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Crop establishment method and planting density effects on weeds, insects and productivity of rice

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ABSTRACT

The effect of establishment methods and seedling density on weed dynamics, pest incidence and productivity of transplanted rice were evaluated in a field study, conducted in summer 2019 at Ludhiana, India.Three rice establishment methods [rice transplanted on puddled flat soil (PFTR), rice transplanted on unpuddled raised bed (UBTR), rice transplanted on unpuddled ridge (URTR)] in main plots, and three planting densities (20, 25, 33 seedling hills/m^2) in sub-plots were evaluated in a split-plot design. It was found that UBTR and URTR methods had higher weed biomass than PFTR at 20 and 70 days after transplanting (DAT). All three establishment methods gave similar rice grain yield. Increase in planting density from 20 to 33 seedling hills/m^2 reduced weed biomass at 20 and 70 DAT but at 45 DAT, all the planting densities had similar weed biomass. Likewise, there was consistent decline in rice grain yield due to reduction in planting densities but differences among consecutive planting densities were not significant. The incidence of insect-pest remained below economic threshold level under all treatments.

India is major producer and consumer of rice after China (FAO 2018). Punjab state with geographical area of 1.53% of India, is contributing 30-48% to the national buffer stock and plays a key role in food security of India (Kumar and Kaur 2019). Therefore, sustainability of rice production system in Punjab is important for ensuring Indian food security. The conventional system of rice production *i.e.* puddle transplanted rice (PTR) is water, labor and energy intensive, which threaten the sustainability of rice production system. Puddling of rice fields alone consumes79 to 150 mm irrigation water (Yadav *et al.* 2011). It has been reported that PTR system requires up to 5000 litres water to produce one kg of rice (Bouman 2009). The excessive pumping of groundwater for rice cultivation under Punjab conditions has resulted in decline of water table by 0.4-1.0 m per year, leading to increased pumping cost and water scarcity (Hira 2009). Repeated puddling destroys soil structure and creates shallow hard pan, which, besides affecting the performance of rice as well as succeeding wheat crop, also make the conditions favorable for emission of methane (CH_4), thereby, contributing to global warming (Rao and Matsumoto 2017, Dhillon and Mangat 2018).

In view of declining water table and deteriorating soil physical conditions associated with conventional system of rice establishment, alternative establishment methods, transplanting rice on beds or ridges under unpuddled conditions were recommended in 2007 (Anonymous 2007). In spite of substantial saving of irrigation water, better soil physical conditions and some other environment related benefits, these alternative methods could not find favor among rice farmers, probably, in part due to higher weed pressure (Rao and Matsumoto 2017). Apart from establishment method, seedling density is another important factor which influence weed growth and grain yield (Dass *et al.* 2017). Farmers, in general, transplant lesser number of seedlings (18-22 seedlings/m^2) in comparison to recommended (33 seedling/m^2). Dense transplanting (28 seedling/m^2) had lower weed pressure than 21 seedling/m^2 (Aggarwal and Singh 2015). The published data on interaction among establishment method and seedling density on weed dynamics and rice grain yield is not available under Indo-Gangetic plains region in India. Keeping in view the above, the present study was undertaken.

A field experiment was conducted at Punjab Agricultural University, Ludhiana, India [30°56' N latitude; 75°52' E longitude; 247 m altitude] located in the Indo–Gangetic Plain Region (IGPR) during summer season *(Kharif)* 2019. Experimental site is characterized as sub-tropical, semi–arid with an annual rainfall of 759 mm, out of which about 80% is received from June to September (Prabhjyot-Kaur *et al.* 2016).The soil was sandy–loam, low in available N and high in available–P and medium in available–K and soil organic carbon (SOC) status of soil pH and electrical conductivity were normal. The treatments included three rice establishment methods (rice transplanted on puddled flat soil (PFTR), rice transplanted on unpuddled raised bed (UBTR), rice transplanted on unpuddled ridges (URTR) in main plots, and three planting densities (20, 25, 33 seedling hills/m^2) in sub plots and each treatment replicated three times. The beds (of 15 cm height) and ridges (of 30 cm height) were prepared by tractor drawn bed maker and ridger. The total size of bed was 67.5 cm with 37.5 cm bed top and 30 cm furrow. Similarly, the spacing between two ridges was kept 60 cm (top to top). In case of PFTR, seedlings were transplanted at 15, 20 and 25 cm spacing in 20-cm spaced rows for 20, 25 and 33 seedlings/m^2. In case of UBTR, rice seedling were transplanted in the middle of slope in two rows on both side of bed (67.5 cm; 37.5 cm bed and 30 cm furrow) at 9, 12 and 15 cm spacing in 33.75 cm spaced rows. In case of URTR, two rows of rice seedlings were transplanted in the middle of slope on both sides of ridge (60 cm spacing) at 10, 13 and 16 cm spacing in 30 cm spaced rows.

Rice variety '*PR 121*' was transplanted on 24 June, 2019 using 30-days old seedlings. The crop was supplied with 105 kg nitrogen (N) and 25 kg $ZnSO_4$/ha; N was applied through urea in three equal splits; as basal at 21 days after transplanting (DAT) and at 42 DAT and $ZnSo_4$ applied as basal. In PFTR, the field was kept ponded (6.5 cm) for first two weeks after transplanting and afterwards irrigation was applied two days after the draining of ponded water. The un puddled ridge and bed plots were supplied with four extra irrigations during first two weeks to keep the field in saturation and afterward alternate wetting and drying was followed. After 15 DAT, crop was irrigated as per the demand. The depth of each irrigation water was 6.5 cm (except 10.0 cm at puddling) in PFTR but 5.0 cm in un-puddled ridge and bed treatments. The crop was raised as recommended package of practices for the region. Pretilachlor 0.75 kg/ha as pre- (2 DAT) and bispyribac-sodium 25 g/ha as post-emergence (20 DAT) were sprayed in all the plots. Weed biomass was recorded at 20, 45 and 70 DAT. Later, all plots were hand weeded. Insect pest also pose a biotic stress to crop, hence to assess the influence of different treatments on insect-pest, data was recorded at 40, 55, 70, 85 days after transplanting and before harvest of the crop as per standard protocol (Anonymous 2019). The data on plant growth and grain yield parameters were recorded from five representative plants per plot. Grain yield obtained from net plot was adjusted at 14% moisture and expressed as t/ha. Data were subjected to statistical analysis using SAS 9.3 software package.

Major weed flora in experimental field included *Echinochloa crus-galli*, *Echinochloa colona*, *Leptochloa chinensis*, *Cyperus difformis, Cyperus iria* and *Ammania baccifera*. Among establishment methods, FPTR had significantly lower weed biomass than UBTR and URTP while UBTR and URTR had similar weed biomass at 20 and 70 DAT. Weed biomass did not vary statistically among establishment methods at 45 DAT (**Table 1**). Sequential application of pretilachlor and bispyribac provided effective control of weeds in all establishment methods. Hence, weed biomass was at par at 45 DAT. After 45 DAT, there was resurgence of weeds, which was significantly higher in un-puddled than in puddled conditions. In flat puddle field, surface remained fully covered with ponded water

Table 1. Interactive effects of rice establishment method and planting density on weeds biomass at 20, 45 and 70 DAT

Planting density (rice seedling/m^2)	Rice establishment method weed biomass (g/m^2)											
	20 DAT				45 DAT				70 DAT			
	Flat	Bed	Ridge	Mean	Flat	Bed	Ridge	Mean	Flat	Bed	Ridge	Mean
33	5.1	8.2	8.0	7.1	4.8	5.5	5.6	5.3	11.4	41.9	27.7	27.0
25	6.4	10.3	9.1	8.6	5.5	6.4	6.0	6.0	15.8	69.6	58.9	48.1
20	7.6	11.5	10.3	9.8	5.8	6.7	6.3	6.2	24.7	110.8	104.9	80.1
Mean	6.4	10.0	9.1		5.4	6.2	6.0		17.3	74.1	63.8	
LSD (p=0.05)	Establishment method: 1.1; Planting density: 0.9, Interaction: NS				Establishment method: NS; Planting density: NS, Interaction: NS				Establishment method: 25.6; Planting density: 5.1, Interaction: 8.8			

Flat- Puddled transplanted; Ridge- un-puddled transplanted; Bed- unpuddled transplanted which decreased weed emergence, whereas, the tops of un-puddled bed and ridge were not inundated and hence weeds emerged on these tops which increased weed biomass. The differences among establishment methods were quite less at 20 DAT but increased at 70 DAT. Seedling densities also had significant effect on weed biomass. Reduction in seedling density from 33 hills to 20 hills/m^2 caused significant increase in weed biomass at 20 and 70 DAT but not at 45 DAT.

The damage by different pests was below economic threshold level (ETL) under different treatments (ETL for stem borer and plant hopper (PH) is 5% dead hearts and 5 PH/hill, respectively) (**Table 2**). It was found that dead hearts and white ears were not influenced by establishment methods and planting densities. The plant hopper (PH) population was observed to be more under ridge transplanting method except at 40 DAT, where differences were not significant. Increasing seedling densities results in higher PH population but differences between consecutive planting densities were not significant. The higher PH population under ridge transplanting method as well as dense planting can be ascribed higher tiller density under respective treatments. Soni and Tiwari (2016) also reported that damage and population of insect-pest varied with establishment method.

Planting methods did not cause significant effect on growth and yield attributes of rice including tiller density, panicle density, grains/panicle and sterility (**Table 3**) resulting into similar rice grain yield under all planting methods. It can be inferred that though all three methods gave similar rice yield but there was 11.3% saving in irrigation water under bed/ridge transplanting over flat-puddle transplanting (data not presented). However, the higher weed pressure under un-puddle bed/ridge method may hamper crop productivity and also results in maximizing weeds seed production, which may increase weed pressure in future. Proper weed management is more critical under these alternate methods of establishments and hence further studies are needed to identify appropriate methods to manage weeds (Rao *et al.* 2017).

Planting density had significant influence on tiller, panicle density and panicle weight. However, grains/panicle and sterility did not vary significantly. Decrease in planting density from 33 to 25 hills/m^2 caused significant drop in tiller and panicle density. Panicle weight was highest under 20 hills/m^2. The highest rice grain yield was recorded at 33 hills/m^2, which was at par to 25 hills/m^2 but significantly higher than 20 hills/m^2 (**Table 3**). The statistical parity in grain yield under 33 and 25 hills/m^2 as well as 25

Table 2. Effect of rice establishment methods and planting density on insect-pests damage at different growth stages of rice

Treatment	Dead heart (%)				Pre-harvest WE (%)	Plant hopper population/hill			
	40 DAT	55DAT	70DAT	85DAT		40 DAT	55 DAT	70 DAT	85 DAT
Rice establishment method									
Flat (puddled)	0.87	1.28	2.78	1.64	2.63	0.53	0.98	1.35	2.28
Beds(un-puddled)	1.89	2.19	3.79	2.60	3.35	0.46	0.80	1.17	1.80
Ridges (un-puddled)	0.83	1.36	2.41	1.54	2.20	0.91	1.55	2.64	3.58
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	0.22	0.13	0.61
Planting density (rice seedling/m^2)									
33	1.55	1.81	3.35	2.09	3.25	0.73	1.29	1.84	2.82
25	1.30	1.75	3.13	2.12	3.19	0.64	1.09	1.69	2.49
20	0.75	1.28	2.50	1.56	2.52	0.53	0.95	1.64	2.35
LSD (p=0.05)	NS	NS	NS	NS	NS	0.15	0.17	NS	0.24

WE; white ears

Table 3. Effect of rice establishment method and planting density on growth, yield attributes and grain yield of rice

Treatment	Plant height (cm)	Tiller density (no./ m^2)	Days to 50% flowering	Panicle (no./m^2	Panicle weight (g)	Filled grains (no./panicle)	Un filled grains (no./panicle)	Sterility (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Rice establishment method											
Flat (puddled)	99.8	343.4	109.8	331.2	3.20	113.2	12.5	9.9	7.83	9.76	44.5
Beds(un-puddled)	100.1	344.4	110.6	327.6	3.13	108.2	12.4	10.3	7.58	9.16	45.3
Ridges (un-puddled)	100.5	350.9	108.1	325.2	3.20	117.8	14.2	10.7	7.73	10.13	43.3
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting density (rice seedling/m^2)											
33	101.2	373.6	109.6	369.6	3.06	109.5	12.3	10.0	8.01	9.89	44.7
25	99.8	337.5	109.3	316.7	3.20	115.2	12.6	9.8	7.76	9.88	44.0
20	99.4	327.6	109.6	297.8	3.28	114.5	14.2	11.0	7.36	9.28	44.2
LSD (p=0.05)	NS	19.5	NS	28.6	0.12	NS	NS	NS	0.47	NS	NS

and 20 hills/m^2 can be ascribed to the higher tillering ability of genotypes '*PR 121*' sown in the experiment. Hence, further studies on this aspect need to be conducted with different genotypes having varying tillering ability and other yield related traits.

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