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Optimum Plant Density for High Yield in Rice (*Oryza sativa* L.)

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Abstract: Three mutant strains basmati 370-32, Jajai 77-30 and Sonahri sugdasi-6 along with their respective mother varieties Basmati 370, Jajai 77, sonahari sugdasi and check variety Basmati 385 were evaluated under different plant population (spacings: 20 x 20 cm^2, 22.5 x 22.5 cm^2 and 25 x 25 cm^2 between plants and rows) for grain yield and yield contributing parameters. An increase in spacing induced vigorous plant growth as well as increased the number of panicles per hill, grain yield per hill, filled grains per panicle and 1000 grain weight. The spacing 22.5 x 22.5 cm^2 proved more appropriate because it produced better plant stand, gave more panicle density and higher grain yield than other two spacings. The mutant strain Jajai, 77-30 produced significantly ($P<0.01$) higher grain yield at all spacings as compared with all other entries.

Key words: Plant density, rice, grain yield, mutant strains

Introduction

The crop plants depend largely on temperature, solar radiation, moisture and soil fertility for their growth and nutritional requirements. A thick population crop may have limitations in the maximum availability of these factors. It is therefore, necessary to determine the optimum density of plant population per unit area for obtaining maximum yields.

A number of workers have reported that maintenance of a critical level of rice plant population in field was necessary to maximize grain yields. Counce (1987) suggested that population density ranging from 159 to 168 kg ha^{-1} were necessary for obtaining maximum yields under direct seeded cultures depending upon planting dates (Jones and Synder, 1987a), spacing between hills and rows (Bari *et al.*, 1984; Bisht *et al.*, 1999) panicles per m^2 (Miller *et al.*, 1991; Gravois and Helms, 1992). Number of panicles per unit area is the most important component of yield and contribute 89% of the variations in yield. Similar results were reported by Kenneth and Helms (1996) for an optimum plant stand in producing high rough rice yields, head rice and total milled rice. Jones and Synder (1987b), however, reported that panicles per m^2 accounted for only 34% of yield variations in direct seeded rice crop and 85% of the yield variations in rato on rice crop. The effect of plant density of kernel dimension were also identified during different panicle development stages (Senanayake *et al.*, 1991; Karim *et al.*, 1992). The present studies were therefore, undertaken to determine the optimum plant density for getting the maximum yield in rice.

Materials and Methods

Three tall growing and late maturing aromatic varieties of rice (*Oryza sativa* L.) i.e., Basmati 370, Jajai 77 and Sonahri Sugdasi and three promising mutant strains i.e., Bas 370-32, Jajai 77-30 and Sonahri sugdasi-6, developed at this Institute, along with a check variety Basmati 385, were taken for these studies. The experiment was conducted at the experimental Farm, Nuclear Institute of Agriculture, Tandojam. The three different spacings i.e., 20 x 20 cm^2, 22.5 x 22.5 cm^2 and 25 x 25 cm^2 between hills and rows were kept for growing the crop and to identify their effect on grain yield and yield parameters.

The layout of the trial was split plot design with four replications having varieties as main plots. The area of each plot was 3 x 3 m^2. Four week old seedlings were transplanted with an average of three seedlings per hill in the square method of planting.

The fertilizer in the form of urea and single superphosphate was applied at the rate of 80 N and 40P (kg ha^{-1}) in two split doses. The basal dose of 40N and 40P (kg ha^{-1}) was applied before transplanting, while the remaining quantity of 40 N (kg ha^{-1}) was applied as top dressing after forty days of transplanting. Standard cultural practices were carried out till the crop was mature. The data on paddy yield per plot and yield parameters i.e. panicle density per m^2, 1000 grain weight (g), filled grain per panicle, grain yield per hill and number of panicles per hill were recorded.

Results and Discussion

The data on yield and yield parameters obtained from the trial were analyzed statistically and the results are given in Table 1. The analysis of variance resolved the yield performance of the varieties and the mutant strains as well as the interactions between the sources of variation. The variety yields, averaged over spacings and replicates, are presented in Table 2. The performance of varieties were respect to number of panicles per hill, grain yield per hill, filled grain per panicle, 1000 grain weight (g), panicle density per m^2 and yield per plot were significantly ($P<0.01$) different from each other. However, the mutant strain Jajai 77-30 gave the highest grain yield (3.45 kgs $plot^{-1}$), followed by S.S-6 (2.95 kg $plot^{-1}$) and Bas 385 (2.65 kg $plot^{-1}$) and Jajai 77 (1.51 kg $plot^{-1}$). Thousand grain weight of mutant strain S. S - 6 (24.38 g) and its mother variety Sonahri Sugdasi (24.14 g) were significantly higher than the other genotypes under study. Number of filled grains (64.58), grain yield per hill (21.76 g h^{-1}) and number of panicles per hill (17.25) of mutant strain Jajai 77-30 were significantly higher than those of other genotypes.

The effect of spacings averaged over varieties and replicates is presented in Table 3. The increased plant spacing considerably resulted in vigorous plant growth and caused a significant ($P<0.01$) increase in number of panicles per hill, grain yield per hill, filled grain per panicle and 1000 grain weight. The effects on panicle density and grain yield were highly significantly ($P<0.01$). The spacing 22.5 cm^2 gave significantly higher grain yield of 2.95 kg per plot, while the spacings of 20 x 20 cm^2 and 25 x 25 cm^2 yielded 2.30 kg and 2.19 kg per plot respectively. Results indicated that wider spacing had linearly increasing effect on the performance of individual plants. The plants grown with wider spacing have more area of land around them to draw the nutrition and had more solar radiation to absorb for better photosynthetic process and hence performed better as individual plants. The reason for deviation of this linearity in case of grain yield per plot is that the yield does not entirely depend upon the performance of individual plant but also on the total number of plants per plot and yield contributing parameters within plant.

The data (Table 4) indicates that the effect of spacings of yield and yield parameters varies within genotypes. There is a significant interaction between varieties and spacings. This reveals that the yield of varieties will be changing if the factor of spacing is changing. The effect of spacing within entries is also significantly different. This also makes intelligible explanation that spacing modify the components that influence the final yield. Eunus and Sadeque (1974) found that the number of panicles per plant and straw yield increased with increased spacing in transplanted rice. Shahi *et al.* (1976) studied the effect of spacings 20 x 20 cm^2 and 15 x 15 cm^2 on the paddy yield of dwarf rice variety Jaya. Although they did not find significant differences in the yields, yet the yields in case of 20 x 20 cm^2 spacing tended to be higher than that of the other two spacings. Chandrakar and Khan (1981) studied the effect of spacings of 10 x 10 cm^2, 15 x 10 cm^2 and 20 x 10 cm^2 on the grain yields on early, medium and late duration tall growing indica rice varieties and found that the spacing of 20 x 10 cm^2 gave the highest yields of medium and late varieties, while the spacing of 10 x 10 cm^2 gave higher yield in case of early maturing varieties. Singh *et al.* (1983) studied the effect of row spacing in combination with nutrient supply on grain yield of semi-dwarf up-land rice variety Narendra 1 (IET 2232). The crop was grown by direct seeding in rows at three spacings of 15, 20 and 25 cm^2. The grain yield was more with 20 cm^2 spacing as compared to other spacings Bari *et al.* (1984) studied the effect of plant density of 15 x 15 cm^2 and 25 x 25 cm^2 between hill and rows and compared for their effect on grain yield and yield components of two standard varieties IR6 and two mutant strains of rice Shadab and Shua 92. The plant density at spacing of 20 x 20 cm^2 was

Table 1: Analysis of variance for yield and yield parameters of rice varieties

		Mean sum of squares					
Source of variation	d.f	No. of panicles Per hill**	Grain yield per hill (g)	Filled grains per panicle	1000 grain weight (g)	Panicle density per m^{2}**	Grain yield per plot (kg)
Replicates	3	0.3968	0.2479	2.6032	0.2506	199.79	1.0183
Spacing	2	145.5834**	21.705**	381.5715**	1.7087	90589.73**	4.04
Error I	6	0.8373	0.3877	2.4603	0.0612	434.52	0.0019
Varieties	6	90.6667**	195.644**	1352.6389**	18.4965**	58386.36**	5.5067**
Vx S interaction	12	1.6667	0.3690	7.2520	0.1126	491.75	0.0367
Error II	54	2.2275	1.2686	7.0635	0.0733	1039.45	0.0076

* = Significant at 5% level of probability, ** = Significant at 1% level of probability

Table 2: Varietal performance of yield parameters of rice varieties

Varieties mutant strains^{-1}	No. of panicles per hill**	Grain yield per hill**(g)	Filled grains per panicle**	1000 grain weight(g)	Panicle density per m^{2}**	Grain yield per plot(kg)*
Basmati.370	10.00	11.17	38.00	21.48	252.17	1.80
Basmati.370-32	14.92	15.38	58.92	22.13	369.41	2.75
Jajai 77	10.42	9.55	41.33	21.24	252.92	1.15
Jajai 77-30	17.25	21.76	64.58	23.31	429.75	3.45
Sonahri Sugdasi	10.33	12.52	38.00	24.14	248.10	2.10
Sonahri Sugdasi-6	14.00	16.52	54.67	24.38	343.10	2.95
Basmati.385	12.92	15.45	45.50	22.5	316.42	2.65
(DMR 1%)	02.13-2.43	01.61-1.81	03.79-4.33	00.39-0.44	045.94-52.42	10.12-0.14

** = Significant at 1% level of probability

Table 3: Effect of different spacings on yield and yield parameter of rice varieties

Spacing between hills and rows (cm^{2})	No. of hill per plot	No. of panicles per hill **	Grain yield per hill**(g)	Filled grains per panicle**	1000 grain weight (g)	Panicle density per m^{2}**	Grain yield per plot(kg)*
20x20	225	10.42	13.64	45.14	22.46	255.75	2.30
22.5x22.5	169	13.11	14.86	49.36	22.38	369.43	2.95
25x25	114	14.96	15.36	52.05	22.93	316.32	2.19
(DMR 5%)		01.58-1.90	01.08-1.30	02.72-3.24	00.43-0.62	036.05-42.55	0.008-0.018
(DMR 1%)		02.40-2.74	04.11-4.70	04.11-4.70	00.64-0.91	054.00-60.55	0.012-0.032

* = Means followed by the same letters are not significantly different from each other at 5%, ** = Means followed by the same letters are not significantly from different from each other at 1%

Table 4: Effect of spacing on yield and yield parameters within varieties and mutant strain of rice

Vanities mutant strains^{-1}	Spacing	No. of panicles Per hill	Grain yield per hill (g)	Filled grains per panicle	1000 grain weight (g)	Panicle density per m^{2}**	Grain yield per plot (kg)
Basmati 370	20x20	07.25	10.08	03.25	21.13	176.00	1.62
	22.5x22.5	10.50	11.26	37.50	21.58	312.75	2.27
	25x25	12.25	12.16	41.25	21.75	267.75	1.52
Basmati 370-32	20x20	11.50	14.76	51.75	21.85	288.75	2.58
	22.5x22.5	15.50	15.99	60.50	21.65	437.75	3.23
	25x25	17.75	15.39	64.50	22.38	374.25	2.45
Jajai 77	20x20	08.25	08.25	37.75	21.08	196.25	1.33
	22.5x22.5	10.25	09.75	41.50	21.20	313.75	1.98
	25x25	12.75	10.40	44.75	21.45	241.25	1.22
Jajai 77-30	20x20	14.75	20.72	61.00	23.15	367.75	3.27
	22.5x22.5	17.75	21.95	64.50	23.28	483.50	3.92
	25x25	19.50	22.60	68.25	23.50	430.50	3.16
Sonahri Sugdasi	20x20	08.25	11.49	34.75	23.88	190.75	1.90
	22.5x22.5	10.25	12.72	38.50	24.20	297.00	2.55
	25x25	12.50	13.37	40.75	24.35	249.00	1.79
Sonahri Sugdasi-6	20x20	12.00	15.52	51.50	24.13	297.25	2.77
	22.5x22.5	14.50	16.67	55.25	24.43	379.00	3.42
	25x25	15.50	17.35	57.25	24.60	345.50	2.66
Basmati 385	20x20	11.00	14.41	44.00	22.03	273.50	2.56
	22.5x22.5	12.25	15.87	47.75	23.00	362.25	2.84
	25x25	14.50	16.28	50.75	22.48	306.00	2.55

more effective and gave significantly higher grain yield per plot than the other two plant densities at other spacings and was therefore, most suitable for obtaining maximum yields. The grain yield per unit area depends evidently on the performance of individual plants, panicle density as well as the total number of plants grown on the area. In the present studies the perofrmance of individual plants grown with wider spacing was better as comared to the plants with narrower spacing. A balance has, therefore to be brought between the performance of individual plants and the plant density per unit area for obtaining optimum crop yields. In the studies reported here the number of hills per plot were 225 in 20 x 20 cm^{2} spacings, 169 in 22.5 x 22.5 cm^{2} spacing and 144 in case of 25 x 25 cm^{2} spacing and corresponding grain yields were 2.30 kg, 2.95 kg and 2.19 kg per plot, respectively. The grain yield of 2.95 kg per plot in case of 22.5 x 22.5 cm^{2} spacing was significantly higher ($P < 0.01$) than that of the other two spacings. On the

basis of these results it is concluded that the spacing of 22.5 x 22.5 cm^2 between hills and rows is most suitable for obtaining optimum grain yields in the rice crop.

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