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Production of direct seeded rice (*Oryza sativa*) under differential plant densities and herbicides in central plains of Punjab

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ABSTRACT

Field experiments were conducted during Kharif season of 2007 and 2008 at research farm of the department of Agronomy, PAU, Ludhiana, Punjab, India to find out the appropriate plant density and most effective weed control method for controlling weeds in direct seeded rice (Oryza sativa L.) under unpuddled conditions. Higher plant density i.e. 250 viable seed m^{-2} (50 kg ha^{-1}) provided good smothering potential on weeds thus reducing the dry matter of weeds. But maximum grain yield was recorded with planting density of 150 viable seeds m^{-2} (30 kg ha^{-1}) during both years, which was significantly higher than 100 viable seeds m^{-2} (20 kg ha^{-1}) but statistically at par with planting density of 200 and 250 viable seeds m^{-2}. Pre-emergence application of pendimethalin 0.75 kg ha^{-1} followed by bispyribac 25 g ha^{-1} (30 days after sowing) recorded lowest dry matter of weeds and highest grain yield during both the years. This was followed by pre-emergence application of pendimethalin 0.75 kg ha^{-1} followed by azimsulfuron (20 g ha^{-1}) and 2, 4-D (0.5 kg ha^{-1}) at 30 days after sowing. Alone application of pendimethalin 0.75 kg ha^{-1} recorded significantly higher dry matter and lower grain yield as compared to other integrated treatments.

Key words: Direct seeded rice, plant density, seed yield, viable seeds, weed control

Rice (*Orzya sativa* L.) is a principal source of food for more than half of the world population especially in Southeast Asia. Elsewhere, it represents a high value commodity crop. In India, it is a dominating staple food crop of fertile and alluvial soils of North West India, particularly Indo-Gangetic plains (Walia and Walia, 2007). It occupies 43.8 million hectares with a total production of 96.4 million tonnes of rice (Anon, 2009a). In Punjab, rice is a major *kharif* crop on an area of about 2.8 million hectares with a total production of 10.5 million tonnes of rice (Anon, 2009b). Transplanting of paddy seedlings is the dominant method of crop establishment in the irrigated rice systems of Asia and Punjab but transplanting is labour intensive (30 persons per ha per day) and land preparation for transplanted paddy (puddling) consumes about 20-40 per cent of the total water required for growing the crop (Bhuiyan *et al.,* 1995). Conventionally, in Punjab, rice is transplanted after puddling and wheat is mostly sown after pulverizing the soil. This reflects an edaphic conflict in traditional soil management for rice and its consequent deleterious effects on the soil environment for the succeeding wheat and other upland crops. Puddling destroys soil structure and adversely affects soil productivity. Over the years, continuous practice of rice – wheat monoculture has led to many ecological problems. The main concern is deepening of water table, which is going down every year at the rate of 74 cm per year. In recent years, there have been concerns related to shortage of labour, which cause transplanting costs to rise and delay the planting of the rice crop. Due to receding water table (Humphreys *et al.,* 2004), rising costs of labour for transplanting of paddy and the adverse effects of puddling on soil health, direct seeded rice (DSR) is gaining popularity in South-East Asia which is probably the oldest method of crop establishment. In Asia, this crop is grown as direct seeded in an area of about 29 million ha, which is approximately 21 per cent of the total rice area in the region (Pandey and Valesco, 2002). The basic question is, can rice culture be like wheat so that it can benefit cropping system productivity and sustainability? The economy of farmers of Punjab is largely dependent on Rice - Wheat system, so diverting them form rice cultivation is very daunting task. Alternatively, we can look at other production techniques which can sustain rice production as well as are ecofriendly and resource conservative. The most promising option for the future is to adopt direct sowing of rice in place of transplanting, reducing its dependence on labour and water, reducing the risk of cracking of soil under limited water supply and for farmers to become familiar with the correct use of herbicides. Direct seeding of rice (DSR) offers certain advantages such as low labour costs, low soil degradation, less drudgery, early crop maturity by 7 -10 days, high tolerance to water deficit, saving of water, energy, seed and fuel, lower production costs and more profit and less methane emissions. It allows more effective growth period to the paddy crop within the same duration. A physiological shock to the crop due to uprooting and harmonising during re-establishment after transplanting is clearly avoided. Simplified, mechanized operations render this alternate crop cultivation technology more acceptable and popular. So, in order to protect natural resources especially water, there is a need to replace puddled transplanted rice with the direct seeded rice. Direct seeding of rice is possible provided there is a good crop establishment as well as adequate weed control

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methods are available to keep the crop free from weeds (Rao *et al.*, 2007., Rao and Nagamani, 2007) , however in absence of proper weed control, rice yields are reduced by 35-100 per cent in DSR (Kumar *et al.*, 2008). The direct-seeded rice offers the advantage of faster and easier planting, ensure proper plant population, reduced labour and hence less drudgery, 10-12 days earlier crop maturity, more efficient water utilization and often higher profit in areas with assured water supply (De Datta, 1986). The appropriate plant density is decisive factor that affects crop micro environment by influencing the degree of inter and intra-row plant competition. Therefore, while fixing seed rates for direct seeded rice, the seeds should be dropped neither too close nor too far away, so that input use efficiency may be enhanced to the maximum possible extent. The direct sown crop has highest risk of competition from weeds because of the absence of the size differential between the crop and the weeds. The conversion from transplanted to direct seeded rice results in more aggressive weed flora and increases reliance on herbicides for weed control. The adoption of direct seeded rice has resulted in a change in the relative abundance of weed species in rice crops. In particular, *Echinochloa* spp., *Ischaemum rugosum*, *Cyperus difformis* and *Fimbristylis miliacea* are widely adapted to conditions of DSR. So, the present study was under taken in order to workout appropriate plant density as well as most effective weed control method for direct dry-seeded rice.

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2007 and 2008 at the research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana (30^0 56' N latitude with 75^0 52' E longitude, 247m above mean sea level) to workout appropriate plant density and most effective weed control method for rice under direct seeded conditions. The soil was sandy loam containing 76.3 % sand, 10.0 % silt and 13.6 % clay. It was low in available nitrogen (245 and 256 kg ha^{-1}), medium in available P (12.7 and 13.1 kg ha^{-1}) and medium in available K (145.8 and 147.5 kg ha^{-1}) during 2007 and 2008, respectively. Short duration variety PR 115 (125 days) was grown during 2007 and long duration variety PAU 201 (144 days) was sown during 2008. The experiment was laid out in split plot design with four replications. Four plant densities (100, 150, 200 and 250 viable seeds m^{-2}) were assigned to main plots and four weed control treatments i.e. pre-emergence application of pendimethalin at 0.75 kg ha^{-1} , pre-emergence application of pendimethalin at 0.75 kg ha^{-1} followed by post-emergence application of bispyribac at 25g ha^{-1} or azimsulfuron at 20 g ha^{-1} or 2, 4-D at 0.5 kg ha^{-1} to the sub plots. The seed rates of 20, 30, 40 and 50 kg/ha corresponding to 100, 150, 200 and 250 viable seeds m^{-2} were used. Sowing of *Sesbania* was done along with the seeds of rice varieties i.e. PR 115 and PAU 201 in only 2, 4- D treated sub-plots. Direct seeding of the seeds of PR 115 and PAU 201 were done manually with hand drill keeping row to row spacing of 20 cm on 08.06.2007 and 07.06.2008 by using plant density as per treatment. The pre-emergence application of pendimethalin at 0.75 kg ha^{-1} was given within two days of sowing. The follow-up applications of bispyribac 25 g ha^{-1}, azimsulfuron 20 g ha^{-1} and 2, 4-D 0.5 kg ha^{-1} were done 25-30 days after sowing. The net plot harvested was 7.0 square metres. The experimental crop was raised by adopting all the recommended agronomic and plant protection measures as for dry-seeded crop. Irrigation of 5 cm was applied at required intervals when the water was completely drained and irrigation was withheld 10 days before the harvest. The sampling techniques for all the growth and yield characters including estimation of yield were followed as per standard procedures. Data on weed dry matter was recorded at 60 DAS with quadrate measuring 50×50 cm and expressed as q ha^{-1}. Data on plant height, effective tillers, panicle length and grain yield was recorded at the time of crop harvest. Weed control efficiency (WCE) was calculated by using the formula given below;

$$\frac{DMC - DMT}{DMC} \times 100$$

DMC = Dry matter of weeds in control plot

DMT = Dry matter of weeds in a particular treatment.

In this study alone pre-emergence application of pendimethalin was considered as control and WCE was calculated using this as control. Data were subjected to analysis as detailed by Cheema and Singh (1991) in statistical package CPCS-1.

RESULTS AND DISCUSSION

Weed growth

The major weed flora of the experiment field consisted of sedges (*Cyperus rotundus*, *Cyperus iria* and *Cyperus compressus*), grasses (*Digitaria sanguinalis*, *Echinochloa spp*, *Eleusine aegyptiacum*, *Leptochloa chinesis* and *Eragrostis spp*) and broadleafs (*Ammania baccifera* and *Caesulia axillaris*). Plant density determines the number of plants per unit area which shows competitive effect against weeds. Higher plant density can put pressure on the availability of space for weed growth. The dry matter of weeds recorded 60 days after sowing showed declining trend with increase in plant density from 20 to 50 kg ha^{-1} during both the years. Significantly less dry matter was recorded in 50 kg ha^{-1} treatment as compared to plant density of 20 and 30 kg ha^{-1} (Table 1). Kehinde (2002) reported that increasing the seed rate from 45 kg to 90 kg ha^{-1} slightly decreased the weed dry matter and increased grain yield. Increasing seed rate from 100 kg to 150 kg.ha^{-1} using sprouted seeds decreased the growth of *Echinochloa* spp. while the trend was reverse in *Cyperus* spp. and no effect on other weed species. Payman and Singh (2008) reported that increasing seed rate from 40 to 60 kg ha^{-1} produced significantly higher emergence count and help in suppressing the weed population at 30 and 60 DAS, resulting in taller plants, more crop dry matter and enabled higher PARI per cent at 30 DAS. Gill (2008) revealed that seed rate also influenced the weed dry matter effectively as the seed rate increased the competition among crops increased which shows excellent smothering effect.

The pre-emergence application of pendimethalin 0.75 kg ha^{-1} followed by post emergence application of bispyribac 25 g ha^{-1} was found to be superior as compared to other herbicidal treatments as it recorded lowest dry matter of weeds during both the years. This treatment was at par with pre-emergence application of pendimethalin followed by post-emergence application of azimsulfuron 20 g ha^{-1} and both these treatments recorded significantly lower dry matter of weeds as compared to application of pendimethalin alone. Weed control efficiency (WCE) was maximum in pre-emergence application of pendimethalin 0.75 kg ha^{-1} followed by post emergence application of bispyribac 25 g ha^{-1} during both the years. In 2007 it was 80.3 per cent whereas in 2008 it was 72.0 per cent. Yadav *et al.*(2009) reported that azimsulfuron 0.030-0.040 kg ha^{-1} at 15 and 25 DAS proved effective against sedges but not *Echinochloa* spp. They further reported that application of metsulfuron + chlorimuron (Almix) 0.004 kg ha^{-1}, ethoxysulfuron 0.1875 kg ha^{-1} or 2, 4-D 0.05 kg ha^{-1} in combination with bispyribac resulted to improved control of broadleaf weeds and sedges.

Yield attributes

Planting density is a crucial factor for better production and also it gives equal opportunity to the plants for their survival and best use of other constraints The difference in plant height among seed rate treatments was found to be non-significant during both years (Table 2). Different weed control treatments significantly influenced plant height during 2007 but differences were non significant during 2008. During 2007 significantly higher plant height was recorded in pendimethalin alone and integration of bispyribac with pendimethalin treatment as compared to other weed control treatments. Effective tillers i.e. tillers with fertile panicles are the important yield attribute, accounting around 64.5 per cent of the variation in rice grain yield. Number of effective tillers m^{-2} was significantly more with plant density of 50 kg ha^{-1} as compared to plant densities of 20, 30 and 40 kg ha^{-1} during 2007. The least number of effective tillers m^{-2} were with plant density of 20 kg ha^{-1}. Kehinde (2002) reported that Seed rate with 150 kg ha^{-1} registered 577 tillers m^{-2} and it was at par with 125 kg ha^{-1} and these were significantly higher than 100 kg ha^{-1}.

The number of effective tillersm^{-2} were found to be significantly less in alone pre emergence application of pendimethalin as compared to integration of pre emergence application of pendimethalin with post emergence application of bispyribac/azimsulfuron/2,4-D treatments during both the years. Rao *et al.* (2007 a) reported that pre-emergence application of pendimethalin 1.0 kg ha^{-1} as well as pretilachlor 0.75 kg ha^{-1}, both supplemented with one hoeing 30 days after sowing, recorded effective control of weeds and gave grain yield at par to conventional method.

During both the years, panicle length was neither influenced by plant density treatment nor by weed control treatments (Table 2). Grain yield is a function of various growth and yield parameters like effective tillers, panicle length etc. It is the most effective parameter to compare different treatments. Results of both the years indicated that use of plant density of 30 kg ha^{-1} recorded highest grain yield which was significantly higher to plant density of 20 kg ha^{-1} and statistically at par with plant densities 40 and 50 kg ha^{-1}. Increasing the seed rate from 100 to 300 viable seeds m^{-2} resulted in a significant increase in yield and decrease in weed biomass, whereas a further increase from 300 to 500 viable seeds per m^2 did not result in further improvement in further improvement in yield and weed suppression (Zhao *et al.,* 2007). The use of 30 kg ha^{-1} plant density resulted in increase in grain yield by 19.6 per cent as compared to 20 kg ha^{-1}. Singh and Kumar (2009) reported that in eastern IGP of India, seed rate of 20-25 kg ha^{-1} is optimum for DSR for cultivars of medium fine grain. Higher seed rate caused nitrogen deficiency, reduced tillering and increased proportion of ineffective tillers, more lodging problems and attack of brown plant hoppers. Among weed control treatments, significantly less grain yield was recorded in alone pre-emergence application of pendimethalin during both years as compared to integration of post-emergence application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} or 2, 4-D 0.5 kg ha^{-1} with pre-emergence application of pendimethalin (Table 2) and these treatments resulted in increase in grain yield by 40.5, 25.5 and 24.3 per cent in 2007 and 43.8, 37.5 and 25 per cent in 2008 as compared to alone application of pendimethalin, respectively. Singh *et al.*(2005) recorded maximum weed control efficacy and grain yield of direct seeded rice with pre-emergence application of pendimethalin 1.0 kg ha^{-1}

followed by either one hand weeding or 2,4 –D 0.5 kg ha^{-1}. Chemical weed control (pre-emergence and post-emergence application provides best weed control and grain yield. It eliminate the early competition due to weeds causing lower weed population and weed dry matter production. The elimination of early competition due to weeds promotes better utilization of the various growth factors which ultimately produce maximum grain yield.

Table 1: Dry matter of weeds (60 DAS) and weed control efficiency (%) of direct seeded rice as influenced by plant density and weed control treatments

Treatments	Dry matter of weeds (q ha^{-1})		Weed control efficiency (%)	
	2007	2008	2007	2008
Seed rate				
100 viable seeds m^{-2} (20 kg ha^{-1})	2.7 (7.7)	2.5 (6.5)	-	-
150 viable seeds m^{-2} (30 kg ha^{-1})	2.7 (7.5)	2.1 (4.6)	-	-
200 viable seeds m^{-2} (40 kg ha^{-1})	2.1 (4.6)	2.6 (6.9)	-	-
250 viable seeds m^{-2} (50 kg ha^{-1})	2.0 (3.9)	1.9 (3.6)	-	-
LSD(0.05)	**0.5**	**0.5**	-	-
Weed control treatments				
Pendimethalin 0.75 kg ha^{-1} fb azimsulfuron 20 g ha^{-1}	2.0 (4.6)	2.4 (5.7)	65.2	30.5
Pendimethalin 0.75 kg/ha fb bispyribac 25 g ha^{-1}	1.6 (2.6)	1.4 (2.3)	80.3	72.0
Pendimethalin 0.75 kg/ha fb 2, 4-D 0.50 kg ha^{-1}	2.3 (5.4)	2.1 (4.4)	59.1	46.3
Pendimethalin 0.75 kg ha^{-1}alone	3.6 (13.2)	2.8 (8.2)	-	-
LSD(0.05)	**0.7**	**0.7**	-	-

* *Figures in parentheses are original values*

Table 2: Influence of plant density and weed control treatments on yield attributes and grain yield of direct seeded rice

Treatments	Plant height (cm)		Effective tillers m^{-2}		Panicle length (cm)		Grain yield (t ha^{-1})	
	2007	2008	2007	2008	2007	2008	2007	2008
Seed Rates								
100 viable seeds m^{-2} (20 kg ha^{-1})	66.4	62.2	238.8	352.0	22.3	23.5	4.2	4.8
150 viable seeds m^{-2} (30 kg ha^{-1})	66.1	63.3	250.8	362.7	22.5	23.4	4.9	6.5
200 viable seeds m^{-2} (40 kg ha^{-1})	64.7	62.9	260.8	380.7	22.9	23.5	4.8	6.5
250 viable seeds m^{-2} (50 kg ha^{-1})	64.8	61.6	272.4	383.0	22.8	23.2	4.6	6.2
LSD (0.05)	**NS**	**NS**	**20.4**	**2.9**	**NS**	**NS**	**0.3**	**0.5**
Weed control treatments								
Pendimethalin 0.75 kg ha^{-1}f.b azimsulfuron 20g ha^{-1}	63.5	61.7	260.0	370.0	22.5	23.4	4.9	6.6
Pendimethalin 0.75 kg ha^{-1}f.b bispyribac 25g ha^{-1}	66.3	62.5	268.0	380.7	22.3	23.3	5.2	6.9
Pendimethalin 0.75 kg ha^{-1}f.b 2, 4-D 0.50 kg ha^{-1}	63.9	62.6	257.6	359.4	22.8	23.2	4.6	6.0
Pendimethalin 0.75 kg ha^{-1}alone	68.3	62.9	237.2	345.4	22.8	23.6	3.7	4.8
LSD (0.05)	**1.9**	**NS**	**18.5**	**NS**	**NS**	**NS**	**0.4**	**0.7**

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