Indian Journal of Agronomy **51** (4) : 283–287 (December 2006)

Growth and yield of direct-seeded rice *(Oryza sativa)* as influenced by seeding technique and seed rate under irrigated conditions

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Received : September 2005

ABSTRACT

A field experiment was conducted during rainy season *(kharif)* 2002 and 2003 at Ludhiana, to find out the suitable seeding technique and optimum seed rate for realizing high yield of direct-seeded rice *(Oryza sativa).* The dry-matter accumulation in direct-seeded rice under compaction and puddled condition was 115.7-139.1 q/ha in 2002 (drought year) and 178.5-197.5 q/ha in 2003 (normal year) compared with 104.1 q/ha under transplanting 25 days after sowing (DAS). The seed rate of 50 kg/ha produced the maximum dry-matter accumulation. The maximum leaf-area index was (4.37-4.97 in 2002 and 5.24-6.06 in 2003) recorded under direct seeding. The maximum grain yield (57.8 q/ha and 179.3 q/ha during first and second years respectively) was recorded under transplanting at 25 DAS (on the day of sowing) which was found on a par with direct seeding done after puddling and compaction at seed rate 50 and 75 kg/ha. It was mainly due to significantly more effective tillers/m^2 (201 and 218 in 2002 and 276.2 and 283.3 in 2003) compared with 25 kg/ha seed rate (166 in 2002 and 267.6 in 2003). The water productivity (kg grain/m^3 of irrigation water applied) in direct-seeded rice in 2002 was 0.35 and in 2003 was 0.76 compared with that of transplanted rice being 0.31 and 0.57 kg grain/m^3 of irrigation water, clearly indicating better water-use efficiency under direct seeding.

Key words : Direct-seeded rice, Compaction, Water productivity, Economic yield

In India, rice *(Oryza sativa* L.) occupied 43.9 million ha, which forms 31 per cent of the total area under foodgrains with 91.6 million tonnes production (Singhal, 2003). In Punjab it is being cultivated on 2.61 million ha area with a production level of 9.15 million tonnes. Presently, rice is primarily grown by transplanting of the seedlings in puddled fields. This technique is, however, combersome, labour intensive and requires continuous ponding of water for the first 15 days. This in turn leads to nutrient loss through leaching, besides causing high evapotranspiration (ET) losses during hot summer. Moreover, contractual transplanting at cultivators' fields leads to less plant population (16-22 hills/m^2) than recommended (33 hills/m^2).

The direct-seeding technique offers an useful option to reduce the limitations of transplanted paddy. This method is being practised in many developed countries where labour is scarce and expensive (Pingali, 1994) and is now fast replacing traditional transplanted rice in areas with good drainage and weed control (Bala Subramanian and Hill, 2000).

The optimum seed rate is another important factor that affects crop micro-environment by influencing the degree of inter- and intra-plant competition. Therefore, while fixing seed rates for direct-seeded crop, the plants should be planted neither too thick not too thin, so that the input-use efficiency may be enhanced to the maximum possible extent.

MATERIALS AND METHODS

The experiment was conducted during rainy season *(kharif)* 2002 and 2003 at Agronomy farm of the university at Ludhiana in randomized block design with four replications. The treatments comprised four methods of sowing (M_1, broadcast in puddled field; M_2, line sowing with drum seeder in puddled field; M_3, line sowing with hand seed-drill in compacted field under moist condition and M_4, line sowing with hand seed-drill in seed-bed without compaction or puddling under moist condition); three seed rates (25, 50 and 75 kg seed/ha) of cv 'PR 115' along with transplanting on the day of sowing and transplanting 25 days after sowing, with total 14 treatments. The seed was treated with Ceresan wet and strepocycline for 8 hr and then kept under moist gunny bags in a thin layer for pre-sprouting (the stage reached after 24 hr under gunny bag). It was sown as per the treatments. Compaction un-

der M_3 method of sowing was done in moist field, with heavy plain-surfaced iron roller and bulk density was increased from 1.66 to 1.68 g/cm^3. In compacted field, the seeds were sown with hand-drill under moist condition, followed by planking twice to provide a thorough soil cover to the seed. Puddling was done under M_1 and M_2 methods of sowing on the day of sowing. The soil was loamy sand, having 78.5 per cent sand, 9.0 per cent silt and 12.5 per cent clay with 1.66 g/m^3 bulk density, 13.59 per cent moisture at field capacity and 5.14 per cent at wilting point. The soil was normal in reaction, low in available nitrogen (229 kg/ha) and medium in both available phosphorus (28.2 kg/ha) and potassium (234.5 kg/ha).

N, P_2O_5 and K_2O were applied @ 120, 30 and 30 respectively. A basal dose of 30 kg/ha each of P_2O_5 and K_2O along with 25 kg $ZnSO_4$/ha was applied to both direct-seeded and transplanted rice. Nitrogen was applied to rice @ 120 kg/ha in three splits, one third each at 1, 4 and 8 weeks after sowing in direct-seeded rice. In transplanted crop the second and third doses were applied 3 and 6 weeks after transplanting.

The nursery was sown on 5 May and 1 June for separate treatments, using pre-sprouted 20 kg seed/ha. The weeds were controlled by applying Sofit 30 EC (pretilachlor and Safner readymix) uniformly 3 days after sowing of sprouted seeds @ 1.25 litres/ha (commercial) after mixing in 150 kg sand in moist-condition, and irrigation was applied. In the transplanted crop, butachlor 50 EC @ 3.0 litres/ha was applied after mixing in 150 kg sand, 2 days after transplanting in standing water. The plots were kept moist for the first 10 days after applying light irrigations at 2-day intervals. The subsequent irrigations in direct-seeded rice were applied on the third day after the previous irrigation as the water did not accumulate in the field due to porous nature, and the last irrigation was applied 15 days before harvesting.

RESULTS AND DISCUSSION

As large variation in rains during the course of study affected the crop greatly, and the results are being presented years-wise. The low rainfall (293 mm) during *kharif* 2002 caused lower yield than in 2003 with normal rainfall (580.3 mm) that helped the crop attain maximum productivity.

Dry-matter accumulation and leaf-area index

The maximum dry-matter accumulation (DMA) was accrued in transplanted rice on the day of sowing, which was significantly more than all other treatments. Accumulation of more DM was the result of sowing 25 days earlier. Among other methods of sowing, seed rate of 75 kg/ha helped to produce maximum DMA, which was on a par with that of 50 kg/ha but significantly more than those of 25 rate/ha and transplanting at 25 DAS. The sequential trend observed was compaction > drum seeding after puddling > broadcasting after puddling > line sowing without compaction or puddling (Table 1). Greater amount of DMA under seed rates 75 and 50 kg/ha was due to more number of plants per unit area compared with seed rate of 25 kg/ha. Under compaction and puddled conditions, DMA was 115.7-139.1 q/ha compared with 147.8 q/ha in transplanting on the day of sowing and 104.1 q/ha in transplanting at 25 DAS. The low DMA under non-compacted unpuddled condition (64.2-87.1 q/ha) was mainly because of non-ponding of water on account of highly porous nature of soil and because the crop remained under oxidized condition throughout the growing season and suffered from acute deficiency of iron (recouped by frequent sprays of ferrous sulphate). Similar trend was observed during the second year *(kharif* 2003), where compaction and puddled conditions under direct seeding gave 178.5 to 197.5 q/ha DMA though in unpuddled or non-compacted condition it was 139.5-150.8 q/ha. At seed rate of 50 kg/ha, maximum DMA was produced compared with 198.3 and 172.8 q/ha under transplanting on the same day and at 25 DAS, respectively. Thus compaction or puddling ensured reduced conditions on account of ponding of water, which encouraged the plants to develop better vigour.

The maximum value of LAI was recorded at 90 days after sowing or transplanting (DAS or DAT), which was 4.37-4.97 under direct seeding in 2002 and 5.24 to 6.06 in 2003. Significantly low values were obtained under non-compacted or unpuddled conditions and highest where the seed was sown after compaction or puddling. The transplanting on the day of sowing and at 25 DAS gave 4.78 and 4.53 LAI in 2002, and 5.93 and 5.57 in 2003, respectively (Table 1). The high values in the second year were owing to favourable weather conditions; the first year suffered drought, which along with loamy sand affected the growth and development substantially.

Yield attributes

Panicles/m^2 was identified as the most important component among the yield attributes, accounting for 89 per cent variation in yield at Rice Experiment Station, California in Stockton clay soil (Miller *et al.,* 1991). The maximum tillers/m^2 were found in line sowing after compaction at all levels of seed rate in 2002, being 184.8-234.9/m^2 (Table 2). Puddling and compaction produced effective

tillers of same magnitude (285.8 to 301.2 tiller/m^2) in 2003. The lowest values were recorded under line sowing without compaction or puddling, viz. 113.8-171.0 in 2002 and 206.3-232.5 tillers/m^2 in 2003, showing the favourable effect of rainfall. The transplanted crop on the day of sowing and at 25 DAS produced 201.8 and 157.0 tiller/m^2 in 2002, and 306.3 and 237.5 in 2003. Seed rate of 50 kg/ha helped produce tillers on a par with that of 75 kg/ha but significantly more than that of 25 kg/ha and transplanting at 25 DAS. In alluvial sandy loam soil the crop with higher seed rate always contained greater number of plants as well as number of panicles/m^2 than those established with low seed rate (Ghosh and Reddy, 1984). More effective tillers under transplanting on the day of sowing, which was 28.5 per cent higher over transplanting at 25 DAS, may be due to favourable environment available to the early-transplanted crops.

The maximum grains/panicle were observed with seed rate 25 kg/ha irrespective of the methods of sowing during both the years (Table 1). It was followed by that of 50 and 75 kg/ha. More grains/panicle at lower seed rate was due to less competition among the plants for light, moisture and nutrients compared with those at higher seed rate. The mutual competition among plants at higher seed rate decreased the grains/panicle (Angiras and Sharma, 1998). However transplanting on the day of sowing produced

Table 1. Dry-matter accumulation, LAI, yield indices and yield of rice at under different seeding techniques and seed rates

Treatment		Dry-matter accumulation (q/ha)		LAI (90 DAS)		Effective tillers/m^2		No. of grains/ panicle		Test weight (g)		Grain yield (q/ha)	
Method	Seed rate (kg/ha)	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Puddling	25	115.7	178.5	4.66	5.83	182.6	285.8	112.9	160.0	22.31	22.56	45.1	71.4
	50	131.2	197.5	4.89	5.87	216.4	293.5	108.7	162.0	21.88	22.80	50.1	79.0
	75	133.8	195.3	4.96	6.00	232.8	300.0	103.2	158.0	21.73	22.95	51.1	78.1
Drum seeding	25	114.5	182.0	4.64	5.66	181.5	290.7	111.3	163.0	22.26	22.67	44.6	72.8
	50	132.7	191.3	4.88	6.00	215.9	291.6	109.5	161.0	21.84	22.38	50.7	76.5
	75	135.1	193.0	4.96	6.03	233.4	301.2	103.4	160.0	21.71	23.03	51.4	77.2
Compaction	25	121.8	179.0	4.68	5.76	184.8	287.5	114.7	158.0	22.37	22.78	47.9	71.6
	50	136.7	188.3	4.91	6.00	219.6	294.6	111.2	156.0	21.91	22.80	52.6	75.3
	75	139.1	188.3	4.97	6.06	234.9	299.4	104.5	159.0	21.79	22.69	53.2	75.9
Line sowing without compaction/puddling	25	64.2	139.5	4.37	5.24	113.8	206.3	108.1	142.0	21.57	23.00	25.0	55.8
	50	82.5	150.8	4.56	5.65	149.9	225.0	105.4	151.0	21.13	22.62	31.7	60.3
	75	87.1	147.3	4.65	5.71	171.0	232.5	97.5	152.0	20.94	21.82	33.3	58.9
Transplanting on the day of sowing		147.8	198.3	4.78	5.93	201.8	306.3	127.7	167.0	22.79	23.00	57.8	79.3
Transplanting at 25 DAS		104.1	172.8	4.53	5.57	157.0	237.5	115.6	159.0	22.61	22.78	40.6	69.1
CD (P=0.05)		5.9	14.8	0.27	0.33	24.6	30.3	11.5	17.1	0.17	0.18	8.1	6.0

Table 2. Water productivity of rice and maturity duration as influenced by seeding technique

Method of sowing	Irrigation water applied (cm)		Water productivity (kg grain/m^3 of irrigation water)		Average maturity duration (days)	
	2002	2003	2002	2003	2002	2003
Direct seeding						
Puddling	125	89	0.390	0.837	124	126
Drum seeding	127	91	0.385	0.848	123	125
Compaction	122	87	0.420	0.835	124	126
Line sowing without compaction/puddling	146	113	0.206	0.525	123	125
Transplanting						
Transplanting on the day of sowing	170	140	0.340	0.566	142	144
Transplanting 25 days after sowing	150	120	0.271	0.576	124	126

maximum filled grains (127.7 and167.0 in 2002 and 2003 respectively), which was significantly more than that at transplanting at 25 DAS. The corresponding increase over direct seeding by broadcasting after puddling, drum seeding after puddling, line sowing after compaction and line sowing without compaction or puddling was respectively 17.9, 18.1, 16.0 and 23.1 per cent during the first year and 4.4, 3.5, 5.9 and 12.6 per cent during the second year. The fewer number of filled grains/panicle under direct seeding probably due to more panicle density and extensive vegetative growth might have caused nitrogen dilution and resulted in less grains/panicle.

The sowing after compaction and in puddled field produced significantly bold grains than line sowing without compaction or puddling. The lower 1,000-grain weight in the latter might be due to water and nutrient stress, owing to more leaching losses and as the crop remained under stress due to adequate availability of iron. The 1,000-grain weight improved by 3.9 per cent in 2003 on account of favourable weather conditions, particularly well-distributed and sufficient rainfall. In direct seeding under puddled, compaction and unpuddled or uncompacted conditions it was 21.71-22.31, 21.79-22.37 and 20.94-21.57 g respectively in 2002; and 22.56-23.03, 22.69-22.80 and 21.82-23.0 g in 2003. In the crop transplanted on the day of sowing and at 25 DAS was 1,000-grain weight was 22.79 and 22.61 g in 2002, and 23.0 and 22.78 g in 2003.

Grain yield

The maximum grain yield during both the years (57.8 in 2002 and 79.3 in 2003) was recorded in transplanting on the day of sowing; which was on a par with the treatments where direct sowing was done by broadcasting and drum seeding under puddled conditions and the sowing after compaction at seed rate of 50 and 75 kg/ha (Table 1). The magnitude of increase in grain yield under 50 and 75 kg/ha was significantly more than that under 25 kg/ha, transplanting at 25 DAS and at all seed rates under line sowing without compaction or puddling. A favourable trend was observed in the effective tillers, filled grains/panicle and 1,000-grain weight under direct seeding in puddled or compacted field and transplanting after puddling on the day of sowing. Compaction apparently serves the same purpose as pudddling, encouraging ponding of water choking the macropores. The yield improved consistently with increase in seed rate from 25 to 75 kg/ha irrespective of the method of sowing, but that of 50 kg/ha produced almost the same yield as of 75 kg/ha but with a discernible margin over that of 25 kg/ha. Higher grain yield under seed rate of 50 and 75 kg/ha was mainly owing to more effective tillers/m^2, i.e. 201 and 218, respectively, compared with under seed rate of 25 kg/ha, i.e. 166/m^2 in 2002; and 276.2 and 283.3 respectively at seed rates of 50 and 75 kg/ha compared with 267.6/m^2 at 25 kg/ha in 2003.

The interaction between seeding technique and seed rate was not significant. But the pooled data showed that the grain yield varied between 40.4 and 64.6 q/ha. Amongst the direct-seeded rice, maximum grain yield (62.7 q/ha) was obtained under line sowing with compaction, which was on a par with that under drum seeding and broadcasting of pre-sprouted seed in puddled field, but significantly more than under line sowing without compaction or puddling, with a margin of 18.5 q/ha. Likewise, seed rate of 75 kg/ha gave 59.8 q/ha grain yield, closely followed by that of 50 kg/ha (59.6 q/ha) but significantly more than that of 25 kg/ha. Thus, direct seeding produced reasonably high yield and compaction proved as good as puddling, which saved substantial quantity of irrigation water required during puddling.

Water productivity

Water is a very crucial and finite input and its rational use is the prime necessity during these days. The direct-seeded rice has explored one possibility to save irrigation water by 29 per cent (Table 2). The saving in direct-seeded rice was realized because irrigations were applied on the third day of each previous irrigation, excluding rainy days up to 15 days before harvesting. Secondly, the direct-seeded crop matured 9 days earlier than transplanted crop on account of vanishing effect of transplanting shock. The water productivity in direct-seeded rice was 0.34 kg grain/m^3 in 2002 and 0.76 kg grain/m^3 in 2003; and in transplanted crops were 0.31 and 0.57 kg grain/m^3 of irrigation water respectively, indicating better water-use efficiency under direct seeding.

For realizing high yield level of direct-seeded rice, the crop should be sown up to 10 June, using seed rate of 50 kg/ha at 20 cm row spacing in compacted or puddled field by drilling or broadcast of pre-sprouted seeds in loamy sand soils under irrigated condition.

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