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Full-Length Research Paper

Yield and yield components of lowland rice (*Oryza sativa* L.) as influenced by different management practices in Guinea savanna ecological zone

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ABSTRACT: To study the influence of weed management practice, seeding method and seed rate on the yield and yield attributes of rice (*Oryza sativa* L.), a field experiment was conducted in 2012 and 2013 wet seasons at the Irrigation Research Stations of the Institute for Agricultural Research, Ahmadu Bello University, Kadawa, Northern Guinea Savannah Zone of Nigeria, 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. In 2013, the highest paddy yield was by drilled (3441 kg ha^{-1}) or dibbled (3483 kg ha^{-1}) manually weeded at 3 and 6 WAS and by drilled (3433 kg ha^{-1}) or dibbled (3528 kg ha^{-1}) rice treated with oxadiazon at 1.0 kg a.i ha^{-1}). From the study, it was observed that the use of optimum seed rate of 70 kg ha^{1} in combination with either manual weeding at 3 and 6 WAS or oxadiazon at 1.0 kg a.i ha^{-1} and drilling or dibbling was promising in rice production in the Nigerian Northern Guinea Savannah ecological zone.

Keywords: Lowland rice, weed management, sowing method, seed rate

INTRODUCTION

Rice is the most important staple food for a large part of the world's human population (FAOSTAT, 2013). It has the third highest production in the world after maize and wheat (FAOSTAT, 2013). Two types are common, *Oryza sativa* L. (Asian rice) and *Oryza glaberrima* L. (African rice).Since a large portion of maize and wheat are grown for other purposes other than human consumption, rice is the most important grain with regard to human nutrition and calorie intake, providing more than one fifth of the calories consumed worldwide by the human species (FAOSTAT, 2013). The world production of rice as at 2013 stood at 672,015,587 metric tonnes produced on 153,652, 007 hectares of land with an average yield of 4.4 tonnes per hectare. The Nigerian production as at 2018 stood at 4,833,000 metric tonnes produced on 2,600,000 hectares of land with an average yield of 1.8 tonnes per hectare (FAOSTAT, 2013). Weeds constitute one of the most important constraints to rice production especially in tropical Africa (Akobundu, 1987). Weeds and shortage of labour for their removal have been identified by Chikoye *et al.* (2004) as the two most important production constraints in small holder farms in the northern Guinea savanna (NGS) of Nigeria. In fact, the crop production system has been characterized by control of weeds. Losses due to infestation of weeds are greater than the combined losses caused by insect pests and diseases in rice (Nasimul, 2010). Reduction in yield of rice caused by weeds ranges from 10-100% (Akobundu, 1987; David, 2009; Nasimul, 2010; Chauchan *et al*., 2011; Mahajan and Chauchan, 2011). Farmers in tropical Africa spend 50-70% of their total available farm labour on weed control, which is mostly carried out by manual weeding (Akobundu, 1987). Manual weeding at 3 and 6 WAS, though effective, is associated with challenges such as drudgery, labour scarcity, high wages and allowing early weed-crop competition before the weeds could reach sufficient size to be pulled out. Herbicides are increasingly used to control weeds in rice, and offer good weed suppression, increase yields and efficiency of production if used at recommended rate (Adekpe and Adigun, 2000). However herbicides alone may not provide season-long control due to weed species diversity and successive emergence coupled with environmental effects that reduce herbicide efficacy duration. Moreover, improper use of herbicide moves the agro-ecosystem to low species diversity with new problem weeds appearing, bringing about the evolution of herbicide resistance weeds. There is also the ultimate concern about environmental protection. There is the need therefore for an ecological approach to weed control instead of relying totally on chemical control methods. Various weed management approaches and agronomic principles need to be integrated to achieve effective, sustainable and long term weed control in direct seeded rice. Farmers use different seed rate and methods in order to obtain good crop establishment, reduce cost, labour, menace of weeds, pests and diseases. Despite the unavailability and high cost of improved seeds, farmers in the Sub-Saharan Africa use seed rate above the recommended rate of 100 kg ha^{-1}. Higher than recommended seeding density affect crop performance due to intense competition for the available resources, increase in number of unproductive tillers and consequently low yield. Seed rate in crops has been tested for effective tool for lowering weed pressure in different crops (Phuong *et al*., 2005; Shinggu *et al*., 2009). The efficiency of a given seed rate on weed suppression depends on weed type and crop cultivar.

Seeding method determines free space between stands from which weeds would emerge. Farmers prefer direct seeding to reduce the drudgery associated with nursery management and seedling transplanting. Broadcast is cheaper and reduces competition between adjacent plants, but is associated with high seed rate and high labour cost in hand pulling of weeds unless one uses herbicides. Although dibbled and drilled methods require less seed inputs, ensure better crop establishment which enhance the competitive ability of the crop with weeds than broadcast method and makes hoe-weeding possible, these methods are expensive as they are labour intensive especially during sowing. A good weed management strategy may include an integrated approach that considers, among other things, appropriate agronomic practices such as effective and selective herbicides and appropriate seeding method and seeding rate. The objectives of this research study was to evaluate the effect of weed management practice, seeding method and seed rate on the yield components and yield of lowland rice.

MATERIALS AND METHODS

Experimental Sites

A 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 Kadawa (11^{o}39`N; 08^{o}02'E) in the Northern Guinea Savanna zone of Nigeria.

Treatments and experimental design

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.

Variety

SIPI-602033 (FARO 44) was used for the experiment. The variety originated from Taiwan. It was introduced to Nigeria through the National Cereal Research Institute (NCRI), Badeggi. The seed was sourced from Zamfara State Agricultural Development Project (ZADP) Gusau.

Cultural practices

The experimental field in each season and site was double harrowed to obtain a fine tilth. The land was thereafter manually prepared into check basins.

Gross plot size was 3.0 m by2.0 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 as per seeding method and seeding rate treatments. The seed was sown on rows, 20 cm apart in both drilled and dibbled plots 10 rows per plot, each 3 m long and at 20 cm between stands in dibbled plots, giving 15 stands per row. 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 crop was harvested at physiological maturity when the entire plants had turned yellow and grain fully filled and at hard dough stage. Data were collected on Harvest index (HI), Panicle length, number of primary and secondary spikes per panicle, number of grains per panicle, 1000 - grain weight and paddy yield. Data collected from the observations were subjected to analysis of variance (ANOVA) as described by Steel and Torrie (1984) and 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

Harvest index

Effect of weed management practice, seeding method and seed rate on harvest index (HI) at Kadawa in 2012 and 2013 and their mean are presented in (Table 1). At Kadawa, oxadiazon and manual weeding resulted in significantly higher HI than orizoplus, which in turn was higher than the weedy check. Seeding method had significant effects on HI only in all the years of study and the mean data. In 2013, drilled and dibbled rice gave similar harvest index and each was higher than that by broadcast crop. In 2012, drilling resulted in higher HI than dibbling, and the broadcast crop was at par with the two other sowing methods. In the combined data, dibbling gave higher HI than drilling and broadcast. Seed rate exhibited significant influence on harvest index in 2013 only at the study location. In that case, rice sown at 40 and 70 kg seed ha^{-1} gave similar harvest index, and each was higher than by 100 kg ha^{-1} seed rate.

Panicle length

Rice panicle length as affected by weed management practice, seeding method and seed rate at Kadawa in 2012 and 2013 and the combined data is presented in (Table 2). There were significant differences in rice panicle length among the weed management practices in both years of the study. In the combined data at Kadawa, the three management practices gave similar panicles and each was significantly longer than that by the weedy check. In 2012, oxadiazon treated gave significantly longer panicles than orizoplus treated, and each was at par with manual weeding. The weedy check gave shorter panicles than all the herbicide treatments and manual weeding. In 2012, drilled rice produced significantly longer panicles compared to dibbled rice, and both were similar to broadcast rice. Seed rate significantly influenced rice panicle length only in the mean data. In that case, rice sown at 40 kg seeds ha^{-1} had significantly longer panicles than that sown at 100 kg seeds ha^{-1}, and both were similar to 70 kg seed ha^{-1}.

Primary spikes per panicle

Weed management practice influenced number of primary spikes significantly in both years of study (Table 3). In 2012, oxadiazon gave more primary spikes than other management practices, and the lowest numbers of primary spikes were produced by the weedy check. In 2013, oxadiazon and manual weeding produced significantly more primary spikes than orizoplus, and the lowest was by weedy check. Seeding method had significant effect on primary spikes per panicle in both years and their mean at Kadawa. 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. Interactions were significant between weed management and seeding method (Table 4), and seeding method and seed rate (Table 5) at Kadawa in the mean data. Table 4 shows that, with each weed management practice, except orizoplus, drilled and dibbled rice had similar primary spikes, which were significantly more than by broadcast rice. In drilled and dibbled rice, oxadiazon and manual weeding gave similar number of primary spikes, and each was significantly higher than by the other treatments. With broadcast, all the three weed management practices produced similar number of primary spikes, and each was higher than weedy check. Interaction of seeding method and seed rate on number of primary spikes shows that, with all the seeding method, varied seed rates had no significant effect on the number of primary spikes. With all the seed rates, drilled and dibbled rice produced similar number of primary spikes that was more than by broadcast rice.

Secondary spikes per panicle

Table 6 shows the influence of weed management practice, seeding method and seed rate on secondary

Table 1: Effect of weed management practice, seeding method and seed rate on harvest index of rice at Kadawa during 2012 and 2013 wet seasons

	Harvest index Kadawa		
Treatment			
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	36.4a	57.6a	47.0a
Orizoplus at 2.8 kg a.i ha^{-1}	28.4b	53.0b	40.7b
Manual weeding at 3 and 6 WAS	36.4a	57.7a	47.0a
Weedy check	24.3c	48.1c	36.2c
SE±	1.61	0.56	0.79
Seeding method (S)			
Drilling	29.1b	55.2a	42.2b
Dibbling	33.9a	55.5a	44.7a
Broadcast	31.1ab	51.6b	41.4b
SE±	1.00	0.46	0.60
Seed rate kg ha^{-1} (R)			
40	31.4	54.7a	43.1
70	31.7	54.7a	43.2
100	31.1	52.9b	42.0
SE±	1.00	0.46	0.60
Interaction			
W x S	NS	NS	NS
W x R	NS	NS	NS
S x R	NS	NS	NS
W x S x R	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. NS = Not significant.

Table 2: Effect of weed management practice, seeding method and seed rate on panicle length (cm) of rice at Kadawa during 2012 and 2013 wet seasons.

Treatment		Panicle length (cm) Kadawa	
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	26.6a	27.1a	27.0a
Orizoplus at 2.8 kg a.i ha^{-1}	24.4b	25.1b	26.3a
Manual weeding at 3 and 6 WAS	25.1ab	28.7a	27.5a
Weedy check	18.5c	23.9b	21.7b
SE±	0.58	0.88	0.54
Seeding method (S)			
Drilling	24.4a	26.2	25.3
Dibbling	23.0b	26.7	24.8
Broadcast	23.7ab	25.8	24.7
SE±	0.46	0.57	0.42
Seed rate kg ha^{-1} (R)			
40	24.2	26.5	25.3a
70	23.6	26.5	25.8ab
100	23.2	25.7	24.9b
SE±	0.46	0.57	0.42
Interaction			
W x S	NS	NS	NS
W x R	NS	NS	NS
S x R	NS	NS	NS
W x S x R	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. NS = Not significant.

spikes per panicle at Kadawa in 2012 and 2013. In 2013, oxadiazon and manual weeding gave more secondary spikes per panicle than the weedy check, and each was similar to orizoplus. At Kadawa in 2012 and the combined mean, all the three weed management practices had similar secondary spikes, which was more than by the weedy check. Seeding method had no significant effect on secondary spikes per panicle throughout. Seeding rate significantly affected number of secondary spikes per panicle in 2012 only.Rice sown at

Table 3: Effect of weed management practice, seeding method and seed rate on primary spikes per panicle of rice at Kadawa during 2012 and 2013 wet seasons,

	Primary spikes per panicle		
Treatment	**Kadawa**		
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	6.4a	7.2a	6.8a
Orizoplus at 2.8 kg a.i ha^{-1}	5.6b	6.1b	5.9a
Manual weeding at 3 and 6 WAS	5.4b	7.2a	6.3a
Weedy check	4.3c	5.0c	4.7b
SE±	0.21	0.34	0.32
Seeding method (S)			
Drilling	5.8a	7.6a	6.7a
Dibbling	5.0b	5.9b	5.4b
Broadcast	5.5a	5.7b	5.6b
SE±	0.12	0.28	0.20
Seed rate kg ha^{-1} (R)			
40	5.6	6.4	5.8
70	5.3	6.6	5.9
100	5.3	6.2	5.8
SE±	0.12	0.28	0.20
Interaction			
W x S	NS	NS	*
W x R	NS	NS	NS
S x R	NS	NS	*
W x S x R	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. NS = Not significant.

Table 4**:** Interaction between weed management practice and seeding method on number of primary spikes per panicle at Kadawa in the mean data of 2012 and 2013

	Seeding method		
Weed management	**Drilling**	**Dibbling**	**Broadcast**
Oxadiazon at 1.0 kg a.i ha^{-1}	6.88a	6.96a	5.84b
Orizoplus at 2.8 kg a.i ha^{-1}	5.31b	5.90b	5.93b
Manual weeding at 3 and 6 WAS	6.76a	6.36a	5.93b
Weedy check	5.53b	4.78b	4.02c
SE±		0.256	`

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

Table 5**:** Interaction between seed rate and seeding method on number of primary spikes per panicle at Kadawa in the mean data of 2012 and 2013

	Seed rate (kg ha^{-1})		
Seeding method	**40**	**70**	**100**
Drilling	5.72ab	6.82a	6.28ab
Dibbling	5.29bc	6.41ab	6.35ab
Broadcast	5.09c	5.18c	5.14c
SE±		0.417	

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

70 and 100 kg seed rate produced similar secondary spikes, though, each significantly more than 40 kg ha^{-1} seed rate.

Number of grains per panicle

The effects of weed management practice, seeding method and seed rate on number of grains per panicle at Kadawa in 2012 and 2013 are presented in (Table 7). In 2012, oxadiazon gave significantly more grains per panicle than other treatments, and the lowest was 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. Seeding method had significant effect on grains per panicle in 2012. In 2012, drilled and dibbled rice produced comparable grains per panicle, and each was significantly lower than drilled rice. Seeding rate had significant effect on the number of grains per panicle in 2012 only. In that case, rice sown at 70 kg seeds ha^{-1} produced significantly more grains per

Table 6: Effect of weed management practice, seeding method and seed rate on secondary spikes per panicle of rice at Kadawa during 2012 and 2013 wet seasons.

	Secondary spikes per panicle		
Treatment	Kadawa		
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	15.2a	25.3a	20.2a
Orizoplus at 2.8 kg a.i ha^{-1}	14.9a	22.5ab	19.6a
Manual weeding at 3 and 6 WAS	14.6a	25.5a	20.5a
Weedy check	10.7b	20.1b	15.5b
SE±	0.33	1.47	0.89
Seeding method (S)			
Drilling	13.5	24.6	19.7
Dibbling	13.8	23.8	18.8
Broadcast	13.5	21.7	18.3
SE±	0.52	1.26	0.68
Seed rate kg ha^{-1} (R)			
40	11.9b	23.4	18.4
70	14.3a	23.7	19.8
100	14.5a	22.9	19.0
SE±	0.52	1.26	0.68
Interaction			
W x S	NS	NS	NS
W x R	NS	NS	NS
S x R	NS	NS	NS
W x S x R	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. NS = Not significant.

Table 7. Effect of weed management practice, seeding method and seed rate on number of grains per panicle of rice at Kadawa during 2012 and 2013 wet seasons.

	Number of grains per panicle		
Treatment	Kadawa		
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	110.8a	85.7	98.3a
Orizoplus at 2.8 kg a.i ha^{-1}	91.0b	74.4	82.7ab
Manual weeding at 3 and 6 WAS	95.1b	85.9	90.5ab
Weedy check	80.7c	63.8	72.3b
SE±	1.81	13.69	6.56
Seeding method (S)			
Drilling	100.9a	76.8	88.9
Dibbling	92.7b	83.6	88.2
Broadcast	89.6b	72.0	80.8
SE±	1.86	6.33	3.32
Seed rate kg ha^{-1} (R)			
40	91.4b	77.3	84.4
70	97.6a	80.1	88.9
100	94.2ab	75.0	84.6
SE±	1.86	6.33	3.32
Interaction			
W x S	NS	NS	NS
W x R	NS	NS	NS
S x R	NS	NS	NS
W x S x R	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. NS = Not significant.

panicle than by 40 kg seed ha^{-1}, and each was similar to 100 kg ha^{-1}sown. Interactions of treatment factors on the number of grains per panicle were not significant.

1000-grain weight

Weed management practice significantly influenced grain weight in both years and their mean (Table 8). In 2012 and mean of the years, herbicide treatments and manual weeding had similar grain weight, and each was heavier than by the weedy check. Neither seeding methods nor seeding rate significantly influenced grain weight in both years.

Paddy yield

The effects of weed management practice, seeding

Table 8: Effect of weed management practice, seeding method and seed rate on 1000- grain weight (g) of rice at Kadawa during 2012 and 2013 wet seasons.

	1000-grain weight (g)		
Treatment	Kadawa		
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	27.2a	15.0a	21.1a
Orizoplus at 2.8 kg a.i ha^{-1}	28.6a	12.7b	20.7a
Manual weeding at 3 and 6 WAS	27.7a	14.9a	21.3a
Weedy check	23.2b	9.2c	16.2b
SE±	0.69	0.58	0.29
Seeding method (S)			
Drilling	27.4	12.6	20.0
Dibbling	26.2	13.4	19.8
Broadcast	26.3	12.8	19.5
SE±	0.52	0.35	0.31
Seed rate kg ha^{-1} (R)			
40	25.9	13.2	19.6
70	26.7	12.5	19.6
100	27.3	13.1	20.2
SE±	0.52	0.35	0.31
Interaction			
W x S	NS	NS	NS
W x R	NS	NS	NS
S x R	NS	NS	NS
W x S x R	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. NS = Not significant.

Table 9. Effect of weed management practice, seeding method and seed rate on paddy yield (kg ha^{-1}) of rice atKadawa during 2012 and 2013 wet seasons.

	Paddy yield (kg ha^{-1})		
Treatment	Kadawa		
Weed management (W)	**2012**	**2013**	**Mean**
Oxadiazon at1.0 kg a.i ha^{-1}	3443.7b	3250.1a	3347.8b
Orizoplus at 2.8 kg a.i ha^{-1}	3132.6b	2664.3b	2898.3c
Manual weeding at 3 and 6 WAS	4656.7a	3255.7a	3956.2a
Weedy check	959.3c	2204.9c	1582.1d
SE±	245.60	65.07	100.76
Seeding method (S)			
Drilling	3156.0a	2960.5a	3058.2a
Dibbling	3301.4a	3016.5a	3158.9a
Broadcast	2686.7b	2554.2b	2620.1b
SE±	125.93	58.546	103.89
Seed rate kg ha^{-1} (R)			
40	2814.1b	2897.4a	2855.6
70	3253.5a	2912.0a	3083.6
100	3076.6ab	2727.6b	2902.2
SE±	125.93	58.54	103.89
Interaction			
W x S	NS	*	NS
W x R	NS	NS	*
S x R	NS	*	NS
W x S x R	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. NS = Not significant.

method and seed rate on paddy yield in 2012 and 2013 and the combined data at Kadawa are presented in (Table 9). The effect of weed management practice was significant on paddy yield in all the years of study and the combined data. In2013, oxadiazon and manual weeding resulted in higher paddy yield than orizoplus, which in turn was higher than the least by the weedy check. In 2012 and the combined data manual weeding gave higher paddy yield than all the other treatments. In turn, yields by oxadiazon and orizoplus were at par, and each

Table 10: Interaction between weed management practice and seeding method on paddy yield at Kadawa in 2013

	Seeding method		
Weed management	**Drilling**	**Dibbling**	**Broadcast**
		Kadawa 2013	
Oxadiazon at 1.0 kg a.i ha^{-1}	3433.2a	3528.2a	2888.7b
Orizoplus at 2.8 kg a.i ha^{-1}	2699.1b	2767.0b	2526.7c
Manual weeding at 3 and 6 WAS	3441.1a	3483.0a	2842.6b
Weedy check	2368.3c	2287.7c	1958.6d
SE±		115.34	

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

Table 11: Interaction between weed management practice and seed rate on paddy yield at Kadawa in the mean data

	Seed rate (kg ha^{-1})		
Weed management	**40**	**70**	**100**
		Kadawa (Mean)	
Oxadiazon at 1.0 kg a.i ha^{-1}	4011.5ab	4117.3a	4147.9a
Orizoplus at 2.8 kg a.i ha^{-1}	3276.3c	3873.4ab	3720.3b
Manual weeding at 3 and 6 WAS	3865.9ab	4043.9a	4085.0a
Weedy check	2020.6d	2091.8d	2088.9d
SE±		107.79	

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

Table 12: Interaction between seed rate and seeding method on paddy yield at Kadawa in 2013

	Seed rate(kg ha^{-1})		
Seeding method	40	70	100
		Kadawa (2013)	
Drilling	2813.1b	3244.1a	2824.2b
Dibbling	2798.5b	3192.5a	2908.4a
Broadcast	2416.8c	2713.5b	2432.4c
SE±		99.89	

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

was higher than by the weedy check, in 2012 at Kadawa, while in the combined data, oxadiazon gave higher yield than orizoplus, which in turn was higher than the least by the weedy check. The response of paddy yield to seeding method was significant in both years and their means. 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. Varied seed rate significantly influenced paddy yield in both years of study, except in the combined data. In 2012, 70 kg seed ha^{-1} resulted in significantly higher grain yield than 40 kg seed ha^{-1}. The yield by 100 kg seed rate was similar to both 40 and 70 kg rates. 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. There were significant interactions of weed management and seeding method on paddy yield in the combined data in 2013 at Kadawa (Table 10). At Kadawa in 2013, with all the weed management practices, drilled and dibbled rice produced similar paddy yield, and each was higher than broadcast rice. With all the seeding methods, plots treated with oxadiazon or manually weeded twice had similar paddy yield and each was higher than orizoplus, and the lowest was by weedy check. Interactions of weed management practice and seed rate were significant in the mean data at Kadawa (Table 11).Varied seed rate had no significant influence on paddy yield with all the weed management practices, except, with orizoplus, in which 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 paddy yield significantly.

The highest paddy yield was by oxadiazon treated or manually weeded rice sown at 40, 70 or 100 kg seed ha^{-1} and orizoplus treated rice sown at 70 kg seed ha^{-1}. The lowest paddy yield was by untreated rice sown at 40, 70 or 100 kg seed ha^{-1}. Interaction of seeding method and seed rate was significant in 2013 (Table 12).With all the seeding methods, increasing the seed rate from 40 to 70 kg ha^{-1} significantly increased paddy yield, beyond which the yield declined. With all the seeding rates, drilled and dibbled sown had similar paddy yield that was more than by the broadcast sown. The highest paddy yield was by drilled or dibbled rice sown at 70 kg ha^{-1}. The lowest paddy yield was by broadcast sown at either 40 kg seed ha^{-1} or 100 kg seed ha^{-1}.

DISCUSSION

Response of rice to weed management practice

Result on paddy yield and yield components such as panicle length, primary spikes, secondary spikes, grain per panicle, 1000 grain weight and harvest index 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 both 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*. (2012a) who found the highest values for yield components where weeds were controlled by manual weeding at 3 and 6 WAS. Longer panicles, higher number of spikelet per panicle and 1000-grain weight were reported by Than (2003) and Akbar (2011) in a less competitive weed free plots than in the untreated control. Razia (2000) however, reported a non-significant effect of weed competition on 1000-grain weight and further stressed that 1000-grain weight is a genetic character and environmental factors have minimum influence on it.

Lower paddy yield obtained in the untreated control could be due to intense crop-weed competition reflected in shorter panicles, low number of grains per panicle and low 1000-grain weight. These conform to the reports of Phuong *et al*. (2005). Ishaya *et al*. (2007) also found that oxadiazon increased rice paddy yield comparable to other weed control treatments and higher than for the weedy check.

Response of rice to seeding method

Reduction in severe weed competition in direct seeded rice calls for improved management practices such as, manipulation of seeding method that will effectively reduce the problem of drudgery, herbicide resistance in weeds, and environmental pollution. Yield and yield attributes such as panicle length, number of primary spikes and 1000-grain weight were significantly influenced by seeding method, with broadcast method having the lowest values compared to drilling and dibbling methods. Drilling was in-turn superior to dibbling method with respect to the ultimate paddy yield. 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. Drilling method forms a continuous closed canopy that closes faster and suppresses the weeds thereby reducing the intensity of inter-specific competition between the crop and weeds. In this study, this was manifested in the lower amount of weed dry matter and also higher weed control efficiency obtained in drilled plots. Anwar *et al.* (2005) also attributed high paddy yield in drilling method to the variation in solar radiation interception and light transmission through the canopy orientation.

Response of rice to seed rate

Each panicle parameter such as panicle length, primary spikes, secondary spikes and grains per panicle contribute to the yield of the rice plant. The insignificant difference in most of these yield components that contribute to the yield indicated that seed rate did not affect these yield components but affected the final yield which could be due to the intra-specific and/or inter-specific competition that existed during the development of the yield components. This result corroborates the reports of Oziegbe and Faluye (2007) and Khaliq *et al*. (2012b) who reported insignificant influence of some yield components to seeding rate. Generally, in this study, paddy yield significantly increased with increase in seed rate up to 70 kg ha^{-1}after which it stabilized. Among the reasons that could be attributed to this is the link between dry matter accumulation and yield. Crop density changes the parameters and quality of environment that is available for the growth of weeds in association with the crop (Singh, 2008). Low seed rate results in poor germination and establishment of the crop due to seed lost to pest, profuse weed growth leading to intense weed-crop competition which ultimately results in low crop growth rate and poor dry matter accumulation. Higher seeding rate could increase paddy yield through enhanced dry matter accumulation resulting from reduced inter-specific competition between the crop and weeds by giving the crop a competitive advantage over weeds through smothering effect, fast canopy development, higher number of harvestable panicles and grasping the limited resources at a faster rate (Anwar *et al*., 2011). Anwar *et al*. (2011); Chauchan *et al*. (2011) and Khaliq *et al*. (2012a) concluded that increasing seed rate increased crop yield. Contrariwise, Payman and Singh (2008) and Mahajan *et al.* (2010) observed lower paddy yield as a result of higher plant density, and attributed this to reduced light interception and Co_2 assimilation, high dilution effect and intensive intra-specific competition for light and nutrients.

Conclusion

For the best paddy yield, rice should be drilled or dibbled at an optimum seed rate of 70 kg ha^{-1} and weeds managed by manual weeding at 3 and 6 WAS or by application of oxadiazon at 1.0 kg a.i ha^{-1}.

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