Gezira J. of agric. sci. 17(2): 253-264 (2019

Response of aerobic rice (*Oryza sativa* L.) to seed rate and inter-row spacing, Gezira State, Sudan

Osama M. A. Elhassan[1] and Ishraga M. Hamid[2]

[1] Gezira Research Station, Agricultural Research Corporation, P.O. Box 126, Wad Medani, Sudan

[2] Rice Production Unit, Ministry of Agriculture and Animal Wealth, Wad Medani, Sudan

ABSTRACT

Field experiments were conducted for two consecutive seasons (2013/14 and 2014/15) at the Gezira Research Station Farm, Wad Medani, Sudan under irrigation condition. A randomized complete block design with four replicates was used. Treatments were arranged in a factorial combination of four inter-row spacing (15, 20, 25 and 30 cm) and five seed rates (59, 71, 83, 95 and 107 kg/ha). Data collected consisted of growth attributes, grain yield and yield components. Data collected were subjected to standard analysis of variance procedure. The results showed that seed rate, inter-row spacing and their interaction exhibited highly significant differences in grain yield and yield components. The highest grain yield was obtained by the seed rate of 95 kg/ha and 15 cm inter-row spacing in both seasons and the combined analysis. To obtain high grain yield of aerobic rice under Gezira conditions, 95 kg/ha seed rate and inter-row spacing of 15 cm is recommended to be used.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops in the world. It is the staple food of nearly one-half of the world's population (FAO, 2007). More than 90% of the world's rice is grown and consumed in Asia where 60% of the world population lives. Rice accounts for 35% to 60% of the calories consumed by 3 billion Asians (FAO, 2007). Rice is planted on about 148 million hectares annually, accounting to 11% of the world's cultivated land. Rice is the only major cereal crop that is consumed almost exclusively by humans (Khush, 1997). It is mostly grown under submerged soil conditions because its water requirement is more than other crops. About 75% of the total rice production comes from irrigated lowlands (Bouman and Tuong, 2001). Sub-Saharan African countries produce about 21.6 million tons of rice and they introduce 32% of the global rice market to fill the gap between their production and their demand (FAO, 2007; Somado and Guei, 2008). This was a result of population growth and the increasing of consumer preference in favor of rice in urban areas (Kijima *et al*., 2006, Atera *et al*., 2011).

The global food shortage imposes a need to extend rice production in the Sudan and, hence, a national strategy to save a dual purpose as food for its growing population and as a cash crop. The central clay plains of the Sudan could be the most suitable and targeted area for any proposed extension in rice culture mainly because of the abundant water for irrigation. The soils in the Gezira, as a part from the central clay plains, are heavy clay- cracking Vertisols, (Soil Survey Staff, 1999). Rice is one of cereal crops which has recently contributed as fourth food source in the Sudan after sorghum, pear millet and wheat. Rice production is very important to fill the gap of consumption and export to Arabic gulf countries to bring hard currency. Sudan has a total estimated potential rice area of more than 300,000 ha (Mohamed, 2010).

Achieving a sustainable increase in rice production can improve global food security and contribute to poverty alleviation. About 57% of the total rice area in Africa is planted by upland rice in diverse cropping systems (Mohamed, 2010). Aerobic rice is a new way of growing rice. Aerobic rice describes a management adaptation to reduce irrigation water supplies but, due to reduced intervals of flooding in this system, this requires revised weed management approaches to reduce costs and provide effective weed control.

One approach is to make the crop more competitive and reduce the effects of weeds on the crop by using higher rice seed rates. Low plant density and high gaps encourage the growth of weeds, and in many cultivars, result in less uniform ripening and poor grain quality. On the other hand, very high plant stand should be avoided because it tends to have less productive tillers, increases lodging, prevents the full benefit of nitrogen application and increases the chances of pest damage.

Methods of planting, row spacing, and seed rates of aerobic rice are important factors affecting plant competition for light, water, nutrients, and space. Optimum plant density and proper row spacing are the principal factors for obtaining higher yield in rice. On the other hand, crop establishment is one of the key factors that affect the success of grain crops (Oghalo, 2011). Optimum crop establishment not only improves crop performance but also reduces seed rates needed for field planting. The objective of this study was to determine the response of aerobic rice to seed rate and row spacing under irrigation condition in the Gezira State.

MATERIALS AND METHODS

The experiment was conducted for two consecutive seasons (2013/14 and 2014/15) during the rainy season in the Gezira Research Station Farm of the Agricultural Research Corporation (ARC) of the Sudan, under irrigation. It is located in Wad Medani, central Sudan (latitude 14° 24´ N, longitude 33° 9´ E and altitude 407 m above sea level). The climate is semi- arid, with a short rainy season (July – September). The rainy season starts in June reaches a peak in July and August; and ends late September or early October. The second season was characterized by a high amount of rainfall. The total rainfall was 264 and 344 mm for the first and second seasons, respectively. Temperature was lower during both growing seasons. The soil of the experimental site was classified as Vertisol (heavy cracking clay), with high clay content (40% – 65%), very low in organic carbon (0.05%), low in N content (0. 03%) and medium in available phosphorus (6 ppm/kg of soil), pH values ranging from 7.5 to 8.2 (Mohamed *et al.* 2016). A randomized complete block design with four replicates was used. Plot size was 3 x 5 m. Treatments were arranged in factorial combinations of four inter-row spacing and five seed rates. The inter-row spacing treatments were 15, 20, 25 and 30 cm and the seed rates were 59, 71, 83, 95 and 107 kg/ha. The soil was disk harrowed during primary and secondary tillage operations then leveled. An aerobic, newly released rice variety, namely Kosti 1, was used in this experiment (Mustafa *et al.,* 2010). Seeds were manually sown directly on a flat dry soil. The planting depth was 2-3 cm. The sowing date was on mid July in both seasons. Irrigation was done as necessary at 7-10 days interval to maintain field capacity throughout the growing period. Hand weeding was done 3-4 times during the growing season to keep the crop free of weeds. Phosphorus in the form of triple super phosphate (TSP 45% P_2O_5) was used at the rate of 95 kg/ha before seeding and nitrogen in the form of urea was top dressed at the rate of 190 kg/ha in split doses, after three and six weeks from emergence. Data collected consisted of plant height (cm), number of tillers/m^2, percentage of filled grains, 1000 grain weight (g) and grain yield (kg/ha). Data were subjected to analysis of variance procedure.

RESULTS AND DISCUSSION

Crop performance

The analysis of variance showed that seed rate, inter-row spacing treatments and their interaction exhibited highly significant differences in grain yield and yield components.

Plant height (cm)

Seed rate significantly affect plant height (Table 1). Plant height was taller (95cm) at the seed rate of 107 kg/ha. Short plants were observed at the seed rate of 71 kg/ha (84cm). This indicates that when the plant density increases (high seeding rate), the plant tends to grow taller in search for light. That means as the number of plant/m^2 increases, plant competes severely for light. Thus, the plants grow taller. The inter-row spacing had no significant effect on plant height. The effect of seed rate x inter-row spacing interaction was significant at ($p \leq 0.05$) level. The tallest plants (96cm) were obtained at the seed rate of 107 kg/ha combined with 25-30 cm inter row spacing. This result is consistent with those reported by Harris and Vijayaragavan (2015). In contrast, Akbar and Ehsanullah (2004) reported that plant density had no significant effect on plant height.

Number of panicles/m^2

The results showed that increasing seed rate significantly ($p \leq 0.01$) increased number of panicle/m^2 (Table 2). Number of panicles/m^2 was significantly ($p \leq 0.05$) increased with the narrow inter row spacing. The effect of seed rate x inter-row spacing interaction was also significant at $p \leq 0.05$. Higher numbers of panicles/m^2 (681) were obtained by the seed rate of 107 (kg/ha) coupled with inter-row spacing of 15 cm. Similar findings were reported by Abdalla (2017), Mahajan *et al.* (2010) and Baloch *et al.* (2002). Also, Harris and Vijayaragavan (2015) stated that increasing seed rate from 61.5 to 102.5 kg/ha gave a substantial rise in panicle number/m^2. The current findings were supported by Baloch *et al.* (2002) who reported that greater number of plants per unit area increased number of panicles per unit area.

Table 1. Effect of inter-row spacing, seed rate and their interaction on plant height (cm) of aerobic rice in the Gezira during seasons 2013/14 and 2014/15 (combined data).

Seed rate (kg/ha)	Inter-row spacing (cm)				
	15	20	25	30	Mean
59	92	94	84	85	88
71	80	90	84	84	84
83	91	81	84	87	86
95	86	93	93	95	92
107	94	95	96	96	95
Mean	89	91	88	90	
	Seed rate	Spacing	Seed rate x Spacing		
SE±	1.4**	1.2ns	3.74*		
CV (%)		7.4			

*, ** significant at P = 0.05 and 0.01, respectively. Ns = Not significant.

Table 2. Effect of inter-row spacing, seed rate and their interaction on number of panicles/m² of aerobic rice in the Gezira during seasons 2013/14 and 2014/15 (combined data).

Seed rate (kg/ha)	Inter-row spacing (cm)				
	15	20	25	30	Mean
59	404	387	361	348	375
71	429	418	401	361	405
83	535	500	484	458	495
95	564	525	512	497	524
107	681	597	577	519	594
Mean	523	485	467	437	
	Seed rate	Spacing	Seed rate x spacing		
SE±	6.3**	7.7*	12.1*		
CV (%)		17.6			

*,** Significant at P = 0.05 and 0.01, respectively.

Percentage of filled grains

The result indicated that filled grains (%) were not significantly affected by inter-row spacing and interaction during 2013/14 and 2014/15 seasons (Table 3). Seed rate had significant ($p \leq 0.05$) effect on filled grains percentage. Results revealed that as seed rate increased, the filled grains

(%) were remarkably reduced. The seed rate of 59 kg/ha had higher percentage (92%) of filled grains than the other treatments. However the differences between 59, 71 and 83 kg/ha seed rates were not significant. Murata *et al.* (1957) stated that when seed rate was increased beyond the optimum point, it reduced the photosynthetic efficiency due to shading of leaves thus resulted in reduction of filled grains. Similar results were obtained by Harris and Vijayaragavan (2015).

Table 3. Effect of inter-row spacing, seed rate and their interaction on percentage filled grains of aerobic rice in the Gezira during seasons 2013/14 and 2014/15 (combined data).

Seed rate	Inter-row spacing (cm)				
(kg/ha)	15	20	25	30	Mean
59	91	91	91	93	92
71	90	90	91	92	91
83	89	90	90	92	90
95	87	89	90	90	89
107	86	88	89	89	88
Mean	89	90	90	91	
	Seed rate	Spacing	Seed rate x spacing		
SE±	0.79*	0.72ns	1.83ns		
CV (%)		7.5			

* Significant at P = 0.05. Ns = Not significant.

1000 grain weight (g)

Inter-row spacing, seed rate and their interaction had highly significant (p< 0.01) effect on grain size (g) of aerobic rice during seasons 2013/14 and 2014/15 (Table 4). The results showed that increasing seed rate decreased grain weight (g). Also, grain weight (g) decreased with the narrow inter-row spacing. Larger grain weight (34.3g) was recorded by row spacing of 30 cm coupled with seed rate of 83kg/ha. This might be due to better performance of panicle density of this treatment. Similar findings were reported by Abdalla (2017); Harris and Vijayaragavan (2015).

Table 4. Effect of inter-row spacing, seed rate and their interaction on 1000 grains weight (g) of aerobic rice in the Gezira during seasons 2013/14 and 2014/15 (combined data).

Seed rate (kg/ha)	Inter-row spacing (cm)				
	15	20	25	30	Mean
59	32.0	34.0	33.0	31.0	32.5
71	30.7	31.1	31.3	33.0	31.6
83	24.7	29.3	32.7	34.3	30.3
95	22.3	22.0	23.7	30.3	24.6
107	23.7	20.7	22.3	23.7	22.6
Mean	26.7	27.5	28.6	30.5	
	Seed rate	Spacing	Seed rate x spacing		
SE±	0.7**	0.5**	1.6**		
CV (%)		5.1			

** Significant at P = 0.01.

Grain yield (kg/ha)

The results showed that grain yield was highly significantly (p≤ 0.01) influenced by row spacing, seed rate and their interaction in both seasons and combined (Tables 5, 6 and 7). The second season had higher grain yield (kg/ha) compared to the first season. Irrespective of inter row spacing, grain yield increased with the increase of seed rate up to 83kg/ha in both seasons and combined. A further increase in seed rate from 83 kg/ha to 107 kg/ha reduced the yield. Irrespective of seed rate, grain yield increased with the narrow inter row spacing in both seasons and combined.

The highest grain yields (5333, 5722 and 5528 kg/ha) were obtained by the seed rate of 95 kg/ha x 15 cm inter row spacing in season 2013/2014, 2014/2015 and combined, respectively. This high yield was the result of high number of panicles/m^2, number of filled grains, and 1000- grain weight. Similar results were reported by Baloch *et al*. (2002). The plants at low and moderate seed rate had sufficient space and this enabled them to utilize more nutrients, water and solar radiation for better photosynthesis (Harris and Vijayaragavan, 2015). The highest yield might also be due to number of panicles/m^2 and 1000 grain weight (Harris and Vijayaragavan, 2015). Furthermore, the grain yield per unit area depended evidently on the performance of individual plants, panicle density as well as the total number of plants grown per unit area. The performance of individual plants grown with lower seed rate was better as compared to the plants with higher seed rate. A balance has, therefore, to be brought between the performance of individual plants and plant density per unit area for obtaining high crop yields (Baloch *et al*. 2002).

Table 5. Effect of inter-row spacing, seed rate and their interaction on grain yield (kg/ha) of aerobic rice in the Gezira during season 2013/14.

Seed rate (kg/ha)	Inter-row spacing (cm)				Mean
	15	20	25	30	
59	4596	3125	2400	2528	3162
71	4557	3750	3133	2056	3374
83	5167	4083	3033	2584	3717
95	5333	2625	3000	2583	3385
107	5167	2759	3100	1778	3201
Mean	4964	3268	2933	2306	
	Seed rate	Spacing	Seed rate x spacing		
SE±	69**	62**	168**		
CV (%)		8.1			

** Significant at P = 0.01.

Table 6. Effect of inter-row spacing, seed rate and their interaction on grain yield (kg/ha) of aerobic rice in the Gezira during season 2014/15.

Seed rate (kg/ha)	Inter-row spacing (cm)				Mean
	15	20	25	30	
59	5244	3458	2767	2750	3555
71	5687	3917	3533	2306	3861
83	5611	4250	3567	2722	4037
95	5722	2792	3367	2917	3699
107	5402	3042	3333	1833	3403
Mean	4964	3268	2933	2306	
	Seed rate	Spacing	Seed rate x Spacing		
SE±	99**	89**	241**		
CV (%)		10.3			

** Significant at P = 0.01.

Table 7. Effect of inter-row spacing, seed rate and their interaction on grain yield (kg/ha) of aerobic rice in the Gezira, combined over 2013/14 and 2014/15 seasons.

Seed rate (kg/ha)	Inter-row spacing (cm)				
	15	20	25	30	Mean
59	4920	3392	2583	2639	3358
71	5122	3833	3333	2181	3617
83	5389	4167	3300	2653	3877
95	5528	2708	3183	2750	3542
107	5284	2900	3217	1833	3302
Mean	4964	3268	2933	2306	
	Seed rate	Spacing	Seed rate x Spacing		
SE±	86**	76**	207**		
CV (%)		5.9			

** Significant at P = 0.01.

CONCLUSION AND RECOMMENDATIONS

- Seed rate, inter-row spacing and their interaction exhibited highly significant differences in grain yield and yield components and the other recorded traits.
- The highest grain yields were produced by the seed rate of 95 kg/ha x 15 cm inter row spacing in both seasons.
- To obtain high grain yield from aerobic rice under Gezira conditions, 95 kg/ha seed rate and inter-row spacing of 15 cm should be recommended.

REFERENCES

Abdalla, A.A. 2017. Effect of seed rate on yield and yield components of aerobic rice under White Nile condition. National Crop Husbandry Committee Meeting, Wad Medani, Sudan.

Akbar, N. and A. Ehsanullah. 2004. Agro-qualitative responses of direct seeded fine rice to different seeding densities. Pakistan Journal of Agricultural Science 41 (1/2): 76-79.

Atera, E.A., J.C. Onyango, T. Azuma, S. Asanuma and K. Itoh. 2011. Field evaluation of selected NERICA rice cultivars in Western Kenya. African Journal of Agricultural Research 6(1): 60-66.

Baloch, A.W., A.M. Soomro, M.A. Javed and M. Ahmed. 2002. Optimum plant density for high yield in rice. Asian Journal of Plant Science 1: 25–27.

Bouman, B.A.M. and T.P. Tuong. 2001. Field water management to save water and increase its productivity in irrigated rice. Agricultural Water Management 49: 11-30.

FAO. 2007. Food and Agriculture Organization. Rice is life. Italy: FAO International Year of Rice.

Harris, K.D. and R. Vijayaragavan. 2015. Optimum seed rate for maximum yield in rice (*Oryzasativa* L.). Research Journal of Agriculture and Forestry Science. International Science Congress Association 13 (11): 1-5.

Khush, G.S. 1997. Origin, dispersal, cultivation and variation of rice. Plant Molecular Biology35: 25–34.

Kijima, Y, D. Serunkuuma and K. Otsuka. 2006. How revolutionary is the "NERICA revolution" Evidence from Uganda Development Economic 44: 252-267.

Mahajan, G., M.S. Gill and K. Singh. 2010. Optimizing seed rate to suppress weeds and to increase yield in aerobic direct-seeded rice in North Western Indo-Gangetic plains. Journal of New Seeds 11(3): 225-238.

Mohamed, K.A. 2010. Assessment of Genetic Diversity using Simple Sequence Repeats Markers and Variability, Heritability and Stability of Grain Yield of some Rice Genotypes. Ph.D. Thesis, Faculty of Agricultural Sciences, University of Gezira, Sudan.

Mohamed, A.A., A.A. Elsiddig. and A.O. Hassan. 2016. Response of aerobic rice to nitrogen and phosphorus fertilizers under Gezira conditions. National Crop Husbandry Committee Meeting, Agricultural Research Corporation, Wad Medani, Sudan.

Mustafa, A.M., K.O. Abdalla, A.E. Hassan and A. Hayat. 2010 Proposal for the release of WAB891SG14, WAB981SG33, Yunlu No.30 and Situppatenggang aerobic rice varieties. National Variety Release Committee, March, 2010, Khartoum, Sudan.

Murata, Y,, A. Osada, J. Iyama and N. Yamada. 1957. Photosynthesis of rice plants, 4. Plant factors constituting photosynthetic ability of rice plants growing on paddy fields. Proceedings of Crop Science Society of Japan. 25: 133-137.

Oghalo, S.O. 2011. Effect of population density on the performance of upland rice (*Oryza sativa* L) in a forest Savanna transition zone, International Journal of Sustainable Agriculture 3 (2): 44-49.

Soil Survey Staff. 1999. Soil Taxonomy. A basic System of Soil Classification for Making and Interpreting Soil Survey. USDA Handbook No. 634.

Somado E.A. and R.G. Guei. 2008. NERICA: the New Rice for Africa – a Compendium. Cotonou, Benin; (WARDA), Africa Rice Center; (FAO), Food and Agriculture Organization, Rome, Italy; (SAA) Sasakawa Africa Association,Tokyo, Japan. p. 210.