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Research Paper

Yield components of lowland rice (*oryza sativa* l.) as influenced by different management practices in Sudan savanna ecology

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Field experiment was conducted in 2012 and 2013 wet seasons at the Irrigation Research Stations of the Institute for Agricultural Research, Ahmadu Bello University, Talata Mafara to assess the effect of different rice production management practices to yield and yield components of lowland rice (*Oryza sativa* L.) in the Sudan savanna ecology. The treatments consisted of four weed management practice (Oxadiazon at 1.0 kg a.i ha^{-1} [pre-emergence], Orizoplus [*premix*- propanil 360 g/l + 2, 4-D 200 g/l] at 2.8 kg a.i ha^{-1} [post emergence at 3 WAS], manual weeding [at 3 and 6 WAS] and Weedy check); three each of seeding methods (Drilling, Dibbling and Broadcast) and seed rates (40, 70 and 100 kg ha^{-1}). The experiment was laid in a split plot design replicated three times. Weed management practice was allocated to the main plots while seeding method and seed rate were factorially combined and allocated to the sub-plots. The general trend in this study revealed that paddy yield was enhanced when plots were weeded twice compared to other weed management practices. Broadcast method of seeding had significantly lower values for yield attributes and paddy yield when compared with drilling and dibbling seeding methods at both years of study. Higher than 40 kg ha^{-1}seed rate increased yield components as primary spikes, secondary spikes and paddy yield. The best paddy yield at Talata Mafara was by dibbled rice manually weeded at 3 and 6 WAS (4800 kg ha^{-1}) or treated with oxadiazon at 1.0 kg a.i ha^{-1} (4789 kg ha^{-1}) and by drilled rice manually weeded twice (4304 kg ha^{-1}).

Key words: Sudan savanna, Field, Experiment, Irrigation, Research, Weed management, *Oryza sativa*

INTRODUCTION

Rice has always been one of the most important food crops in the world. It is estimated that 40% of the world's population take rice as their major source of food (FAOSTAT, 2014). The world production yield of rice as at 2013 was averaged at 4.4 tonnes per hectare while the Nigerian yields was1.8 tonnes per hectare (FAOSTAT, 2014). Rice production in Nigeria is seriously constrained by weed infestations, poor soil fertility lack of improved technology and inappropriate agronomic management practices which can cause a total crop failure (Akobundu, 1987).Weeds constitute one of the most important constraints to rice production especially in tropical Africa (Akobundu, 1987). Reduction in yield of rice caused by weeds ranged from 10-100% (Akobundu, 1987; David, 2009; Nasimul, 2010; Chauchan et al., 2011; Mahajan and Chauchan, 2011; Chauchan, 2012). Several weed control methods are being employed to reduce the menace of weeds in rice fields. But each single method is associated with challenges ranging from drudgery, high cost and environmental pollution. In rice, the conventional method of weed control, that is, hand weeding, is very laborious, expensive and time consuming, and therefore considered inefficient.

Herbicides have become a major tool for weed management in rice, and their use has increased further with rise in labour cost and scarcity. Crop establishment is a key factor in determining the outcomes of weed–crop interactions and preventive weed management measures. A vigorous rice crop with a closed canopy denies weeds of space and light. Crop establishment involves several steps of land preparation and sowing or planting depending on the agroecosystem. Though, better crop yields as a result of better crop establishment has been reported when rice or other crops are drilled compared to broadcast and dibbling sowing methods, drilling is an expensive method in the form of labour requirements (Oyewole et al., 2010).High seed rates are used in direct seeded rice to suppress weeds and to compensate for poor seed quality and crop establishment and for losses due to rodents, birds and earthworms. A sustainable rice production require an integrated management approach that considers, among other things, appropriate agronomic practices such as effective and selective herbicides and appropriate seeding method and seeding rate. This research was design to assess the effect of weed management practice, seeding method and seed rate on yield and yield components of lowland rice

MATERIALS AND METHODS

Field experiment was concurrently conducted in each of the wet seasons of 2012 and 2013 at Irrigation Research Stations of the Institute for Agricultural Research Talata Mafara (12° 34' N; 06° 04'E) in the Sudan savanna zone of Nigeria. The treatments consisted of four weed management practices (oxadiazon at 1.0 kg a.i ha^{-1} applied pre-emergence, Orizoplus [a proprietary mixture of propanil, 360 g/l and 2,4-D, 200 g/l] at 2.8 kg a.i ha^{-1} applied post emergence at 3 WAS, manual weeding at 3 and 6 WAS and untreated control); three each of seeding method (Drilling, Dibbling and Broadcast) and seed rate (40 kg ha^{-1}, 70 kg ha^{-1} and 100 kg ha^{-1}).

The treatments were laid in a split plot design and replicated three times. Weed management practice was allocated to the main plots, while seeding method and seed rate were factorially combined and allocated to the sub-plots.Gross plot size was 3.0 m by 2.0 m (6.0 m^2) and the net plot size was 2.0 m by 1.6 m (3.2 m^2).The seed was sown 20 X 20 cm spacing in both drilled and dibbled plots. SIPI-602033 (FARO 44) was used for the experiment. It is a variety recommended for shallow swamp and irrigated conditions. It is a medium maturing variety, with a yield potential of 4-7 t ha^{-1}.

Inorganic fertilizer was applied by broadcast at the rate of 60 kg ha^{-1} N; 60 kg ha^{-1} P_2O_5; 60 kg ha^{-1} K_2O at planting using a compound fertilizer NPK 15:15:15. The second application of 60 kg ha^{-1} N was done at 6 WAS using Urea (46%) as a source of N. The herbicides were applied as per the treatments using a CP 3 knapsack sprayer fitted with a green deflector nozzle at a pressure of 2.1 kg cm^{-2} to deliver spray liquid volume of 240 L ha^{-1}.

Data analysis

Data collected from the observations were subjected to analysis of variance (ANOVA) differences between treatment means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability as described by Gomez and Gomez, (1984).

RESULTS

Panicle length

Rice panicle length as affected by weed management practice, seeding method and seed rate at Talata Mafara in 2012 and 2013 and their combined data are presented in (Table 1). In 2012, the three management practices gave similar panicles and each was significantly longer than that by the weedy check. In 2013 and mean data, rice treated withorizoplus and manually weeded produced longer panicles than that treated with oxadiazon, whichin turn gave longer panicles than rice in the weedy check. In 2013, drilled rice produced longer panicles than broadcast. Dibbled was at par with drilled and broadcast.

Number of grains per panicle

The effects of weed management practice, seeding method and seed rate on number of grains per panicle at Talata Mafara in 2012 and 2013 are presented in (Table 2). At Talata Mafara, in both years and their mean, the three weed management practices resulted in similar number of grains per panicles, and each was significantly higher than by the weedy check. In the mean data, oxadiazon gave higher grains per panicle than the weedy check, and both were comparable with other treatments. In 2012, drilled and dibbled rice produced similar grains per panicle, and each significantly higher than by broadcast. In 2013 and mean data, drilling gave more grains per panicle than broadcast, and either comparable to dibbling.

Primary and secondary spikes per panicle

Weed management practice influenced number of primary spikes significantly in both years of study (Table 3).

Table 1. Effect of weed management practice, seeding method and seed rate on panicle length (cm) and grain per panicle of rice at Talata Mafara in 2012 and 2013 wet seasons.

Treatment	Panicle length (cm)			Grains per panicle		
	2012	2013	Mean	2012	2013	Mean
Weed management (W)						
Oxadiazonat1.0 kg a.i ha^{-1}	22.3a	28.7b	25.5b	108.7a	92.4a	100.6a
Orizoplus at 2.8 kg a.i ha^{-1}	23.5a	31.6a	27.6a	109.1a	85.9a	97.5a
Manual weeding at 3 and 6 WAS	22.3a	31.1a	26.7a	109.5a	95.0a	102.2a
Weedy check	94.3b	40.8b	67.6b	94.3b	40.8b	67.6b
SE±	2.17	3.99	1.93	2.17	3.99	1.93
Seeding method (S)						
Drilling	21.0	28.7a	24.9	108.3a	88.7a	98.5a
Dibbling	21.7	27.8ab	24.8	109.0a	75.8ab	92.4ab
Broadcast	21.1	27.1b	24.1	98.9b	71.1b	85.0b
SE±	0.40	0.50	0.33	2.19	4.71	2.80
Seed rate kg ha^{-1} (R)						
40	21.4	28.3	24.8	102.9	84.7	93.8
70	21.2	27.9	24.6	107.5	74.2	90.8
100	21.3	27.5	24.4	105.8	76.7	91.3
SE±	0.40	0.50	0.33	2.19	4.71	2.80
Interaction						
W x S	NS	NS	NS	NS	NS	NS
W x R	NS	NS	NS	NS	NS	NS
S x R	NS	NS	NS	NS	NS	NS
W x S x R	NS	NS	NS	NS	NS	NS

Means followed by same letter (s) within the same column and treatment group are not significantly different at 5% level of probability using DMRT. NS = Not significant.

Table 2. Effect of weed management practice, seeding method and seed rate on primary and secondary spikes per panicle of rice at Talata Mafara during 2012 and 2013 wet seasons.

Treatment	Primary spikes/ panicle			Secondary spikes/ panicle		
	2012	2013	Mean	2012	2013	Mean
Weed management (W)						
Oxadiazonat1.0 kg a.i ha^{-1}	6.0a	8.4a	7.2a	14.8a	21.5a	18.2a
Orizoplus at 2.8 kg a.i ha^{-1}	6.3a	6.3b	6.3b	14.5ab	19.1ab	16.8a
Manual weeding at 3 and 6 WAS	5.5b	8.8a	7.1a	13.6b	21.7a	17.7a
Weedy check	3.7c	5.0c	4.3c	9.4c	17.1b	13.2b
SE±	0.09	0.16	0.07	0.35	1.23	0.77
Seeding method (S)						
Drilling	5.5	7.2	6.3	13.5	20.9	17.2
Dibbling	5.6	7.3	6.4	12.8	20.2	16.5
Broadcast	5.2	6.9	6.1	13.0	18.4	15.7
SE±	0.17	0.44	0.16	0.31	1.07	0.57
Seed rate kg ha^{-1} (R)						
40	5.7	5.8b	5.7b	12.3b	19.9	16.1
70	5.4	7.9a	6.6a	13.7a	20.2	16.9
100	5.2	7.7a	6.5a	13.2ab	19.5	16.4
SE±	0.17	0.44	0.16	0.31	1.07	0.57
Interaction						
W x S	NS	NS	NS	NS	NS	NS
W x R	NS	NS	NS	NS	NS	NS
S x R	NS	NS	NS	NS	NS	NS
W x S x R	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability using DMRT. ** = significant at 1% level of probability. NS = Not significant.

Table 3. Effect of weed management practice, seeding method and seed rate on 1000- grain weight (g) and yield of rice at Talata Mafara during 2012 and 2013 wet seasons.

Treatment	1000-grain weight (g)			Paddy yield (kg ha^{-1})		
	2012	2013	Mean	2012	2013	Mean
Weed management (W)						
Oxadiazonat1.0 kg a.i ha^{-1}	23.4b	17.1a	20.1a	5414.1a	3429.1a	4421.6a
Orizoplus at 2.8 kg a.i ha^{-1}	24.7ab	14.4b	19.6b	3909.1b	2987.3b	3448.2b
Manual weeding at 3 and 6 WAS	25.6a	17.0a	21.3a	5838.1a	3420.7a	4629.4a
Weedy check	21.5c	10.5c	16.0c	1541.9c	2527.9c	2034.9c
SE±	0.67	0.66	0.49	180.79	65.07	90.72
Seeding method (S)						
Drilling	24.2	14.4	19.3	4303.2a	3208.0a	3755.6a
Dibbling	23.7	15.2	19.5	4355.1a	3264.0a	3809.5a
Broadcast	23.5	14.6	19.1	3644.1b	2801.7b	3222.9b
SE±	0.46	0.40	0.33	149.88	57.67	118.80
Seed rate kg ha^{-1} (R)						
40	24.2	15.1	19.7	3700.2b	3144.9a	3422.6
70	23.5	14.2	18.9	4332.1a	3159.5a	3745.9
100	23.7	14.9	19.3	4270.1a	2969.1b	3619.6
SE±	0.46	0.40	0.33	149.88	57.67	118.80
Interaction						
W x S	NS	NS	NS	NS	NS	NS
W x R	NS	NS	NS	**	NS	NS
S x R	NS	NS	NS	NS	**	NS
W x S x R	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability using DMRT. NS = Not significant.

In 2012, herbicide treatments produced similar primary spikes, which were significantly more than by manual weeding and the weedy check. In 2013 and the combined data, oxadiazon and manual weeding produced significantly more of primary spikes than orizoplus and the weedy check. Orizoplus in turn produced significantly more primary spikes than weedy check. In 2012, drilled and broadcast rice had similar primary spikes, and each produced significantly more primary spikes than dibbled rice. In 2013 and the mean data, drilled rice produced significantly more number of primary spikes than dibbled and broadcast rice. Varied seed rate had significant effect on primary spikes per panicle in 2013 and combined data. In both cases, increasing seed rate from 40 to 70 kg ha^{-1} increased significantly the number of primary spikes per panicle beyond which there was no significant increase in number of primary spikes.

Table 2 shows the influence of weed management practice, seeding method and seed rate on secondary spikes per panicle at Talata Mafara and Kadawa in 2012 and 2013. At Talata Mafara in 2012, oxadiazon had significantly more secondary spikes than manual weeding, and each was at par with orizoplus. The lowest was produced in the weedy check. In 2013 oxadiazon and manual weeding gave more secondary spikes per panicle than the weedy check, and each was similar to orizoplus. Seeding rate significantly affected number of secondary spikes per panicle in 2012only.Rice sown at 70 kg seeds ha^{-1} produced significantly more secondary spikes than which was sown at 40 kg seed ha^{-1}, and each was at par with 100 kg seeds ha^{-1}.

1000-grain weight

Weed management practice significantly influenced grain weight in both years and their mean (Table 4). In 2012, manual weeding resulted in significantly heavier grains than the other weed managements, though, at par with orizoplus, which in turn was similar to oxadiazon. In 2013 and in the combined data, oxadiazon and manual weeding had similar grain weight, and each heavier than by orizoplus. The lightest grains were from untreated plots.

Paddy yield

The effects of weed management practice, seeding method and seed rate on paddy yield in 2012 and 2013 and the combined data at Talata Mafara presented in

Table 4. Interaction between weed management practice and seed rate in 2012 and planting method and seed rate in 2013 on paddy yield at Talata Mafara.

	Seed rate (kg ha^{-1})		
Weed management	**40**	**70**	**100**
		(2012)	
Oxadiazon at 1.0 kg a.i ha^{-1}	4317.7c	5527.0a	5397.4ab
Orizoplus at 2.8 kg a.i ha^{-1}	2899.2cd	4127.0c	4701.1bc
Manual weeding at 3 and 6 WAS	5071.4b	6093.5a	5447.4ab
Weedy check	1512.2d	1578.8d	1534.4d
SE±		299.76	
		(2013)	
Drilling	3060.6c	3491.6a	3071.7c
Dibbling	3226.6abc	3410.0ab	3153.9bc
Broadcast	2764.1d	2761.0d	2679.9d
SE±		179.95	

Means followed by the same letter (s) are not significantly different at 5% level of probability using DMRT.

(Table 3). In both years and the combined data, oxadiazon and manual weeding resulted in higher paddy yield than orizoplus, which in turn was higher than the least by the weedy check. In both years, as well as the combined data, drilled and dibbled consistently gave similar paddy yield, and each was higher than by broadcast crop. In both years, 70 kg ha^{-1} seed rate consistently gave the highest paddy yield that was similar to that by100 kg ha^{-1} seed rate in 2012 and 40 kg ha^{-1} seed rate in 2013. Interactions of weed management practice and seed rate were significant in 2012 (Table 4). With oxadiazon and manual weeding, increasing the seed rate from 40 to 70 kg ha^{-1} significantly increased the paddy yield and further increase to 100 kg seed ha^{-1}did not change the yield significantly. The highest paddy yield was by oxadiazon treated or manually weeded rice sown at 70 or 100 kg seed ha^{-1}. The lowest paddy yield was obtained from rice sown at 40 or 70 or 100 kg seed ha^{-1} left weedy, and by plots treated with orizoplus sown at 40 kg seeds ha^{-1}. Interaction of seeding method and seed rate was significant in 2013 (Table 4). At 40, 70 and 100 kg seed ha^{-1}, drilled and dibbled sown had similar paddy yield that was more than by the broadcast rice. The highest paddy yield was by dibbled at 40 kg seed ha^{-1} and by drilled or dibbled at 70 kg seed ha^{-1}. The lowest yield was by broadcast rice in all the seed rates.

DISCUSSION

Result on paddy yield and yield components such as panicle length, primary spikes, secondary spikes, grain per panicle, 1000 grain weight indicated the superiority of each weed management treatment over the weedy check. This observation could be attributed to reduction in competition for growth resources between crop plants and weeds by the weed management practice employed. Uncontrolled weeds compete with crops for environmental resources that are available in limited supply and as a consequence, competition may reduce yield, yield attributes and quality of the crop. The general trend of this study revealed that all the yield components were higher in manually weeded rice compared to other weed management practices. The manual weeding at 3 and 6 WAS controlled weeds more efficiently compared to the application of oxadiazon and orizoplus. As rice is a poor weed competitor, a long season competition reduces yield and yield attributes (Saito, 2010). These results are in conformity with the findings of Khaliq et al. (2012), who found the highest values for yield components where weeds were controlled by manual weeding at 3 and 6 WAS.

Yield and yield attributes such as panicle length and grains per panicle were significantly influenced by seeding method, with drilling being superior to dibbling and broadcast methods with respect to yield and the yield components. This finding is in conformity with the findings of Phuong et al. (2005), who attributed higher crop yield in row seeding to better seedling establishment. Drilling method could also be superior to other seeding methods because it gives the crop higher competitive ability against weeds due to its closed canopy architecture. The highest paddy yield obtained by the use of higher seed rates of 70 kg ha^{-1} and 100 kg ha^{-1} in combination with application of oxadiazon or manual weeding at 3 and 6 WAS could be attributed to the fact that high seed rate enhanced seed germination, emergence and establishment of the crop coupled with an early weed free period enforced by these weed management practices. Increased number of primary and secondary spikes per panicle and the paddy yield obtained at a higher seed rate in both drilling and dibbling could also be as a result of the synergistic effect of both the crop seeding arrangement which enhanced fast canopy closure and the higher population density which gave a competitive advantage to the crop over the weed and also provided good crop architecture that provided proper and optimum sunlight penetration for photosynthesis. Efthimiadou et al. (2009) opined that cultivars which are able to tolerate or compete strongly with weeds through faster growth rate and shading ability in combination with increased seed rate would make significant contribution to productivity and stability on farmers.

Conclusion

To obtain the best paddy yield from lowland rice production in the Sudan savanna zone of Nigeria, lowland rice could be drilled or dibbled at 70 kg ha^{-1} seed rate using a pre-emergence herbicide, oxadiazon at 1.0 kg a.i ha^{-1} as a weed management measure.

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