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Effects of Planting Distance on Yield and Agro-Morphological Characteristics of Local Rice (*Bara Variety*) in Northeast Afghanistan

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Abstract

To evaluate the effect of planting distance on yield and agro-morphological characteristics of *Bara* variety (local variety of rice), a field experiment was carried out at the experimental station of the Agricultural Faculty of Kunduz University in 2016. Randomized Completely Block Design (RCBD) with four replications was used in the experiment. Transplanting distances with four levels *viz*. 10x10 cm, 15x15 cm, 20x20 cm, and 25x25 cm were used as treatment. Results showed that planting distance had significant effects on tillers number, leaf color, non-filled grain, total grain, and 1000 grains weight. In contrary, no significant effects on plant height, panicle length, number of filled grain per panicle and grain yield were observed between spacing. The spacing of 25x25 cm had produced the highest performance for most of the agro-morphological traits evaluated. Grain yield was found similar in all spacing but other yield components like total number of tillers (16.63) and total grain per panicle (119.43) were found statistically superior in 25x25 cm planting distance. Overall, the results of this study revealed that the planting distance of 25x25 cm seemed to be the best as requires

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lower seed and fertilizer (lower cost) and can, therefore, be suggested to the farmers for a better valorization of *Bara* variety in northeastern Afghanistan. Similar investigations are strongly recommended in other agro-ecological zones of the country where *Bara* variety is largely grown to confirm these findings.

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops which cultivates as the second-largest cropland and provides the staple food for half the world's population.[1] While rice production has increased in recent decades, current population growth and ever-rising demand for rice production have caused many countries to face second-generation challenges, such as higher rice production with lower cost.[2] Worldwide, rice is cultivated over an area of about 155 million hectares with a production of about 596 million tons (paddy) but so far not enough to feed the people.[3] To fulfill the rice demanding gap, global efforts are needed to increase its production.[1] In Afghanistan, during 2015–2016, rice production exceeded 33,600 metric tons, but 623,050 metric tons are required for self-sufficiency.[4] Consequently, rice deficiency in Afghanistan has resulted in the import of 270,250 metric tons annually from neighboring countries including Pakistan, India, and Iran. Thus, it is anticipated that any type of researches on rice production can promote farmers' income, ultimately strengthening the country's economy.[5,4,6] In terms of cultivated area(143,689 ha), rice is the second-largest cereal crop in Afghanistan and the main source of calories for people after wheat.[4,7] Rice is mainly grown in northeast provinces, and along the Kunduz river basin within the much larger Amu Darya river basin that crosses international boundaries.[8] In Afghanistan, the average yield of rice is 2.8 tons per ha which are well below its optimal productivity. Insufficient breeding techniques for new rice cultivars with high yield and acceptable quality, mismanagement of agronomical practices, and unprogressive milling and processing may explain this lands' low yielding capacity.[4]

However, in recent years several techniques have been broadly developed and direct seeding and transplanting methods are most adopted.[9] The varieties with aroma like "*Bara*" (local variety of rice) have good quality grains with good market and adaptation in Kunduz climate, Northeastern Afghanistan.[10] Our previous study titled "Effects of cultivation methods on the yield of local rice varieties in Northeastern of Afghanistan" revealed that *Bara* variety in transplanting system is a successful method of rice cultivation.[6] However, there is a lack of information about the optimum planting distance required. Earlier findings revealed that optimum spacing was found to be well parameter to achieve the potential yield.[11] It was reported that wider row spacing increases rice yield, and linearly increases the individual plant's performance with higher tillering and spike production.[12] Farmers in Northeast Afghanistan do not manage plant spacing and use higher seed density where majority of the growers follow broadcasting system impacting the yield. This research was carried out to investigate the effect of planting distance on yield and agro-morphological characteristics of local rice, and to find out the most appropriate spacing for *Bara* variety in transplanting cultivation system.

Material and Methods

The experiment was carried out in the 2016 harvesting season at the experimental field of Kunduz University, Faculty of Agriculture in Northeast Afghanistan. The Kunduz's altitude is 404m (68.6˚52.5'E longitude and 36.22˚58.12'N latitude). The previous crop was wheat and the soil belongs to the terrace soils with clay loam, pH 8.03, 2.38% organic matter, 0.22 % total N, 23 ppm P, 100 ppm extractable K and 0.8 mhos EC. A Randomized Complete Block Design (RCBD) with four replications was used for the experiment. The trial comprised a total of 16 plots. Each repetition had 4 elementary plots of 5 x 2m dimension. The distance was 50cm and 90cm between plots and repetitions respectively. The treatments comprised of four planting distances, including (10x10 cm, 15x15 cm, 20x20 cm, and 25×25 cm). Before sowing on April 24, 2016, the selected grains with at least a 95% germination rate were soaked for 24h in water and incubated for 24h. The seed rate for nursery beds was 50 kg/ha. 40 days old seedlings were transplanted in each hill with 3-5 plants per hill on June 5, 2016. After transplanting, 4-inch water depth was kept till ten days before harvest and the plots were drained to facilitate harvesting. Chemical fertilizer was applied three times for a total amount of 105 kg/ha and 70 kg/ha of urea and DAP, respectively. The first application consisted of 100% DAP and 25% urea at the time of field preparation, the second application consisted of 50 % urea 30 days after transplanting and the last application consisted of 25% urea applied before spiking stage. Insects, diseases, and weeds were thoroughly controlled until harvesting.

Data on plant height, leaf color, productive tillers per hill, panicle length, filled grains per panicle, non-filled grains per panicle, total grains per panicle, 1000 grains weight and grain yield were collected from each treatment and individuals selected randomly. Plant height was measured from ground level to the tip of the highest panicle (or leaf, whichever was longer) from three random hills per plot. Tillers' number was recorded from three random hills in each plot. Total grains per panicle, grain yield, filled grains number, non-filled grains number, and panicle length were determined from 12 spikes randomly selected in each plot. The spike length was determined from the node just below the spike to the tip of the spike. The 1000 grains weight was determined from filled grains settled to 14% moisture content. Harvesting was done on October 15, 2016. The harvested rice was dried under sunlight for 2 days, and then the grains were separated from the spikes by the local system. Collected data were compiled in Excel software for statistical analysis. The means, standard deviations and the coefficient of variation (CV) were calculated. To compare the performances of different traits per treatment, analysis of variance(ANOVA) completed by Fisher Least Significant Difference (LSD) test at 5 % probability level was operated. All the analysis was performed using SPSS version 22.0 (SPSS for windows Inc., Chicago, Illinois, USA).[13]

Results and Discussion

Plant Height

Based on the results of the analysis of variance, spacing seemed to have little effect on plant height with no significant differences observed (Table 1/Figure 1/ A). The distance of 15x15cm showed the maximum plant height (93.91cm) and the minimum (84.33cm) plant height was observed with the planting distance of 20x20cm. Agreed findings were reported in other studies.[14 15,16]

Tiller No/Hill

The number of tillers per hill especially productive tillers is one of the most important components of yield. Therefore, the higher the number of productive tillers, the more would be the yield. A highly significant difference ($P<0.01$) between different spacing (Table 1/Figure 1/B) was observed about the number of productive tillers per hill. The maximum number of productive tillers per hill (16.2) was performed with a distance of 25×25 cm while the minimum (9.92) with a distance of 10x10cm. As the surface area per hills was greater in 25x25 cm compared to 20x20 cm, 15x15 cm, and 10x10cm spacing, plants will have more nutrient use efficiency, light penetration, moisture and space for better crop establishment. As a result, there will be less competition between plants as they are spaced apart. Our results are in accordance with previously reported by Ninad *et al.,*.[15, 16, 17,18]

Panicle Length

It was earlier speculated by Dejen *et al.,*[17] that an optimum higher length of panicle contributes to the high number of grains per panicle. Analysis of variance about panicle length showed no significant difference between planting distances (Table 1/Figure 1/B). The spacing of 25x25 cm with 21.78cm had the highest spike length and the spacing of 10×10 cm had the lowest spike length (20.32cm) but statistically similar. In contrast with this result, Asmamaw *et al.,*[19, 15, 16, 17] reported that wider spacing produced the tallest panicle length than closer spacing. The divergence between our study and the previous report may be attributable to the difference in the plant material and the spacing investigated.

Leaf Color

The results for leaf color revealed a highly significant difference ($P < 0.01$) amongst distances (Table 1/Figure 1/C). The average of observations of leaf greenness (chlorophyll content) by using Leaf Color Chart had shown that spacing ranged from

4.56 to 5.50. The maximum leaf color was recorded for 25x25 cm (5.5), followed by 20x20 cm (5.12) and the minimum for 10x10 cm (4.56). Wider spacing allows a larger leaf area, which increases net photosynthetic assimilates and helps for the vigorous growth of plant.[15] Inline findings were observed by Asmamaw[19] who recorded higher chlorophyll content at sparse planting density while lower chlorophyll content was showed at high planting density treatment. The reasons for the decreasing in the leaf greenness may belong to the high competition between plants for sunlight, moisture, and nutrients in narrow spacing.

Table 1: Bara rice agro-morphology and yield components traits in treatments

Treatment	Plant Height	Tiller No/hill	Panicle Length	Leaf Color	Filled Grain/pa	Non-filled Grain/pa	Total Grain/pa	1000- grain Weight(g)	Yield (t/ha)
25 X 25 cm	82.54a^{ns} ± 5.07	16.63a** ± 3.01	21.79a ^{ns} ± 1.821	5.50a** ± 0.38	89.13a ^{ns} ± 16.08	30.31a** ± 11.00	119.43a* ± 7.08	26.78b ^{ns} ± 0.386	1.76a ^{ns} ± 282
20 X 20 cm	79.99a^{ns} ± 12.25	13.22b* ± 1.296	21.20a ^{ns} ± 1.436	5.12ab* ± 0.467	84.44a ^{ns} ± 20.68	28.88b ^{ns} ± 7.59	113.31b ^{ns} ± 14.55	27.28a* ± 1.212	1.97a ^{ns} ±105.4
15 X 15 cm	78.15b^{ns} ± 15.79	11.39c ± 0.563	20.42a ^{ns} ± 1.436	4.78b ± 0.404	85.56a ^{ns} ± 15.25	19.56b ^{ns} ± 7.49	105.12b ^{ns} ± 9.33	26.78b ^{ns} ± 0.330	1.81a ^{ns} ± 405
10 X 10 cm	80.98a^{ns} ± 7.51	9.92c ± 2.211	20.32a ^{ns} ± 3.03	4.56b ± 0.413	92.31a ^{ns} ± 15.28	20.63b ^{ns} ± 8.39	112.93b ^{ns} ± 10.29	26.48b ^{ns} ±0.310	1.70a ^{ns} ± 391
Correlation	**ns**	**	**ns**	**	**ns**	**	*	*	**ns**
LSD(0.05)	4.39	6.70	1.46	45.95	5.25	7.17	9.54	0.80	116.2
CV (%)	3.55	10.45	4.89	3.45	8.98	11.86	5.52	2.29	33.01

Means were followed by different lowercase letters into a column in each treatment and parameter, as are significantly different $p < 0.05$ according to the Fisher test. ** Significant at $p < 0.01$; * Significant at $p < 0.05$; ns, Non-significant. CV (%)= Coefficient of variation, LSD (0.05) =Least significant difference at 5%, No= number and pa= panicle.

Filled Grain/Panicle

No significant difference was observed among distances for the number of filled grains per spike (Table 1/Figure 1/A). The spacing of 10×10 cm performed the highest number of grains per panicle (92.30) whereas the spacing of 20×20 cm produced the lowest number of grains per panicle (84.43). In contrast with this result, Nimadi *et al.,*[15,17] reported the highest number of filled grains per panicle in larger spacing.

Non-Filled Grain /Panicle

A highly significant difference ($P<0.01$) in the number of non-filled grains per panicle was observed amongst distances (Table 1/Figure 1/B). The spacing 25x25 cm performed the maximum unfilled grains (30.31) per spike while the spacing 15x15 cm had the minimum number of unfilled grains (19.56) per spike.

Total Grain/Panicle

A significant effect ($P<0.05$) of planting distance on the total grains per panicle was observed (Table 1/Figure 1/A). The highest total grains per panicle (119.43) were obtained from the spacing of 25×25 cm and the lowest (105.12) from the distance of 15×15 cm. Plants grown at more spacing produced more grains per panicle due to higher sunlight, moisture and nutrient achievement. Many authors viz.,[20,21,22] and [23] also revealed that larger planting distance could produce a higher number of grains per panicle.

1000 Grains Weight

Thousand grains weight is an important parameter that defines the grain quality and the yield per hectare. Analysis of variance revealed that 1000 grains weight was significantly affected by spacing

(P<0.05). The results indicated that with the increase in spacing the thousand grains weight also increased significantly (Table 1/Figure 1/B). The highest 1000 grains weight (27.27g) was obtained when the crop was transplanted at 20x20 cm spacing and the lowest (26.47 g) at 10x10 cm spacing. Higher plant density was noted in narrow spacing than other spacing and this higher plant density was accompanied by strong intra and inter-row competition that might have caused the decrease in 1000 grains weight.[17] In agreement with this result, Alam *et al.,*[20] and Biswas *et al.,*[24] reported highest thousand-grain weight was obtained in wider spacing (30 x 20 cm) than narrow spacing (15 x20 cm). In addition, Ali *et al.,*[25] obtained increased 1000 grains weight at wider spacing as compared to narrow spacing in wheat.

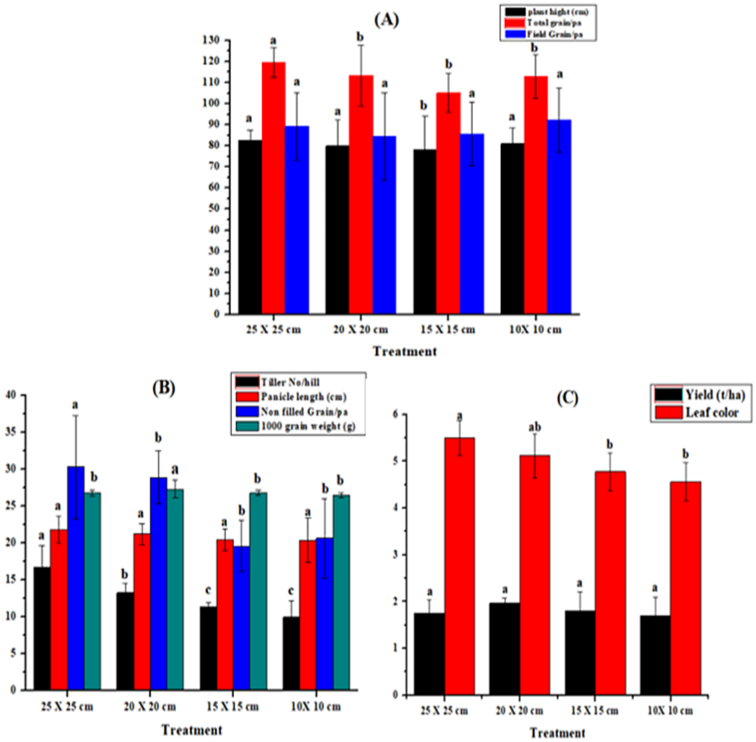

Fig.1: Represents *Bara* rice agro-morphology and yield components, (A) plant height, filled grain and total gran per panicle, (B) tiller number per hill, panicle length(cm), non-filled grain and 1000-grain weight(g), (C) yield tons per hectare and leaf color affected by different spacing treatments. Means were followed by different lowercase letters into a bar in each treatment parameter, as are significantly different p < 0.05 according to the Fisher test

Yield

Grain yield is the final product that is of great value and economically important to the producer or consumer.[16] The results revealed no significant difference between distances for grain yield per treatment (Table 1 / Figure 1/C). The planting distance of 20×20 cm performed the highest grain yield (1.97 t/ha) whereas the spacing of 10×10 cm produced the lowest one (1.70 t/ha) but statistically same. These findings are similar to those reported by Angassa,[26] Hossain *et al.,*[27] and Uddin *et al.,*[28] in contrast to Haque *et al.,*[29] who revealed wider spacing(25x20 cm) performed better grain yield as compared to closer spacing(20x15 cm) statistically. Recently, many other researchers reported the decrease in grain yield with decreasing plant spacing.[16,15,3]

Table 2: Bara rice agro morphology and yield components traits in blocks

Block	Plant Height (cm)	Tiller No/hill	Panicle Length (cm)	Leaf Color	Filled Grain/pa	Non-filled Grain/pa	Total Grain/pa	1000- grain Weight(g)	Yield (t/ha)
B1	83.55	13.01	20.73	5.25	87.44	28.38	115.81	26.93	1.90
B2	85.19	13.89	20.82	5.06	91.81	19.56	111.38	26.13	1.35
B3	72.48	11.20	21.34	4.89	80.81	27.19	108.00	26.98	0.81
B4	80.45	13.06	20.83	4.77	91.38	24.25	115.63	26.98	1.04
Significance	**	*	ns	**	ns	**	ns	ns	ns
LSD(0.05)	12.71	2.68	0.61	20.69	7.33	5.08	5.21	0.85	257.17

Conclusion and Recommendations

Results of this study revealed that planting distance significantly influenced tillers number, leaf color, Non-filled grain per panicle, total grain per panicle and thousand grains. Spacing showed a non-significant effect on plant height, panicle length, the number of filled grain per panicle and grain yield. Whether statistically or arithmetically, most of the traits were found superior in 25x25 cm and 20x20 cm spacing which suppose *Bara* variety performed better in wider than narrower spacing. Comparing the results of the two planting distances (25x25 cm and 20x20 cm), it can be seen that spacing of 25x25 cm performed the best for most of the agro-morphological characters evaluated. Furthermore, similar yield (as no significant differences observed) for the different spacing assumes that the spacing of 25x25 cm will be the best as in that system we will have the lowest seeds and nutrients requirements (lower cost). Taken together, these findings suggest that planting distance of 25×25 cm can be recommended to afghan northeastern farmers for *Bara* variety cultivation in the transplanting system. Similar investigations are also recommended in other agro-ecological zones of the country where *Bara* variety is largely grown.

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Conflict of Interest

The authors declare that no conflict of interest exists in the publication of this research work.

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