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Effect of Seed Rate and Row Spacing on Yield and Yield Components of Rain Fed Lowland Rice (*Oryzasativa* L.) Variety

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Abstract: *An experiment was conducted at Fogera Plain during the rainy seasons of 2017 and 2018 to determine the effects of seed rate and row spacing on yield and yield component of rain fed lowland rice ecosystem. Four row spacing's (15, 20, 25and 30 cm) and Seven seed rates (40, 60, 80, 100, 120,140 and160 kg/ha) were combined factorially and laid in RCB Design with three replications.The objective of the experiment was to determine the effect of row spacing and seed rate on yield and yield components of rice in Fogera plain. All collected data were subjected to analysis of variance. Economic analysis was also done for grain yield. The results of the experiment showed that the main effect of seed rate was significantly affecting, panicle length, number of total and effective tillers per row meter length, grain yield, straw yield and harvest index whereas row spacing was significantly affected grain yield and number of total and effective tillers per row meter length. The interaction effect of seed rate and row spacing was significantly ($p<0.01$) affected total tillers, number of effective tillers and grain yield. The highest grain yield (3.25tha^{-1}) was obtained at a seed rate of 120 kgha^{-1} and 30 cm row spacing. The economic analysis indicated that a seed rate of 100 kg ha^{-1} and row spacing of 20 cm is the most profitable treatment with mean net benefit of 50982.5.Birrha^{-1}. Therefore it can be concluded that a seed rate of 100 kg/ha and row spacing of 20 cm is preferable and recommended for rain fed lowland rice production ecosystem in Fogera plain.*

Keywords: *Low land rice, grain yield; row spacing; seeding rate. Economic analysis*

1. Introduction

Rice (*Oryza sativa* L.), is one of the most important food crops and is considered as a major source of calories for more than half of the global population (Carrijo *et al*., 2017), covers 11% of total arable land (Khush, 2005). Rice has become a commodity of strategic significance across many African countries (Hegde and Hegde, 2013). It is also the most rapidly growing food sources across the continent due to the great urbanization in Africa more than any other region in the world.

Rice consumption is increasing faster than that of any other food staple in Africa at about 5.5% per year (2000–2010 average). This increase is driven by urbanization and related changes in eating habits, and population growth (Seck *et al*., 2012).Africa has sufficient land and water resource to produce enough rice to feed its own population and, in the long term, generate export revenues. Rice cultivars, rice-based cropping systems and the rice itself will, however, have to undergo adaptations and improvements in order to meet future demands for both food security of the growing population and environmental conservation (Asch and Brueck, 2010). Rice productivity in Africa is generally low about 1 t ha^{-1} in uplands, 1 to 2 t ha^{-1} in rain fed lowlands and 3 to 4 t ha^{-1} in the irrigated zones and a range of factor explains this low productivity (African Rice, 2010).

Ethiopia has a huge potential in both rain-fed and irrigated areas for rice production, which is, estimated about thirty million ha (MoARD, 2010; CSA, 2012) According to the National Rice Research and Development Strategy of Ethiopia, the trend in the number of rice producing farmers, area allocated and production showed high increase especially since 2006 (NRRDSE, 2009). Area rose from 6,000 hectares in 2005 to nearly 222,000 hectares in 2010 and paddy production from 15,460 tons to 887,400 tons, at the same time, the number of rice farmers increased from 18,000 to more than 565,000 (MoARD, 2010).At the Fogera plain, rice plays an important role in relaxing the problem of food-insecurity of the farming community. Besides, rice is among the target commodities that have received due emphasis in the promotion of agricultural production, and it is considered as the "millennium crop" expected to contribute to ensuring food security in Ethiopia. Although rice is introduced to the country very recently, it has proven to be a crop that can assure food security in Ethiopia, the second most populous nation in SSA (MoARD, 2010).

Optimum seeding rate and proper adjustment of row spacing are the most important production factors for higher grain yield. Spacing determines the number of plants per unit area (Yoshida *et al*., 1981). The plant toplant and row to row distance determines the plant population per unit area which has direct effect on yield. Closer spacing hampers intercultural operations, more competition arises among the plants for nutrient, air and light as a result plants become weaker and thinner and consequently, yield is reduced (Alam *et al*, 2012). Wider spacing also allows more competition among crop plants and weeds. As a result plant growth slows downand their grain yield decreases.

On the other hand, Closer spacing increases competition among plants for nutrients, air, light, which results in weaker plants, mutual shading thus favors more straw yield than grain yield (Sultana *et al*., 2012). Lower and higher plant densities have a positive influence on the yield of rice (*Harris et al, 2015*). High seeding rate leads to non-productive tillers, more severe disease pressure and susceptible to lodging (Garba et al, 2013).Optimum plant spacing ensures the plant to grow properly with their aerial and underground parts by utilizing more solar radiation and nutrients (Mohaddesi *et al*., 2011).

There are a number of agronomic management constrains with this crop. Rice is becoming a high potential crop and there is a lack of appropriate agronomic management recommendations that could help to maximize the productivity of the cultivation techniques in the study area. Among the rice production constrains seed rate and row spacing is an important factor Fogera Plain. Area specific recommendation of seed rate is vital to set optimum seed rate and row spacing for rice production in the study area. Therefore the objective of the present study is to determine the effect of row spacing and seed rate on yield and yield components of rice in Fogera plain.

2. Materials and Methods

2.1. Site Description

The experimental site is located at $11^0 49'55$ North latitude and 37^0 37′ 40 East longitudes. The altitude of the experimental site is 1815 meters above sea level. The average mean annual minimum and maximum temperature is 12.75 ^{0}C and 27.37 ^{0}C, respectively. The main rainfall is in July and August (Fig. 1). The experiment was conducted from 2017 to 2018.

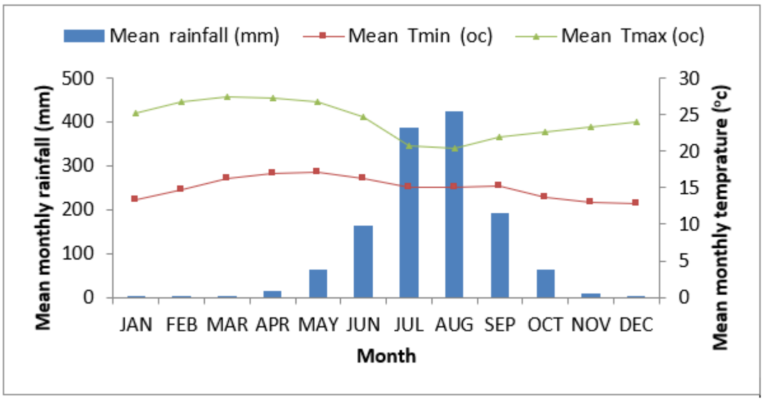

Figure1. *The Average rainfall and temperature condition of Fogera plain for the period of 1981-2017.*

2.2. Treatments, Design and Management

The treatments consists a factorial combination of four levels of row spacings (15, 20, 25and 30cm) and seven levels of seed rates (40, 60, 80, 100, 120,140 and160 kgha^{-1}) in randomized complete block design with three replications. The gross plot size was 3m*4 m. The net plot was made by excluding the left and right two outer rows and a plot length of 0.5 m from the top and bottom sides of the plot area. Thus the net plot size for the respective row spacings (15, 20, 25 and 30 cm) were 3m*2.4m; 3m*2.2m, 3m*2m and 3m*1.8m.The variety Edget was used for this experiment. Recommended fertilizer rates of 69/23 kg N/P_2O_5 ha^{-1}was used in the experiment (Tilahun *et al*., 2007).

2.3. Data Collected

Data's such as plant height (cm), Panicle length (cm), number of total tillers/row meter length, number of effective tillers/row meter length,, thousand seeds weight, grain yield, straw yield and harvest index were recorded from the net plot.

2.4. Statistical Data Analyses

All collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.2 (SAS-Institute, 2008). Combined analysis over locations and years was performed. Between treatments, comparisons of means were made using the Least Significant Difference (LSD) test at 1 and 5% probability levels. The mean grain and straw yield data was adjusted by 90% and economic analysis was carried out by following CIMMYT (1988) procedures by taking all variable costs. The prevailing cost of inputs and out puts in year 2019 considered for the analysis. The cost of rice grain and straw were Birr 13.5 and 1.2 /kg, respectively. Total costs that varied (seed and planting cost) for each treatments was calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The prices of the inputs that were prevailing at the time of their use were considered for working out the cost of cultivation. Net returns per hectare were calculated by deducting cost of production per hectare from gross income per hectare. A treatment which is non-dominated and having the highest net benefit is said to be economically profitable (CIMMYT, 1988).

3. Results and Discussion

The analysis of variance exhibited that seed rate had significantly ($P< 0.05$) influenced panicle length. Whereas, row spacing and interaction effect did not show significant effect on panicle length.(Table 1).The highest panicle length (18.6) was observed at a seed rate of 40 kgha^{-1} and the lowest panicle length (17.1 and 17.2) recorded from 160 and 140 kg ha^{-1} seed rate respectively (Table 2). At the lower seed rate of 40 kg ha-^{1}, the panicle length was higher compared to higher seed rate of 140 and 160 kg ha-^{1}. This might be due to more free space between plants at the lower seed rate and less intra-plant competition for available resources that resulted in higher panicle length. This result is in line with the finding of ZewdieBishaw *et al.* (2014) who reported that plant height and panicle length are negatively interrelated on wheat. Shorter plant produce longer panicle length and longer plant produce shorter panicle and higher biomass production. Gafaar (2007) also stated that increasing sowing density from 200 up to 400 grains m^{-2} significantly decreased spike length. Similarly, Seleiman *et al*. (2010) reported that the longest spikes were obtained from 250 and 300 grains per m^{2} but without significant differences between both of them.

The analysis of variance indicated that the main effects of seed rate and row spacing highly significantly ($p<0.01$) affected both number of total and effective tillers per row length. Moreover, the interaction of seed rate and row spacing also highly significant ($P<0.01$) (Table1) The maximum number of total tillers per row meter length (66.5) and the minimum (56.3) were recorded from the seed rate of 140 kg ha-^{1} and 60 kg ha-^{1}, respectively (Table 2). In regard to the row spacingmore number of total tillers per row meter length (65.5) was recorded from (30 cm) row spacing .On the other hand, smallest number of total tillers per row meter length (54.8) was observed from 15 cm row spacing. With regard to the interaction effect, the maximum number of total tillers (75.85) was obtained at 120 kgha^{-1} seeds rate and a row spacing of 30 cm (Table 3).

The analysis of variance indicated that the main effects of seed rate and row spacing highly significantly ($p<0.01$) affected number of effective tillers per row meter length (Table 1). However, the interaction effect of seed rate and row spacing also had highly significant ($p<0.01$) effect on number of effective tillers per row meter length. The highest number of effective tillers per row meter length (64.96) was observed at seed rate of 140 kg ha-^{1} while the lowest number of effective tillers per 1m row length (55.28 and 54.95) observed at seeding rate of 40 and 60 kg ha-^{1} respectively and statistically similar. In addition to this the highest number of effective tillers (63.79) per row meter length was recorded at row spacing of 30 cm while, the minimum number of effective tillers (53.73) per row meter length was recorded at row spacing of 15 cm(Table 2).

Wider spacing produced higher tillers per hill than closer spacing. The production of more tillers in widely spaced plants was probably due to absorption of more nutrients and moisture and also to the availability of more sunlight in comparison to densely plants. Similar results were reported by (Haque, 2002).This result was also in agreement with (SewunetAshebir, 2005) reported the highest effective tillers were recorded at medium spacing performed better as compared to lower spacing. (Yamada, 1961) also showed that under dense planting, the growth of each plant decreases and the size of the plants and productive tillers become smaller. The more densely the rice plants, fewer are the number of stems or tillers and productive tillers per hill but their number increases per unit area.

Analysis of variance showed that the main effect of seed rate and row spacing had highly significant effect ($P < 0.01$) on grain yield. On the hand seed rate affected significantly ($P < 0.01$) straw yield (Table 1). However, the interaction effect of seeding rate and row spacing showed highly significant ($p < 0.01$) effect on grain yield but not in straw yield (Table 1). The highest grain yield (3.45 tha^{-1}) was obtained at the seed rate of 100 kg ha-^{1} and the lowest grain yield (3.1 t/ha-^{1}) was obtained at seed rate of 160 kg/ha (Table 2). The row spacing of 25 cm produced maximum grain yield (3.31 t/ha-^{1}) followed by 30 and 20 cm (3.2 and 3.1 t/ha^{1}) respectively and the lowest grain yield (3.12 t/ha) was observed at a row spacing of 15 cm. From the above result it could be suggested that as seeding rate increased there was no significant and proportional yield increment observed. Likewise, grain yield of rice, was significantly affected at optimum seed rate but further increase in seed rate did not increase the yield. (Balock*et al*., 2002) who reported that the increased plant spacing considerably resulted in vigorous plant growth and caused a significant increase in number of panicles per hill, grain yield per hill, filled grain per panicle and thousand grain weights. Furthermore, other workers (Mosalem*et al*., 2000) reported that increasing seeding rates decreased the number of spikelets/panicle, spike length, number and weight of grains/spike in wheat. Grain yield of rice increased with the increase in the number of plants per unit area as long as there is space in the cultivated areas. When planting density exceeds optimum level, competition among plants for light above ground and for nutrients below ground becomes severe. Consequently, plant growth slow and grain yield decreases. Zeng and Shannon (2000) reported that the reduction in fertility at high density was one of the causes for the reduction of seed yield per plant with the increase of seeding density.

The main effect of seed rate highly significantly ($P < 0.01$) affected straw yield whereas the main effect of row spacing and its interaction effect didn't show significant ($p>0.05$) effect on straw yield (Table 1). The highest straw yield (6.51 and 5.96 tha^{-1}) was observed at seed rate of 100 kgha-^{1} and 160 kg ha^{-1} which is statistically similar. While the lowest straw yield (4.75 t ha^{-1}) was found with a seed rate of 40 kg ha^{-1} (Table 2). There was a linear increase in straw yield as the seeding rate was increased. However, it was statistically in parity with in straw yield obtained in response to the seeding rate of 60, 80 and 140 kg ha^{-1}. The lowest spacing might have influenced vegetative growth in terms of plant height and number of tillers per hill (effective and non-effective tillers) which resulted in increased straw yield. Sultana *et al*. (2012) also reported a similar results and the higher straw yield was obtained in 20 cm row spacing in rice.

Harvest index represents the ratio of grain yield to the total above ground dry matter production (Marschener, 1995). The present results showed that harvest index was highly significantly ($p<0.01$) affected by seed rate but not by row spacing and its interaction effect (Table 1). The highest harvest index (38.68%) was recorded at a seed rate of 40 kg ha-^{1} while lowest harvest index (35.1%) was recorded at the seeding rate of 100 kg ha^{-1} respectively, (Table 2). The ability of a cultivar to convert the dry matter into economic yield is indicated by its harvest index. The higher the harvest index value, the greater the physiological potential of the crop for converting the dry matter to grain yield. One of the ways to increase the yield is to increase harvest index. Sink formation and ripening are the two physiological processes that explain the improvement in HI (Akita, 1982).Based on the principles of economic analysis CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be 100%.The economic analysis was done on the basis of the prevailing prices of variable costs using the Ethiopian currency (Birr). Grain and straw yields adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Table 4). Dominance analysis was performed after arranging the treatments in their order of TVC. Treatments are considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 5). Non dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 6). Highest NB (Birr 50982.5 ha^{-1}) with acceptable level of MRR (913.01) was observed at a row spacing of 20 cm and 100 kg seed rate ha^{-1} (Table 6). The combined application of a seed rate of 100 kgha^{-1} and 20 cm row spacing is the most profitable rate to be recommended for rice production in Fogera plain.

4. SUMMARY AND RECOMMENDATION

Treatments had a significant effect on yield and yield components of rice. Among the treatments, drilling 100 kg ha-^{1} seed rate and a row spacing of 25 cm produced maximum grain yield (3.3t/ha-^{1}) than other treatments. Partial budget analysis also revealed that highest NB (Birr 50982.5 ha^{-1}) with acceptable level of MRR (913.01) was observed at a row spacing of 20 cm and 100 kg seed rate ha^{-1}. Therefore the combined application of a seed rate of 100 kgha^{-1}and 20 cm row spacing is the most profitable rate to be recommended for rice production in Fogera plain and other similar agro-ecologies.

Table1. *Analysis of variance (ANOVA) for Panicle length, Total tillers , Number of effective tillers, Grain Yield, Straw Yield and Harvest Index of seed rate and row spacing of low land rice*

Sources of variation	DF	Plant height (cm)	Panicle length (cm)	Total tillers/m row	Number of Effective tillers/ m row	No. of fertile spikes/panicle	Grain Yield (t/ha)	1000sw/g	Straw Yield (t/ha)	HI (%)
Location	6	2199.59087NS	207.057770**	11167.33794**	12275.75459**	249.983925**	42.3264057**	923.715607**	150.6996278**	1221.089392**
RS_cm	3	90.0074 NS	7.922211 NS	2757.40261**	2434.77069**	21.427138NS	0.9094447*	0.884915 NS	3.0498545NS	18.498529NS
Rep	2	109.89685 NS	48.667029**	172.84895NS	295.70697NS	37.207743NS	3.0444334**	15.951580*	13.3123320**	34.730535NS
SR_kg	6	383.72317 NS	23.865346**	1130.66347**	1085.35617**	16.330392NS	2.5747444**	0.509947 NS	24.5151543**	104.100818**
Location*RS_cm	18	27.58775 NS	2.050647 NS	114.99189NS	124.20404NS	15.553819NS	0.5211896*	4.878561 NS	2.0449448NS	43.408344NS
Location*Rep	12	198.12207 NS	22.356332**	85.56525 NS	82.23709 NS	20.201949NS	0.4950907NS	4.538268 NS	3.5895440*	29.404303NS
Location*SR_kg	36	47.53449 NS	3.014579 NS	196.69964*	189.21097*	21.746970NS	0.4969310*	9.032433**	2.5529528NS	36.084373NS
Rep*RS_cm	6	10.59217 NS	2.063982 NS	56.73911 NS	27.45025 NS	3.241493 NS	0.3136306NS	2.577858 NS	0.6701674NS	20.271441NS
RS_cm_*SR_kg	18	48.25296 NS	3.395149 NS	542.71487**	519.49354**	14.374103NS	0.8231471**	5.956512 NS	2.5680084NS	37.902706NS
Rep*SR_kg	12	5.67498 NS	1.477806 NS	179.86349NS	171.22095NS	29.099674NS	0.5991860*	6.926008 NS	2.0675822NS	32.008968NS
Location*Rep*RS_cm	36	30.33543 NS	2.094019 NS	87.05057 NS	96.08728 NS	20.548652NS	0.3663119ns	5.617603 NS	2.1813658NS	21.628395NS
Locatio*RS_cm_*SR_kg	108	19.69245 NS	2.590732 NS	129.19829NS	129.13342NS	14.180899NS	0.4957133**	5.374410 NS	2.7440891**	33.910274NS
Location*Rep*SR_kg	72	20.31090 NS	1.847621 NS	83.06587 NS	80.32154 NS	15.680810NS	0.2132807ns	4.892966 NS	1.8185534NS	31.139849NS
Rep*RS_cm_*SR_kg	36	37.19827 NS`	4.155389 NS	90.77742 NS	99.06439 NS	15.489706NS	0.5008023*	4.457263 NS	2.2509809NS	24.974174
Error	216	26.81062	2.851737	121.9432	116.7209	374.7861	0.3092598	5.036729	1.815973	30.38443
CV%		6.71	9.55	18.26	18.33	24.31	17.23	6.93	23.59	15.02

PL=Panicle length, TT/RML, Number of Total tillers/row meter length, NET/RML=number of effective tillers /row meter length, GY (ton) grain yield ton /ha, SY (ton) straw yield ton /ha and HI (%) harvest index.

Table2. *Main effects of seed rate and row spacing on yield and yield components of low land rice*

Seed rate (kgha^{-1})	PL (cm)	TT/RML	NET/RML	GY(tonha^{-1})	SY(tonha^{-1}	HI (%)
40	18.6195A	56.619D	54.952D	2.89050D	4.7512D	38.6831A
60	18.0133B	56.369D	55.286D	3.24097BC	5.4290C	36.8615AB
80	17.9026BC	58.571CD	56.845CD	3.25961BC	5.6222BC	37.0289AB
100	17.5579BCD	62.262B	60.762B	3.45280A	6.5158A	35.1723B
120	17.3793CD	62.607B	60.798B	3.31124B	5.8944B	35.9450B
140	17.1824D	66.548A	64.964A	3.25198BC	5.8179BC	37.0223AB

160	17.1250D	60.238BC	58.857BC	3.10017C	5.9638A	36.1051B
Row Spacing (cm)						
15	17.5376	54.850C	53.735C	3.12488B	5.5423	36.8460
20	17.4366	60.231B	58.476B	3.22968AB	5.8631	36.2114
25	17.8337	61.197B	59.687B	3.31715A	5.8147	37.0476
30	17.9235	65.558A	63.796A	3.18960AB	5.6339	36.6483

PL=Panicle length, TT/RML= Number of Total tillers/row meter length, NET/RML=number of effective tillers /row meter length, GY= grain yield ton ha-1, SY= straw yield ton ha^{-1} and HI (%) = harvest index.

Table3. *Interaction effect of seed rate by row spacing on yield and yield components of lowland rice at Fogera.*

TRT	Row space	Seed Rate	TTN/RML	NNET/ RML	GY (tha^{-1})	SY (tha^{-1})
1	15	40	53.381HIJ	51.952HIJ	2.9043IJKL	4.7247
2	15	60	53.524HIJ	52.571GHIJ	3.0649FGHIJKL	5.3416
3	15	80	52.762J	51.571IJ	3.3315BCDEFGH	6.0545
4	15	100	52.381J	51.238J	3.2075CDEFGHIJKL	5.7321
5	15	120	55.476FGHIJ	54.333GHIJ	3.0654FGHIJKL	5.5386
6	15	140	56.762FGHIJ	56.048GHIJ	3.3482BCDEFG	5.4599
7	15	160	59.667EFGHIJ	58.429DEFGHIJ	2.9523GHIJKL	5.9445
8	20	40	53.619HIJ	51.667IJ	2.8268L	4.6429
9	20	60	53.333IJ	51.095J	3.1543CDEFGHIJKL	5.6952
10	20	80	57.048FGHIJ	55.476GHIJ	3.0582FGHIJKL	5.6579
11	20	100	70.000ABC	69.000ABC	3.7705L	7.1490
12	20	120	57.952EFGHIJ	55.714GHIJ	3.1371DEFGHIJKL	5.9444
13	20	140	70.952ABC	68.762ABC	3.2904CDEFGHIJ	6.1108
14	20	160	58.714EFGHIJ	57.619EFGHIJ	3.3703BCDEF	5.8417
15	25	40	62.000DEF	60.190DEFG	2.9374HIJKL	4.7961
16	25	60	59.000EFGHIJ	57.048FGHIJ	2.8782KL	4.9622
17	25	80	54.000GHIJ	54.333GHIJ	3.5205ABCD	5.7009
18	25	100	59.286EFGHIJ	57.857EFGHIJ	3.6355AB	6.7918
19	25	120	61.143DEFGH	59.333DEFGH	3.5464ABC	6.3497
20	25	140	65.524CDE	63.667CDEF	3.2242CDEFGHIJKL	5.7718
21	25	160	67.429BCD	65.381BCD	3.4780ABCDE	6.3302
22	30	40	65.286CDE	63.571CDEF	2.8935JKL	4.8410
23	30	60	60.619DEFGHI	59.095DEFGHI	3.3033BCDEFGHI	5.7171
24	30	80	61.667DEFG	59.762DEFG	3.1283DEFGHIJKL	5.8584
25	30	100	67.381BCD	64.952BCDE	3.1977CDEFGHIJKL	6.3903
26	30	120	75.857A	73.810A	3.2589BCDEFGHIJK	5.7451
27	30	140	72.952AB	71.381AB	3.1011EFGHIJKL	5.1464
28	30	160	55.143FGHIJ	54.000GHIJ	3.4444ABCDEF	5.7386
CV			**18.26**	**18.33**	**17.23**	**-**

Table4. *Economic analysis for grain and straw yield for seed rate by row spacing interaction of low land rice at Fogera*

Treat ments	**RS**	**SR**	**GY (t/ha)**	**SY (t/ha)**	**AGY (t/ha)**	**ASY (t/ha)**	**TVC (Birr/ha)**	**GB (Birr/ha)**	**NB (Birr ha^{-1})**
1	15	40	2.9043	4.7247	2613.87	4252.23	2140	40389.921	38249.921
2	15	60	3.0649	5.3416	2758.41	4807.44	2410	43007.463	40597.463
3	15	80	3.3315	6.0545	2998.35	5449.05	2680	47016.585	44336.585
4	15	100	3.2075	5.7321	2886.75	5158.89	2950	45161.793	42211.793
5	15	120	3.0654	5.5386	2758.86	4984.74	3220	43226.298	40006.298
6	15	140	3.3482	5.4599	3013.38	4913.91	3490	46577.322	43087.322
7	15	160	2.9523	5.9445	2657.07	5350.05	3760	42290.505	38530.505
8	20	40	2.8268	4.6429	2544.12	4178.61	1740	39359.952	37619.952
9	20	60	3.1543	5.6952	2838.87	5125.68	2010	44475.561	42465.561
10	20	80	3.0582	5.6579	2752.38	5092.11	2280	43267.662	40987.662
11	20	100	3.7705	7.149	3393.45	6434.1	2550	53532.495	50982.495
12	20	120	3.1371	5.9444	2823.39	5349.96	2820	44535.717	41715.717

13	20	140	3.2904	6.1108	2961.36	5499.72	3090	46578.024	43488.024
14	20	160	3.3703	5.8417	3033.27	5257.53	3360	47258.181	43898.181
15	25	40	2.9374	4.7961	2643.66	4316.49	1540	40869.198	39329.198
16	25	60	2.8782	4.9622	2590.38	4465.98	1810	40329.306	38519.306
17	25	80	3.5205	5.7009	3168.45	5130.81	2080	48931.047	46851.047
18	25	100	3.6355	6.7918	3271.95	6112.62	2350	51506.469	49156.469
19	25	120	3.5464	6.3497	3191.76	5714.73	2620	49946.436	47326.436
20	25	140	3.2242	5.7718	2901.78	5194.62	2890	45407.574	42517.574
21	25	160	3.478	6.3302	3130.2	5697.18	3160	49094.316	45934.316
22	30	40	2.8935	4.841	2604.15	4356.9	1440	40384.305	38944.305
23	30	60	3.3033	5.7171	2972.97	5145.39	1710	46309.563	44599.563
24	30	80	3.1283	5.8584	2815.47	5272.56	1980	44335.917	42355.917
25	30	100	3.1977	6.3903	2877.93	5751.27	2250	45753.579	43503.579
26	30	120	3.2589	5.7451	2933.01	5170.59	2520	45800.343	43280.343
27	30	140	3.1011	5.1464	2790.99	4631.76	2790	43236.477	40446.477
28	30	160	3.4444	5.7386	3099.96	5164.74	3060	48047.148	44987.148

RS= Row spacing (cm); SR= seed rate (kg ha^{-1}); TVC= Total variable cost (Birr ha^{-1}) GY, Average grain yield (t ha^{-1}) AGY= Adjusted grain yield (ton ha^{-1}); SY=Average straw yield (ton ha^{-1}) ASY= Adjusted straw yield (ton ha^{-1}); GB= Gross benefit (Birr ha^{-1}); NB = Net benefit (Birr ha^{-1})

Table5. *Dominance analysis for seed rate by row spacing interaction for grain yield of low land rice at Fogera*

Treatments	RS	SR	TVC(B ha^{-1})	NB	Dominance
22	30	40	1440	38944.3	
15	25	40	1540	39329.2	
23	30	60	1710	44599.6	
8	20	40	1740	37620.0	**D**
16	25	60	1810	38519.3	**D**
24	30	80	1980	42355.9	**D**
9	20	60	2010	42465.6	**D**
17	25	80	2080	46851.0	
1	15	40	2140	38249.9	**D**
25	30	100	2250	43503.6	**D**
10	20	80	2280	40987.7	**D**
18	25	100	2350	49156.5	
2	15	60	2410	40597.5	**D**
26	30	120	2520	43280.3	**D**
11	20	100	2550	50982.5	
19	25	120	2620	47326.4	**D**
3	15	80	2680	44336.6	**D**
27	30	140	2790	40446.5	**D**
12	20	120	2820	41715.7	**D**
20	25	140	2890	42517.6	**D**
4	15	100	2950	42211.8	**D**
28	30	160	3060	44987.1	**D**
13	20	140	3090	43488.0	**D**
21	25	160	3160	45934.3	**D**
5	15	120	3220	40006.3	**D**
14	20	160	3360	43898.2	**D**
6	15	140	3490	43087.3	**D**
7	15	160	3760	38530.5	**D**

RS= Row spacing (cm); SR= seed rate (kg ha^{-1}); TVC= Total variable cost (Birr ha^{-1}); NB= Net benefit (Birr ha^{-1})

Table6. *MRR analysis for seed rate by row spacing interaction for grain yield of low land rice at Fogera*

Treatments	RS	SR	TVC (Birr/ha)	NB Birr ha-1	MRR (%)
22	30	40	1440	38944.3	
15	25	40	1540	39329.2	384.893
23	30	60	1710	44599.6	3100.2147
17	25	80	2080	46851.0	608.50919

18	25	100	2350	49156.5	853.86
11	**20**	**100**	**2550**	**50982.5**	**913.013**

RS= Row spacing (cm); SR= Seed rate (kg ha^{-1}); TVC= Total variable cost (Birr ha^{-1}); NB= Net benefit (Birr ha^{-1}); MRR%= Marginal rate of return in percent

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