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Research Article

Rice Response to Herbicides under Lowland and Irrigation Ecologies of Sudan Savanna Ecological Zone of Nigeria

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Abstract

A field trial was conducted in 2008 growing season in lowland and irrigation rice ecologies to study the effect of various herbicide combinations on weed characteristics, crop growth and the corresponding grain yield and financial return of rice cultivation. The treatments were Butachlor, Propanil and 2, 4 - D applied at 3 levels in various combinations with or without supplementary hoe weeding. The trials were laid out by using randomized complete block design. The data collected were subjected to analysis of variance were significant the means were separated using Duncan multiple range test. The results indicated that the use of all the herbicides lowered the weed cover score and weed dry weight compared to weedy check. Application of Butachlor at the rate of 2.25 kg a.i. ha $^{-1}$ followed by Propanil and 2, 4 - D mixture at the rate of 2.52 and 1.44 kg a.i. ha^{-1} , respectively produced higher crop vigor and number of tillers per plant and the highest grain yield per hectare. Gross margin and cost benefit analysis were employed to determine the profitability of each of the control methods. The same treatment that produced higher grain yield also gave the highest gross margin and Cost- benefit ratio over manual hoe weeding and as such considered the best treatment for rice production in both ecologies.

Keywords: *Weed control, herbicides, grain yield, and profitability*

1. Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in the world, because it was estimated to be supplying more than 50% of the total world's food (IRRI, 2007). Food and Agricultural Organization (FAO) estimated the world production in 2010 at 701 m tones of paddy rice. Asia alone produced more than 92% of the world figure. Nigeria consumes about 5.4 m tones of rice annually (USAID, 2009), while annual local production stood at 3.4 m tones per year (FAO, 2013) and as such the remaining 2.0 m tones has to be imported and this make Nigeria to be second largest importer of rice in the world (USAID, 2009).

Weed infestation causes reduction in crop yield and grain quality (De Datta, 1980). Akobundu (1989) reported that uncontrolled weed can cause up to 80 – 100% yield losses in Nigeria. Weed control is one of the major labour demanding farm operations in rice production; the labour requirement is very costly and may not be available at the time of need. Although no single weed control method can give effective and satisfactory weed control in all the ecologies, however, chemical weed control may provide a better alternative, because it is fast, cheap, easy and more effective (Lagoke, *et.al*., 1991). The ecological difference in rice production zones stress the need to have an herbicide dosage and combinations that can economically and effectively control weeds with or without the use of cultural method of weed management. This is because rice being a closely spaced crop, yield losses could even be caused by hoe weeding through crop injury and stand losses, while some grass weeds which have close resemblance to the rice crop may escape hand weeding.

The objective of the study was to determine the most effective combinations of herbicides and possibility of supplementary hoe weeding (SHW) which might give better weed control, rice growth, grain yield and higher profitability.

Materials and Methods

Experimental Site

The trial was conducted in 2008 growing season in two locations: Kumbotso Fadama site chosen as lowland ecology and Kadawa irrigation research station considered as irrigation ecology both in Kano State of Nigeria within the Sudan savanna agro-ecology. The annual mean rainfall of both locations was 823 mm and the mean daily temperature was 26.9^{o}C. The soil of the lowland Fadama site was sandy loam of pH 6.0,

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organic matter content 5.3g kg $^{-1}$ and total nitrogen 0.55 g kg^{-1} while for the irrigation ecology the soil was sandy loam, of pH 6.5, organic matter content 7.3 g kg^{-1} and total nitrogen was 0.48g kg^{-1}.

Experimental Treatments and Design

The trial comprised of 17 treatments that were replicated three times, using three herbicides namely, Butachlor, Propanil and 2, 4 – D applied at three levels alone or in combination at different rates with or without supplementary hoe weeding (SHW) and three hoe weeding and weedy plots to serve as control. The trial was laid out using randomized complete block design and the pre-emergence application (Butachlor) was done a day after sowing while the post emergent application (Propanil and 2, 4 – D) was done 4 weeks after sowing (WAS).

Data Collection on Weed, Crop Growth and Grain Yield

Data were collected on weed cover score, weed dry weight, crop vigor score, number of tillers per plant and grain yield per hectare. Growth and weed characteristics were taken at 12 WAS while grain yield was taken at harvest.

Gross Margin and Cost-Benefit Analysis

An economic assessment was done to determine the production cost, revenue and gross margin that could be derived from each of the treatments. The cost of all variable inputs was recorded along with the price of the produce at the prevailing market price in the month of January, 2009. The gross margin analysis is the difference between the total revenue and the total production cost. The cost- benefits analysis measures the rate of return on investment , It gives the amount of profit on any Naira invested in each of the treatments. It is calculated as Cost-benefit ratio = GM/ PC, where GM= Gross margin and PC = Production cost for each of the weed control methods.

Data Analysis

Data collected were subjected to analysis of variance as described by Snedecor and Cochran (1967) using the general linear model in SAS (SAS, 1987). Where significant, the treatments means were separated by using Duncans Multi Range Test (DMRT).

Results and Discussion

Weed Characteristics

Significantly lower weed cover scores were obtained in the lowland ecology using all the herbicides compared to weedy check as shown in table 1, while in the irrigation ecology there was no significant difference between weedy check and the use of Propanil and 2, 4 – D at the rate 2.16 and 1.08 kg a.i. ha^{-1} and all the rates of Propanil and 2, 4 – D with SHW. The highest weed dry weight per m^2 observed in the weedy check plots were statistically similar with the one produced by manual hoe weeding in both ecologies and were due to the uncontrolled weed infestation, which was an indication of the effectiveness of the herbicides in the rest of the treatments. The result obtained was similar to the earlier findings of Atangs (1997) who reported that the herbicide treated plots of maize and rice had significantly lower weed infestation and weed dry matter than the weedy plots.

Growth and Yield

The Pre-emergent application of Butachlor at the rate of 2.25 kg a.i. ha^{-1} followed by Propanil and 2, 4- D mixture post emergent at the rate of 2.52 and 1.44 kg a.i. ha^{-1}, respectively, resulted in the highest crop vigour score in both ecologies (Table 2) which was similar to the report of Man *et. al*. (1986) who observed that late application of 2, 4 –D resulted in the least injury on direct seeded rice. The weedy check had significantly the lowest crop vigour score in both ecologies and this was due to above and below-ground competition of weeds which retarded the growth of the rice crop. The highest number of tillers per plant was obtained with the same treatment with the highest crop vigor (Pre-emergent application of Butachlor at 2.25 kg a.i. ha^{-1} followed by post-emergent application of Propanil mixed with 2, 4–D at the rate of 2.52 and 1.44 kg a.i. ha^{-1}, respectively). The result could be attributed to effective weed control by the pre- and post-emergent herbicide application which coincided with the time of rapid growth in the plant tillers. Qayyum *et al*. (1989) reported that application of Butachlor at 2 l ha^{-1} gave better weed control than Oxadiazone at the rate of 5 l ha^{-1} and resulted in increased tillering in rice.

The Pre-emergent application of Butachlor at 2.25 kg a.i. ha^{-1} followed by post-emergent application of Propanil at 2.52 kg a.i. ha^{-1} mixed with 2, 4–D at 1.44 kg a.i. ha^{-1} in both ecologies resulted in the highest grain yield (Table 2). This treatment was at par with post emergent application of Propanil and 2,4-D mixture at the rate of 2.52 and 1.44 kg a.i. ha^{-1} in the lowland rice ecology or by applying Butachlor pre-emergent at the rate of 1.75 kg a.i. ha^{-1} followed by post emergent application of Propanil and 2,4-D mixture at the rate of 2.16 and 1.08 kg a.i. ha^{-1}. This was clearly as a result of better weed control by these herbicides which allowed for good crop growth. Duby and Habans (1986) reported that Pre-emergent application of Butachlor at the rate of 1 and 1.5 kg a.i. ha^{-1} gave higher panicle numbers and this may result to the production of increased yield. Tomar (1987) applied Butachlor 6 days after sowing and compared it with hoe weeding and it resulted in increased grain yield from 5.6 to 7.1 ton ha^{-1} of paddy rice. The weedy check had the lowest grain yield while the manual three hoe weeding did not produce better yield compared to many of the pre- and post emergent herbicides.

Table 1: Effect of herbicides on weed cover score, weed dry weight and cost-benefit ratio under low land and irrigation rice

Ecologies		Weed cover score		Weed dry weight (g/m²)		Cost-benefit ratio	
Treatments/methods	Rate kg a.i. ha $^{-1}$	Lowland	Irrigation	Lowland	Irrigation	Lowland	Irrigation
Butachlor	1.25	2.50 b	2.17 f	46.2 bc	39.1 e-g	0.45ab	0.66ab
Butachlor	1.75	3.33 b	2.33 f	42.1 bc	37.3 fg	0.51ab	0.32ab
Butachlor	2.25	2.83 b	2.00 f	44.1 bc	36.4 fg	0.54ab	0.76ab
Propanil+2,4-D	1.8+0.72	3.50 b	3.00 c-f	44.6 bc	35.6 fg	0.48ab	0.77ab
Propanil+2,4-D	2.16+1.08	3.00 b	5.00 ab	43.3 bc	39.6 efg	0.28ab	0.84ab
Propanil+2,4-D	2.52+1.44	3.50 b	3.66 c-f	36.1 bc	45.0 d-g	0.52ab	0.27ab
Butachlor Fb Propanil+2,4-D	1.25 Fb 1.8+0.72	3.67 b	2.33 f	53.5 bc	45.7 d-g	0.04b	0.68ab
Butachlor Fb Propanil+2,4-D	1.75 Fb 2.16+1.08	2.83 b	2.67 def	45.7 bc	57.0 bcd	0.59ab	0.22ab
Butachlor Fb Propanil+2,4-D	2.25 Fb 2.52+1.44	2.33 b	2.00 f	52.5 bc	50.4 c-f	0.75a	1.08a
Butachlor Fb SHW	1.25 Fb SHW	3.17 b	2.50 ef	55.9 bc	39.6 efg	0.20ab	0.61ab
Butachlor Fb SHW	1.75 Fb SHW	3.17 b	3.0 c-f	47.8 bc	40.4 efg	0.43ab	1.00a
Butachlor Fb SHW	2.25 Fb SHW	2.67 b	2.66 def	39.6 bc	37.0 fg	0.37ab	0.38ab
Propanil+2,4-D	1.8+0.72 Fb SHW	3.17 b	4.33 a-e	47.1 bc	52.9 b-e	0.39ab	0.50ab
Propanil+2,4-D	2.16+1.08 Fb SHW	4.00 b	4.50 a-d	58.6 bc	60.1 abc	0.33ab	0.44ab
Propanil+2,4-D	2.52+1.44 Fb SHW	3.67 b	4.67 abc	51.9 bc	62.2 abc	0.38ab	0.68ab
Hoe weeding	4,8 & 12 WAS	3.00 b	3.50 b- d	56.0 bc	64.5 ab	0.17ab	0.54ab
Weedy check		5.67 a	5.93 a	72.6 a	71.2 ab	0.08b	0.23ab
SE+		0.528	0.573	4.96	4.33	0.01	0.04

NB: Fb =followed by SHW = Supplementary hoe weeding, Means with the same letter(s) in the same column are not significantly different (P <0.05) using D.M.R.T

Table 2: Effect of herbicides on crop vigour, number of tillers plant and grain yield per hectare under lowland and irrigated rice ecologies

		Crop vigour score		Number of tillers per plant		Grain yield ton ha^{-1}	
Treatments/methods	Rate kg a.i. ha $^{-1}$	Lowland	Irrigation	Lowland	Irrigation	Lowland	Irrigation
Butachlor	1.25	6.83 ab	6.33 a	8.1 c	12.1 b	2.84 b	3.32 bc
Butachlor	1.75	6.33 ab	6.33 a	7.1 c	10.6 b	2.81 bc	2.81 bc
Butachlor	2.25	6.67 ab	5.33 ab	8.1 c	11.2 b	3.08 b	3.51 bc
Propanil+2,4-D	1.8+0.72	6.17 ab	6.10.ab	7.9 c	12.0 b	2.94 b	3.47 bc
Propanil+2,4-D	2.16+1.08	7.00 ab	6.27 a	8.8 bc	10.3 b	3.02 b	3.68 bc
Propanil+2,4-D	2.52+1.44	7.00 ab	6.67a	12.8 a	13.2 b	3.67 ab	2.70 c
Butachlor Fb Propanil+2,4-D	1.25 Fb 1.8+0.72	6.17 ab	6.83 a	8.9 BC	11.1 b	2.36 BC	3.45 BC
Butachlor Fb Propanil+2,4-D	1.75 Fb 2.16+1.08	6.50 ab	6.50 a	8.9 bc	12.6 b	3.29 ab	2.59 c
Butachlor Fb Propanil+2,4-D	2.25 Fb 2.52+1.44	7.17 a	7.33 a	13.3 a	16.0 a	4.52 a	5.14 a
Butachlor Fb SHW	1.25 Fb SHW	6.50 ab	5.83 ab	8.7 bc	10.6 b	2.59 bc	3.70 bc
Butachlor Fb SHW	1.75 Fb SHW	6.67 ab	6.50 a	8.5 bc	11.2 b	2.67 b	4.19 ab
Butachlor Fb SHW	2.25 Fb SHW	6.33ab	5.33 ab	9.2 bc	12.4 b	2.44 bc	3.50 bc
Propanil+2,4-D	1.8+0.72 Fb SHW	6.67 ab	5.67 ab	9.2 bc	10.9 b	2.70 bc	2.85 bc
Propanil+2,4-D	2.16+1.08 Fb SHW	6.00 ab	6.83 a	9.3 bc	11.7 b	2.51 bc	3.20 bc
Propanil+2,4-D	2.52+1.44 Fb SHW	6.17 ab	6.50 a	11.0 ab	10.9 b	3.10 b	3.57 bc
Hoe weeding	4 ,8 & 12 WAS	6.17 ab	5.17 a	9.4 bc	11.0 b	2.54 b	3.07 bc
weedy check		4.90 c	3.83 b	3.4 d	4.80 c	1.33 c	1.49 d
SE+		0.311	0.651	0.79	0.95	0.45	0.38

NB: Fb = followed by SHW = Supplementry hoe weeding, Means with the same letter(s) in the same column are not significantly different (P <0.05) using D.M.R.T

Gross Margin and Cost Benefit Analysis

The result of economic analysis(Table 3) had shown significant differences among the treatments in the production cost, revenue and the gross margin. The application of butachlor pre-emergent at the rate of 2.25 kg a.i ha^{-1} followed by post emergent mixture of propanil and 2,4-D at 2.52 and 1.44 kg a.i ha^{-1} produced the highest revenue and gross margin and at a relatively lower production cost. The result was similar with the findings of Muhd and Muhd (1988) who concluded that the use of herbicides greatly increased the marginal return from 80-119 %. In another work Srinvason and Pothiraj (1989) and Aliyu and Lagoke (2000) both indicated that use of herbicides have substantially reduced the labour requirement and hence increased the revenue which can directly affect the cost-benefit. Higher cost benefit ratio (0.75 and 1.08 for lowland and irrigated ecology, respectively) was derived from the application of pre-emergent butachlor at the rate of 2.25 kg a.i ha^{-1} followed by post emergent mixture of propanil and 2,4-D at 2.52 and 1.44 kg a.i ha^{-1}. Similar report was compiled by Ibrahim *et.al*. (2011) that use of herbicide in rice field gives higher cost benefit ratio and more profitable return (Table 1). The manual hoe weeding however gave very

Table 3: Effect of herbicides on Production cost, Revenue and Gross margin under lowland and irrigation rice ecologies

		Production cost (N)		Revenue (N)		Gross margin(N)	
Treatments/methods	Rate kg a.i. ha $^{-1}$	Lowland	Irrigation	Lowland	Irrigation	Lowland	Irrigation
Butachlor	1.25	137061 P	142654 p	199957 ab	237291 ab	62896 ab	94637 ab
Butachlor	1.75	138061 o	143654 o	195291 ab	219557 ab	57230 ab	75903 ab
Butachlor	2.25	139061 n	144654 n	215357 ab	255267 ab	76296 ab	110613 ab
Propanil+2,4-D	1.8+0.72	139383 m	144913 m	206957 ab	256667 ab	67574 ab	111754 ab
Propanil+2,4-D	2.16+1.08	140581 l	146111 l	182448 ab	269024 ab	40668 ab	122913 d
Propanil+2,4-D	2.52+1.44	141780 k	147310 k	214424 ab	187581 ab	73843 ab	40271 b
Butachlor Fb Propanil+2,4-D	1.25 Fb 1.8+0.72	141861 j	147454 j	136024 b	248267 ab	-5837 b	100813 ab
Butachlor Fb Propanil+2,4-D	1.75 Fb 2.16+1.08	143059 h	149652 g	227467 ab	182933 ab	84408 ab	33281 ab
Butachlor Fb Propanil+2,4-D	2.25 Fb 2.52+1.44	144258 e	151851 c	252953 a	315933 a	108657 a	164082 a
Butachlor Fb SHW	1.25 Fb SHW	142061 i	147654 i	170800 ab	240800 ab	28739 ab	91148 ab
Butachlor Fb SHW	1.75 Fb SHW	143061 g	148654 h	204624 ab	298667 ab	61563 ab	150013 a
Butachlor Fb SHW	2.25 Fb SHW	144061 f	149654 f	200891 ab	224933 ab	56830 ab	75279 ab
Propanil+2,4-D	1.8+0.72 Fb SHW	144383 d	149913 e	192957 ab	216291 ab	48574 ab	66378 ab
Propanil+2,4-D	2.16+1.08 Fb SHW	145581 c	151111 d	201824 ab	255024 ab	56243 ab	103913 ab
Propanil+2,4-D	2.52+1.44 Fb SHW	146861 b	152310 d	201824 ab	263667 ab	54963 ab	111357 ab
Hoe weeding	4 ,8 & 12 WAS	151875 a	152951 a	177800 ab	235891 ab	25925 ab	82940 ab
weedy check		133061 q	138654 q	133061 b	170800 b	11230 b	32146 b
SE+				27603	31051	27603	31051

NB: Fb = followed by SHW = Supplementry hoe weeding, Means with the same letter(s) in the same column are not significantly different (P <0.05) using D.M.R.T

low gross margin and cost benefit ratio of 0.17 for lowland ecology and 0.54 in the irrigated ecology on any naira invested relative to many of the herbicide treatments. Gross margin for the weedy plots is the lowest and the cost benefit ratio is nearly zero due to the deleterious effect of dense weed infestation in the plots. Mirza *et.al.* (2008) also reported that infestation of weed is one of the most important causes for low yield of rice.

Summary and Conclusion

The result showed significant reduction in weed cover score and increase in crop vigour score, number of tillers per plant and the grain yield per hectare by the use of Butachlor pre- emergence at the rate of 2.25 kg a.i. ha $^{-1}$ together with post emergence application of Propanil and 2, 4-D at the rate of 2.52 and 1.44 kg a.i. ha^{-1}, respectively. However, other herbicides rates showed promising results. If the appropriate herbicide rates and combinations are used, the use of manual hoe weeding alone or as a supplement to herbicide use may not be necessary in rice production in both lowland and irrigation ecologies. Herbicide treatments can be used to replace manual weed control in rice production because it had shown to cost significantly lower and hence gives higher cost-benefit ratio and higher profitability.

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