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Rice Productivity and Profitability Under Different Crop Establishment Methods, Plant Densities and Weed Control in North-Western Indo-Gangetic Plains

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ABSTRACT

The experiments were conducted at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during summer seasons of 2009 and 2010 to study the yield and economics of rice under different establishment methods, plant densities and weed control methods. Rice was directly sown with different drills or broadcasting technique and manual transplanting. For weed control, alone pre-emergence application of pendimethalin 0.75 kg ha^{-1} and sequential application of bispyribac sodium 0.025 kg ha^{-1}/azimsulfuron 0.02 kg ha^{-1} was done along with one weed free treatment. Grain yield did not vary significantly among establishment methods and the highest benefit:cost ratio (B:C) was obtained when rice was direct seeded with the help of drills. The maximum grain yield (71.06 q ha^{-1}) was recorded in weed free treatment which was statistically at par with sequential use of pendimethalin 0.75 kg ha^{-1} with bispyribac 0.025 kg or azimsulfuron 0.02 kg ha^{-1} applied 30 DAS. The B:C ratio increased as seed rate increases from 20 kg to 50 kg ha^{-1} and it was more for closer spaced direct seeded rice crop.

Key Words: Direct Seeded Rice, Puddled Transplanted Rice, Establishment Methods, Plant Densities, Weed Control, Grain Yield.

INTRODUCTION

The rice–wheat system is critical to the food security of India and to the livelihoods of the rural communities across the Indo-Gangetic Plains. The demand for food grains in India is increasing day by day and the requirement by the year 2025 is estimated to be increased by 40 per cent as compared to 2003-04. To sustain present food self-sufficiency and to meet future food requirements, there is need to increase rice productivity by 3 per cent per annum. In Punjab, rice occupied 2.8 m ha. with total production of 11.4 MT and productivity of 39.98 q ha^{-1} (Anonymous, 2014). In the Indo-Gangetic Plains, rice is traditionally transplanted in the end of the dry season (May/June) manually in standing water after puddling which is an important traditional soil management operation used to reduce soil permeability and preserve the aquatic, anaerobic conditions suited for the growth of wetland rice. With the advances made in rice-based cropping systems, it has been realized that repeated puddling damaged the soil structure which adversely affects the soil productivity and can negatively affect the following non-rice upland crop in rotation. Land preparation for rice consumes about 20-40 per cent of the total water required for growing the crop (Bhuiyan *et al* 1995). Further, with cultivation of water guzzling crop (rice) during summer season, estimates are that from 1997-2007, there has been a four-fold increase in the cumulative water-table drop in the central districts of Punjab (Hira, 2009). Hence, there is dire need for change in rice establishment methods to improve productivity, economics and long-term sustainability. The alternative tillage and crop establishment are site specific and therefore, evaluations under wide agro-ecological conditions is important to have significant adoption (Ladha *et al* 2009). Some innovative farmers of Punjab

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state have started growing direct seeded rice adopting different drills with different plant densities which needs standardization. Uniform crop emergence with optimum plant density is crucial for achieving good yields for any system, including direct drill-seeded rice. Good crop establishment depends on many factors including land preparation, planting date, seed rate, types of planting machinery used and depth of seeding.

MATERIAL AND METHODS

Two field experiments were conducted at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab during summer seasons of 2009 and 2010. Ludhiana is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plains at 30° 56' N latitude, 75° 52' E longitude and at an altitude of 247 m above mean sea level. The soil of the experimental site was loamy sand with normal soil reaction and electrical conductivity, low in organic carbon and available nitrogen and medium in available phosphorus and potassium. One experiment was laid out in split plot design with 4 replications comprising 5 crop establishment methods viz; direct seeding with zero till drill, Modified furrow drill, Conventional drill, puddled broadcasted and puddled transplanted in main plots and 4 weed control methods viz; pendimethalin 0.75 kg ha^{-1} pre-emergence alone and follow-up application of bispyribac 0.025 kg/azimsulfuron 0.02 kg ha^{-1} at 30 DAS/T and weed free in sub-plots. Zero Till Drill is conventionally used for growing wheat in no-till system and almost every village have one zero till drill so this drill was used for evaluating sowing of direct seeded rice. It has fluted roller mechanism as seed metering system and seeds fall continuously while sowing. At the used seed rate of 35 kg ha^{-1}, problem of seed breakage (5-6 %) was observed which was taken care of while calibration of drill. Modified furrow drill, prepared by a progressive farmer of village Kularh, district, Ludhiana, Punjab was evaluated for performance of direct seeded rice on ridges. It made alternate furrow and ridges and drilled the seeds on each slope of ridge (two rows per ridge). It has inclined plate mechanism as seed metering system. The third drill evaluated in this study was conventional drill, manufactured by M/s ASS Foundry, Jandiala Guru, District, Amritsar, Punjab. It was fitted with inclined plate seed metering system and places seeds and fertilizer using an inverted T-type opener. The field was levelled with Laser land leveller to allow drills to place seeds at a uniform distance and depth and enabled uniform distribution of irrigation water across the field, resulting in uniform crop stand. The drill sowing of rice cv. PAU 201 was done at 20 cm row spacing using primed seed after seed treatment on seed-bed prepared in three respective main plots. In the fourth establishment technique, primed seed was broadcasted in puddled field (wet seeding) and suspended mud is allowed to settle down and form a protective cover over the seeds sown (same operation was done as practiced in nursery sowing). In the fifth establishment technique, after seed bed preparation on the day of direct sowing, the respective plots were left unsown and weeds were allowed to germinate. For this puddled transplanting crop establishment method, nursery was raised by sowing on the date of direct seeding i.e. 6th June 2009 and transplanted manually with 30 days old seedlings at 20 cm×15 cm spacing in puddled field. Prior to the transplanting, the respective plots were cleaned off weeds and puddling operation was done. The weed control treatments were applied in the respective plots. Weed free plots were kept free from weeds by hand weeding as and when needed. All the pre and post-emergence herbicides were applied with back mounted knapsack sprayer fitted with flat fan nozzle using 375 l ha^{-1} of water. The recommended package of practices for raising rice crop was followed.

In second experiment, 16 combinations of 4 seed rates {20 kg, 30 kg, 40 kg and 50 kg ha^{-1}} and 4 row to row spacing {15, 20, 25 and 30 cm}were tested in randomised complete block design with 3 replications. Sowing of rice cv. PAU 201 was done in first week of June using primed seed after seed treatment on fine seed-bed with single row seed drill as per seed rate and row spacing treatments. Total package of practice was followed for raising crop.

The harvested produce from the net plot was threshed manually and grain yield and straw yield was recorded in kg. It was then converted to t ha^{-1} at 14 per cent moisture content. The economic

requirements for all the treatments were measured for the growing period of the crop during 2009 and 2010. Different economic indicators were calculated based on the existing price of the inputs and outputs. Variable cost of cultivation was worked out and the fixed cost was not taken into account. Gross returns were calculated by taking into account the main product and was calculated on the basis of minimum support price offered by Government of India for rice. Net returns (benefit) was calculated as the difference between gross returns and variable cost. Benefit:cost ratio was worked out by dividing net returns with variable cost.

RESULTS AND DISCUSSION

Grain Yield

Grain yield is a function of various growth and yield attributing parameters like crop dry matter accumulation, effective tillers, panicle length, number of grains panicle^{-1} and grain weight etc. It is the most important parameter to compare the effectiveness of different applied treatments. The effect of different crop establishment methods on the grain yield was statistically non-significant and its numerical value ranged from 57.42 q to 64.08 q ha^{-1} and 50.59 q to 56.99 q ha^{-1} during first and second year of study, respectively (Table 1).

In case of puddled broadcasting method, numerically lower grain yield (57.42 q ha^{-1} and 50.59 q ha^{-1}) was observed as compared to other direct seeding methods (drills) during the first and second year of study, respectively. Various yield attributes viz; number of effective tillers, panicle length, grains panicle^{-1} and 1000 grain weight (data not shown) was not influenced significantly by different crop establishment methods, consequently, the grain yield also remained statistically unaffected. These results are in affirmation to those reported by Bhullar *et al* (2012) that rice drilled directly in moist seed bed or in dry soil followed by irrigation and broadcasted with or without puddling recorded grain yield at par to puddled transplanting method.

The maximum grain yield (71.06 q ha^{-1} and 62.77 q ha^{-1}) was obtained in weed free treatment which was at par with integrated application of pendimethalin 0.75 kg ha^{-1} applied as pre-emergence followed by bispyribac 0.025 kg or azimsulfuron 0.02 kg ha^{-1} applied at 30 DAS during 2009 and 2010, respectively. Alone application of pendimethalin 0.75 kg ha^{-1} applied

Table 1. Effect of crop establishment methods and weed control treatments on rice grain yield, variable cost, gross returns and benefit:cost ratio.

Treatments	Grain yield (q ha^{-1})		Variable cost (000 ‘)		Gross returns (000 ‘)		Benefit: Cost ratio	
	2009	2010	2009	2010	2009	2010	2009	2010
Establishment methods								
Direct Seeding with Zero Till Drill	63.27	54.74	24.1	25.2	65.2	56.4	1.67	1.23
Direct Seeding with Modified Furrow Drill	64.04	55.69	24.5	25.2	66.0	57.4	1.70	1.27
Direct Seeding with Conventional Drill	64.08	56.66	24.5	25.2	66.0	58.4	1.70	1.32
Puddled Broadcasted	57.42	50.59	26.6	27.8	59.1	52.1	1.21	0.93
Puddled Transplanted	64.02	56.99	34.7	35.4	66.0	58.7	0.90	0.66
C.D. (p=0.05)	**NS**	**NS**	-	-	-	-	-	-
Weed control								
Pendimethalin 0.75 kg ha^{-1} pre-em.	39.09	36.03	24.2	24.8	40.3	37.1	0.70	0.52
Pendimethalin 0.75 kg ha^{-1} pre-em. f.b. bispyribac 0.025 kg ha^{-1} at 30 DAS	70.83	61.23	26.1	26.8	73.0	63.1	1.85	1.39
Pendimethalin 0.75 kg ha^{-1} pre-em. f.b. azimsulfuron 0.02 kg ha^{-1} at 30 DAS	69.30	59.71	24.8	25.4	71.4	61.5	1.95	1.46
Weed free	71.06	62.77	32.8	33.5	73.2	64.6	1.26	0.96
C.D. (p=0.05)	**4.89**	**3.50**	-	-	-	-	-	-

Table 2. Effect of seed rates and row to row spacing on rice grain yield, variable cost, gross returns and benefit : cost ratio of direct seeded rice.

Treatments	Grain yield (q ha^{-1})		Variable cost (000 ‘)		Gross returns (000 ‘)		Benefit: Cost ratio	
	2009	2010	2009	2010	2009	2010	2009	2010
Seed rate (kg ha^{-1})								
20	52.88	54.73	24.7	25.4	54.5	56.4	1.20	1.22
30	54.98	54.78	24.9	25.6	56.6	56.4	1.28	1.21
40	55.14	55.61	25.1	25.8	57.0	57.3	1.27	1.22
50	56.92	57.36	25.2	26.0	58.6	59.1	1.32	1.27
C.D. (p=0.05)	NS	NS	-	-	-	-	-	-
Row to row spacing (cm)								
15	58.68	56.89	25.5	26.2	60.4	58.6	1.38	1.24
20	54.99	56.48	25.1	25.8	56.6	58.2	1.26	1.25
25	53.19	55.81	25.0	25.5	54.8	57.5	1.21	1.25
30	53.07	53.29	24.5	25.2	54.7	54.9	1.23	1.18
C.D. (p=0.05)	NS	NS	-	-	-	-	-	-

as pre-emergence recorded significantly lower grain yield (39.09 q ha^{-1}) as compared with all other herbicidal treatments during 2009. Similar trend was also observed in the second year of study. The yield levels were low during the second year of the study due to the more weed pressure. Different growth and yield attributing characters viz; number of effective tillers, panicle length, number of grains panicle^{-1} and 1000 grain weight were significantly lower in case of alone application of pendimethalin 0.75 kg ha^{-1}, thus resulted in significantly lower grain yield. These results were in conformity with the findings of Mahajan and Timsina (2011), Mahajan *et al* (2009) and Walia *et al* (2009) that where integrated weed management practices were used , rice grain yield was significantly more than that of alone application of a herbicide. The interaction effect of crop establishment methods and weed control treatments was found to be non-significant.

Effect of Seed Rate

The effect of different seed rates and row to row spacing in Table 2 was non-significant on the grain yield. Numerically, an increasing trend of grain yield was observed with each increase in seed rate and the grain yield ranging from 52.88 q to 56.92 q ha^{-1} and 54.73 q to 57.36 q ha^{-1} during first and second year of study, respectively. Although the differences were non-significant, suggesting that direct seeded rice can be drilled with lower seed rate without any yield losses under weed-free conditions to save the cost of vital input (seed). As the effect of different seed rates on yield attributes viz; number of effective tillers, panicle length, number of spikelets panicle^{-1}, grains panicle^{-1} and 1000 grain weight was non-significant, the differences in the grain yield due to different seed rates was also reflected as non-significant during both the years of study. Payman and Singh (2008) also reported that increasing seed rate from 40 kg to 60 kg ha^{-1} did not influence the grain yield significantly. Chauhan *et al* (2011) and Zhao *et al* (2007) also reported that under weed-free conditions, grain yield were not influenced by the seed rates within the range of 15 kg to 125 kg ha^{-1}.

In case of row to row spacings, no significant difference in grain yield was observed. Numerically, the lowest grain yield (53.07 q $^{ha-1}$ and 53.29 q ha^{-1}) was obtained with wider row spacing of 30 cm as compared with narrow row spacings during 2009 and 2010, respectively although the differences were non-significant, suggesting that direct seeded rice can be drilled at 15 cm to 30 cm without any yield losses under weed-free conditions. The effect of different growth and yield attributing characters viz; number of effective tillers, panicle length, number of spikelets panicle^{-1}, grains panicle^{-1} and 1000 grain weight was non-significant, hence the different row to row spacings were also found to

be statistically at par with each other in respect of the grain yield. Lampayan *et al* (2010) also reported that the grain yields were similar for row spacings ranging from 25 to 35 cm. The interaction effect of seed rates and row to row spacings was also found to be non-significant.

The benefit accrued was more in case of direct seeding preferably with drills as compared with either broadcasting seeds in puddled field or manual transplanting in puddled field (Table 1). The numerical values for B:C ratio ranged from 0.80 to 1.51 and 0.56 to 1.16 in 2009 and 2010, respectively. The lower value of B:C ratio in conventional puddled transplanted was due to higher variable cost incurred in this practice as compared to that in direct seeded rice. The values of gross returns were more or less similar in all crop establishment methods. Amongst weed control methods, integrated application of pre- and post-emergence herbicides resulted in more B:C ratio as compared with weed free and alone application of pre-emergence herbicide. The lower value of B:C ratio in weed free was due to more variable cost involved whereas in alone application of pendimethalin kg ha^{-1}, low gross returns obtained were the reason for lower value of B:C ratio.

The numerical value of B:C ratio increased as seed rate increases from 20 kg to 50 kg ha^{-1} (Table 2). This might be due to more gross returns obtained with higher seed rates and thus, covering the cost of extra seed. The numerical value of B:C ratio ranged from 1.20 to 1.32 and 1.21 to 1.27 with increase of seed rate from 20 kg to 50 kg ha^{-1} in 2009 and 2010, respectively. The value of B:C ratio was more for closer spaced direct seeded rice crop. More value of B:C ratio might be due to more gross returns obtained in closer sowing crop instead of higher variable cost involved. The numerical values of B:C ratio varied from 1.21 to 1.38 and 1.18 to 1.25 for different row to row spacings during 2009 and 2010, respectively.

CONCLUSION

Rice can be seeded directly with zero till drill, Modified furrow drill and Conventional drill with inclined plate metering system for optimum productivity and profitability. Optimum seed rate for direct seeding is worked out to be 20 kg ha^{-1} and optimum row to row spacing can be varied from 15-30 cm.

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