SN/ha, 17.44 kg P/ha and 33.2 kg K/ha for lowland rice in shallow swamp areas in Nigeria was used. At 2 WAS/T compound fertilizer (NPK 15-15-15) and urea were used to supply half the nitrogen and all the phosphorous and potassium requirements. The second half of nitrogen was applied as top dressing at 6 WAS/T using urea.

2.4.9 Supplementary irrigation

Supplementary irrigation quantify was carried out by the application of 18 litre of water per plot as applicable throughout the period of experiment to ensure that moisture was not limiting for plant growth.

2.4.10 Harvesting

All rice plants in the net plot area were harvested manually using a sickle by cutting the stem at ground level when the paddy reached dough stage at physiological maturity. The crop was harvested on 16 November, 19 December and 14 December in 2005, 2006 and 2007 respectively. The harvested paddy was later sun dried and threshed and the paddy yield recorded per plot.

2.5 Observations and Data Collection

Observations on the rice crop and weeds were made at 3, 6, 9 and 12 WAS/T

2.5.1 Leaf area index (LAI)

Four plants within the border rows were randomly selected and the length and breadth of the leaves measured with a meter ruler. The linear method of determining leaf area of rice by multiplying leaf length and breadth by a constant (k) of 0.7 as suggested by Harper [12] was adopted. The average leaf area (LA) was computed. The leaf area obtained was divided by the land area occupied by the plants to obtain LAI, which is the assimilatory surface per unit area of land.

$$LAI = \frac{\text{Total leaf area per plant (cm2)}}{\text{Area of ground per plant (m2)}}$$

2.5.2 Paddy yield (Kg/ha)

Harvested paddy from each net plot was threshed after sew drying, winnowed and the weight obtained expressed on per hectare basis and recorded accordingly.

2.6 Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) using the F – test described by Snedecor and Cochran[13]. The means separation was done at 5% level of probability, using Duncan Multiple Range Test (DMRT) [14].

3.0. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Leaf area index

At 12 WAS/T, significant effect of rice variety on LAI was only obtained in 2005 when FARO 52 and FARO 50 had higher LAI than FARO 44 (Table 2). In 2005 and the mean direct seeded had significantly higher LAI than transplanted rice. However, the reverse was the case in 2006, while planting method had no effect on LAI in 2007.Significantly higher LAI was produced with handpulled control (0.75a) at 12 WAS/T compared with other weed control treatments. Similarly in 2006 significantly higher LAI was also produced with handpulled control (0.72a) at 12 WAS/T compared with other weed control treatments while in 2005 post-emergence application of piperophos p lus propanil at 1.5 kg a.i.ha^{-1} produced the highest LAI (0.77a) which was significantly different from other control measures (Table 2). In 2005, the handpulled (0.70d) and weedy check (0.70d) had the least LAI. In 2006 and 2007 the weedy check gave the least LAI than all other treatments (Table 2). The mean value for the three years showed that application of pre – emergence Oxadiazon followed by post – emergence piperophos+propanil five weeks after direct seedingor transplanting produced the highest LAI of 0.73a, closely followed by handpulling (0.72a) with no significant different between the two values while the least was weedy check (0.67c) with significant different across the weed control treatment.The interaction effect did not differ significantly in the years of study and the mean of the years (Table 2)

Table 2: Effects of planting methods and weed control on leaf area index of lowland rice varieties at 12 WAS/T in 2005, 2006, 2007 and combined mean.

Treatments	Rate (kg a.i.ha^{-1})	Leaf area index 12 WAS/T [1]			
		2005	2006	2007	Mean
Rice Variety (V)					
FARO 44	`	0.71b[2]	0.70	0.72	0.71
FARO 52		0.74a	0.67	0.72	0.71
FARO 50		0.73a	0.68	0.70	0.70
SE (±)		0.005	0.005	0.006	0.005
Planting Method (M)					
Direct seeding		0.73a	0.64b	0.71b	0.69b
Transplanting		0.71b	0.72a	0.72a	0.72a
SE (±)		0.004	0.004	0.005	0.004
Weed Control (W)					
Oxadiazon (PE)[3]	1.0	0.74ab	0.67c	0.70c	0.70b
Oxadiazon (PE) fb[4] handpulling 6 WAS/T	1.0	0.73b	0.67c	0.72ab	0.71ab
Piperophos+propanil (POE)[5] 2 WAS/T	1.5	0.77a	0.68b	0.71b	0.72a
Piperophos+propanil (POE) 2 WAS/T fb handpulling	1.5	0.71c	0.67c	0.72ab	0.70b
Oxadiazon (PE) fb piperophos+propanil (POE) 5 WAS/T	1.0/1.5	0.74ab	0.71ab	0.74a	0.73a
Handpulled (at 3,6 WAS/T) Control		0.70d	0.72a	0.75a	0.72a
Weedy check		0.70d	0.64d	0.66d	0.67c
SE (±)		0.008	0.007	0.009	0.008
Interaction					
P×V		NS[6]	NS	NS	NS
W×P		NS	NS	NS	NS
W×V		NS	NS	NS	NS
W×V×P		NS	NS	NS	NS

[1]Weeks after sowing/transplanting; [2]Means in a column of a set of treatment followed by same letter(s) are not significantly different (P≤ .05) using DMRT; [3]Pre emergence; [4]Followed by; [5]Post emergence; [6]Not significant.

3.1.2 Paddy yield

The effect of weed control treatments and planting method on lowland rice varieties is contained in Table 3. The rice varieties differed significantly in paddy yield in combined mean of 2006, 2007. FARO 52 rice variety resulted in significantly higher paddy yield of rice compared to FARO 44 and FARO 50 respectively (Table 3).The planting method did not differ significantly on paddy yield in year

2005 and 2007 (Table 3). Transplanting of rice gave significantly higher paddy yield than direct seeding in year 2006 and when averaged over 2005-2007 (Table 3).

The pre-emergence application of oxadiazon at 1.0 kg a.i.ha^{-1} fb post-emergence application of piperophos plus propanil at 1.5 kg a.i.ha^{-1} gave significantly highest paddy yield in 2005 and mean of the years which were similar with handpulled control but was comparable to the maxima obtained in 2006 and 2007 (Table 3). Other herbicide treatments gave significantly higher paddy yield than their respective maxima. Similarly, significantly higher paddy yield occurred with all weed control treatments than the weedy check (Table 3). All possible interactions were not significant throughout the study period except the interaction between planting method and rice varieties in the combined mean of the years (Table 3). Yield of the three varieties did not differ significantly under direct seeding, however, under transplanting FARO 52 gave significantly higher grain yield than FARO 50 and FARO 44 that were similar, change in planting method from direct seeding to transplanting had no effect on grain yield (Table 4). However with FARO 50 and FARO 52 such change resulted in significant yield increase. FARO 52 under transplanting method gave the highest paddy yield of 4.6 t ha^{-1}. This was followed by FARO 50 under transplanting method and FARO 52 in direct seeding and FARO 44 under both planting method which were comparable (Table 4).

3.2 Discussion

3.2.1 Effects of weed control treatments on LAI of lowland rice.

The weed suppression enhanced increased LAI. The combined application of pre- emergence oxadiazon at 1.0 kg a.i.ha^{-1} followed by post emergence piperophos plus propanil at 1.5 kg a.i.ha^{-1} increased LAI due to the fact that oxadiazon gave good weed control in the early stage while piperophos plus propanil controlled the late emerging weeds. Several studies have also found combined herbicides to be effective in controlling weeds in rice (DB Ishaya, ABU, Zaria, Nigeria, Unpublished PhD Thesis results) and (JO Adeosun, ABU, Zaria, Nigeria, Unpublished PhD Thesis results)

3.2.2 Effects of weed control treatments on yield of lowland rice.

The maximum grain yield of 5.3 and 5.5t ha^{-1} observed with the application of pr-emergence application of oxadiazon at 1.0 kg a.i .ha^{-1} followed by post-emergence application of piperophos plus propanil at 1.5 kg a.i.ha^{-1} in 2005 and 2007, respectively could be directly related to the fact that the combined application of both pre and post- emergence herbicides gave better broader spectrum weed control. More so, the herbicides were tolerated by the crop. In fact single herbicide treatments could not give season long weed control and therefore serious weed competition which coincided with grain filling stage contributed to the significant yield reduction recorded compared to the combined treatment. The percent yield losses encountered due to uncontrollable weed in the three years of study were 41%, 63% and 54% in 2005, 2006 and 2007 respectively. (JO Adeosun, ABU, Zaria, Nigeria, Unpublished PhD Thesis results), reported 42.1%, 74.5% and 60% in 1992, 1993 and 1994 respectively.

3.2.3 Effect of planting method on LAI of lowland rice.

In this study, the effect of planting method significantly differed on LAI. The initial reduction in LAI with direct seeding could be due to the detrimental effect of high soil pH on crop emergence and high plant densities which restricted leaf area development resulting in the inability of the crop to fully utilize solar radiation and soil nutrients.

3.2.4 Effect of planting methods on yield of lowland rice.

Rice sown under transplanting method gave higher yield than that sown by direct seeding although the differences were significant only in 2006 and the combined mean of the years. This observation could be due to better weed control ability of transplanted rice than direct seeding, initial and better crop establishment and ability to use environmental resources better, thus resulting in increase growth performance of the crop. Pal *et al.* [15], also obtained higher yields from transplanting and early sowing than direct seeding. Significantly longer number of days to 50% heading observed with direct seeding compared to transplanting throughout the experimental period maybe due to the disparity of four weeks between the sown seed and transplanted seedling.

3.2.5 Effect of varietal differences on LAI of lowland rice

The rice varieties FARO 52 had higher LAI than FARO 50 and FARO 44 in the year 2005. Ishaya [7], had better weed suppression and higher LAI in FARO 40 and WAB 56-50 than FARO 38.

3.2.6 Effect of varietal differences on yield

The higher paddy yield produced by FARO 52 compared with FARO44 and FARO 50 could be attributed to differences in plant height and duration of the crop. The better adaptation of FARO 52 to the environment enabled it to compete favourably with weeds as evident from its better growth performance. NCRI [10] recommended FARO 52 as one of the most suitable variety for lowland ecologies. The better utilization of the natural resources available and ability to compete favourably with weeds resulted in bigger superstructure of the plants as well as higher yield component and higher grain yield of FARO 52 which emerged compared with the other varieties. Goeh and Verma [16], reported higher grain yield with Pusa-33, HKR-120 rice variety.

3.2.7 The effect of interactions between rice variety, planting method and weed control on LAI and paddy yield.

Results indicated that transplanting of rice increase leaf area index at 6 and 9 WAS/T in each year of the study. Transplanting of rice resulted in high paddy yield than direct seeding in 2006 and combined mean of the years. Naeem [17], had significantly higher yield with Basmati-370 rice variety under transplanting condition than direct seeding in Pakistan. FARO 52 rice varieties had significantly higher, leaf area index than FARO 50 and FARO 44 in 2005.. FARO 52 had increase in paddy yield than other varieties in all the years of investigation, except in 2005.Significantly lower weed cover, weed dry weight, increase number of branches and delay in days to 50% heading were observed with rice treated with compared to the weedy check. The combined herbicide application of pre-emergence oxadiazon at 1.0 kg a.i.ha^{-1} followed by (pfb) post-emergence piperophos plus propanil at 1.5 kg a.i.ha^{-1} applied at 5 WAS/T, gave the highest addy yield in 2005 and the combined mean of the years and was similar to handpulled control in 2007 compared to the weedy check.. Other weed control treatments that consistently suppressed weed growth and increased paddy yield comparable to the handpulled at 3 and 6 WAS/T were pre-emergence oxadiazon followed by handpulling at 6 WAS/T in 2005 and 2006 and post emergence piperophos + propanil at 1.5 kg a.i.ha^{-1} followed by handpulling at 6 WAS/T in all the years. Pre-emergence oxadiazon at 1.0 kg a.i.ha^{-1} and post emergence piperophos plus propanil at 1.5 kg a.i.ha^{-1} applied singly resulted in lower grain yield than when supplemented with post emergence and handpulled control. The lowest yield occurred with the weedy check. The interaction between planting methods and rice varieties was also significant on leaf area index at 3 and 12 WAS/T and paddy yield in the combined mean. A highly significant positive correlation between paddy yield and leaf area index was obtained at 9 WAS/T in the mean of the yearsThe percent yield loss encountered due to uncontrolled weed in the three years of study compared with the respective maxima was 41%, 63% and 54% in 2005, 2006 and 2007, respectively. Based on the result of this study, transplanting of FARO 52 and pre-emergence application of oxadiazon at 1.0 kg a.i.ha^{-1} followed by post-emergence piperophos + propanil at 1.5 kg a.i.ha^{-1} produced highest paddy yield of 5.5 t ha^{-1}compared to the lowest 2.6 t ha^{-1} with the weedy check. ‘

Table 3: Effects of weed control, planting methods and lowland rice varieties on paddy yield in 2005, 2006, 2007 and mean during the rainy season.

Treatments	Rate (kg a.i.ha^{-1})	Paddy yield (kg/ha) 2005	2006	2007	Mean
Rice Variety (V)					
FARO 44	`	4232	3729b[1]	4120b	4027b
FARO 52		4450	4205a	4365a	4340a
FARO 50		4249	3687b	4174ab	4037c
SE (±)		140.50	101.20	69.56	62.20
Planting method (P)					
Direct seeding		4222	3506b	4161	3963b
Transplanting		4398	4240a	4270	4304a
SE (±)		14.72	82.63	56.77	47.64
Weed Control (W)					
Oxadiazon (PE)[2]	1.0	3822c	4012b	3609d	3844c
Oxadiazon (PE) fb[3] handpulling 6 WAS/T[4]	1.0	4285bc	3742bc	3776d	3934c
Piperophos+propanil (POE)[5] 2 WAS/T	1.5	4331bc	3491c	4092c	3972c
Piperophos+propanil (POE) 2 WAS/T fb handpulling	1.5	4735b	3721bc	4535b	4332b
Oxadiazon (PE) fb piperophos+propanil (POE) 5 WAS/T	1.0fb1.5	5495a	4612ab	5273a	5127a
Handpulled (at 3,6 WAS/T) Control		4901ab	4615ab	5410a	5067a
Weedy check		2600d	2922d	2845e	2789d
SE (±)		214	154	106	89
Interaction					
P×V		NS[6]	NS	NS	**[7]
W×P		NS	NS	NS	NS
W×V		NS	NS	NS	NS
W×V×P		NS	NS	NS	NS

[1]Means in a column of a set of treatment followed by same letter(s) are significantly different P≤ 0.05 level of probability using DMRT; [2]Pre emergence; [3]Followed by; [4]Post emergence; [5]Not significant.

Table 4: Interaction between planting methods and rice varieties on paddy yield of lowland rice at in the mean of year 2005-2007.

Rice variety	Paddy yield (Kg ha^{-1})	
	Direct seeding	Transplanting
FARO 44	3976bc[1]	4087bc
FARO 52	4120bc	4656a
FARO 50	3816c	4258b
SE±	61	

[1] Means in a column or row of treatments followed by same letter(s) are not significantly different (P≤ 0.05) using DMRT.

4.0 CONCLUSION

It can be concluded that transplanting of FARO 52 rice variety and combined application of pre-emergence application of oxadiazon at 1.0 kg a.i.ha^{-1} followed by post-emergence piperophos plus propanil at 1.5 kg a.i.ha^{-1} could hereby be recommended as economically viable integrated package for lowland rice production in the sudan savanna agro-ecological zones.

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