

Impact of different crop-establishment methods and cono weeding on growth, productivity and water economy of rice (*Oryza sativa*)

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ABSTRACT

A field study was conducted during the rainy (*kharif*) season of 2017 at Pantnagar, Uttarakhand, to assess the impact of different crop-establishment techniques on productivity and irrigation water-use efficiency (IWUE) of transplanted rice (*Oryza sativa* L.). The experiment was laid out in a 3 time replicated randomized block design. Treatments included 7 methods of establishment, viz. puddled transplanting at 20 cm × 20 cm (control), unpuddled transplanting at 20 cm × 20 cm, puddled transplanting at 25 cm × 20 cm with conoweeding twice, unpuddled transplanting at 25 cm × 20 cm with conoweeding twice, double-square transplanting with conoweeding twice (25/15cm), ridge and furrow method of transplanting (ridge 20 cm and furrow 25 cm) and transplanting in wide furrow (wide furrow 35 cm and ridge 25 cm). All the growth parameters and yield attributes like panicles/m² (258), filled grains/m² (33,789) and filled grain weight/m² (841g) as well as yield were significantly improved by different crop-establishment methods. The highest grain yield (6.7 t/ha) was recorded in double-square transplanting. Ridge and furrow transplanting and wide furrow transplanting saved 32.9% irrigation water as compared to the all puddled treatments. The highest irrigation water-use efficiency was noticed in ridge and furrow method of transplanting (123 kg/ha-cm).

Key words: Crop-establishment methods, Conoweeding, Irrigation water-use efficiency, Rice

India is the second largest producer of rice in the world, having an area of 43.0 million ha with 112.0 million tonnes production (Pathak *et al.*, 2019). Rice is a water-loving crop and consumes about 50% of total freshwater of the world. Puddled transplanting is the ruling method of rice production in India. It is estimated that, 3,000–5,000 litres water is required to produce 1 kg rice by conventional puddled method (Satyanarayana *et al.*, 2007). Puddling of soil consumes about 200–250 mm water, equivalent to 17% of the total water use by rice (Mahajan *et al.*, 2011). Puddling also destroys soil aggregates and creates a plough pan that impedes root penetration for following crops (Haque *et al.*, 2016). In spite of all such issues, rice cultivation is bound to continue, as it is a staple food for huge chunk of world population. So development of alternate rice-establishment techniques needs to be emphasized to save water and improve upon the issues being encountered

with the conventional method of rice cultivation. Establishment method in rice significantly affects yield, water consumption, cost of cultivation and soil conditions. Although direct seeding of rice (under upland and puddled conditions) has low water needs, but due to high infestation of weeds, low plant population and iron deficiency, transplanted rice still has an edge over direct seeding of rice. Considering the problems associated with conventional mode of cultivation there is urgent need of alternative establishment methods for transplanted rice which is devoid of puddling and consumes less irrigation water.

Generally, for rice transplanting, puddling is considered essential to curtail the percolation losses. However, with improved management approaches, transplanting has been found equally successful without performing puddling operation. Yadav *et al.* (2014) observed higher water productivity (0.47 kg/m³) with unpuddled transplanted rice than puddled transplanted rice (0.36 kg/m³) with non-significant variation in grain yield. Transplanting of rice on raised beds has also shown great promise in sustaining the crop productivity and saving of irrigation water. Bhuyan *et al.* (2016) reported that, raised bed planting of *boro* rice saved irrigation water by 35% as well as increased the irrigation efficiency. Rice has surficial roots, which can be manipu-

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lated to improve nutrient and water uptake. Conoweeder which trims the roots of rice and also incorporates the weeds in to the soil can be a promising option in this regard. Poonam *et al.* (2016) observed better growth rate, yield attributes and significantly higher yield under conoweeded plots when compared with manual weeding and chemical weed-control methods. Keeping these facts in consideration, present investigation was undertaken to find out the suitable alternative establishment techniques for cultivation of transplanted rice.

The field experiment was carried out at the Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29°N, 79.5°E and 243.83 m above mean sea-level), Uttarakhand. Soil was sandy loam in texture, categorized as medium in organic carbon (0.67%), high in available P, low in available N and high in available K. Soil reaction was neutral (pH 7.1). The total available soil water was 12.1% with field capacity moisture of 20.1% and permanent wilting point moisture 8.0%. The total rainfall received during the crop season was 1,364.1 mm. The maximum amount of rainfall (504.6 mm) was received in July. The experiment comprising 7 treatments, *viz.* puddled transplanting at 20 cm × 20 cm (control), unpuddled transplanting at 20 cm × 20 cm, puddled transplanting at 25 cm × 20 cm with conoweeding twice, unpuddled transplanting at 25 cm × 20 cm with conoweeding twice, double-square transplanting with conoweeding twice (plant spacing 15 cm followed by 25 cm in both the directions), ridge and furrow method of transplanting (ridge 20 cm and furrow 25 cm) and transplanting in wide furrow (wide furrow 35 cm and ridge 25 cm) was laid out in a randomized block design, replicated thrice. Rice variety 'Narendra Dhan 359' was used in the present study. The rice seedlings were produced on a bed size of 1.0 m × 10.0 m with wet-bed method on 30th May, while in main field seedlings were transplanted on 21st June. Crop was harvested on 14th October. The field was harrowed and cross-harrowed twice in all puddled treatments, while thrice in all unpuddled treatments. For puddling under wet conditions, the soil was ploughed twice with spade and then leveled. It was followed by planking using a small wooden plank to smoothen the land surface. In unpuddled transplanting treatments, simply the plots were leveled without tilling after filling the water under wet condition. In ridge and furrow transplanting and wide furrow transplanting, ridges were made with small-size spade under dry condition. In double-square transplanting, plant spacing was 15 cm followed by 25 cm in both the directions thus leaving 25 cm spacing on both sides for conoweeding. In ridge and furrow method of transplanting, the size of ridge was 25 cm and that of furrow 20 cm. The planting was done in mid of

slope of the ridge. In wide furrow planting, the ridge size was 25 cm and that of furrow 35 cm and the rice seedlings were planted in the mid of the slope of the ridge as well as in center of the wide furrow. Twentytwo days old seedlings were transplanted @ 2 seedlings/hill. A week after transplanting, gap filling was done by planting seedlings from the same nursery to maintain optimum plant population. After transplanting, irrigation was applied on common dates to all the treatments, *i.e.* 2 days after disappearance of surface water in conventional puddle-controlled plots. The irrigation depth varied for seedling transplanting among different treatments. It was 10 cm for puddled plots, 8 cm for unpuddled plots and 7 cm for ridge and furrow systems. The depth of irrigation was 6 cm in flat-bed plots and 4 cm in ridge and furrow and wide furrow transplanting plots applied through a plastic pipe after measuring the discharge rate. Total 12 irrigations were given during the crop-growing period. Total irrigation depth is presented in Table 3. The crop was uniformly fertilized with 120 kg N + 26.4 kg P + 33.3 kg K + and 25 kg zinc sulphate /ha. Nitrogen, phosphorus and potassium were supplied through urea (46% N), NPK (12-32-16), muriate of potash (60% K₂O) and zinc sulphate heptahydrate (21% Zn). Half dose of nitrogen and entire amount of phosphorus, potassium and zinc sulphate was applied uniformly as basal before transplanting. In ridge transplanting treatments, basal fertilizer was applied in flat fields under dry conditions and then ridge and furrows were made. The remaining nitrogen was top dressed in 4 equal splits at 7, 25, 45 and 60 days after transplanting (DAT). Weeds were managed by applying pretilachlor @ 0.75 kg/ha at 2 days after transplanting in all the plots. Conoweeder was used twice at 15 and 25 days after transplanting only in rows direction. Except conoweeding plots, hand-weeding was done to remove the second flush of the weeds. Stem-borer was controlled by application of Cartap hydrochloride @ 25 kg/ha at 10 DAT and spray of Monocrotophos (2 ml/litre) at 45 DAT. Further, during panicle initiation/ emergence, leaf-streak disease was controlled by foliar application of copper oxychloride @ 500 g/ha.

Biometric observations, *viz.* plant height, shoot dry matter and number of tillers/m² were recorded 50 days after transplanting. The plant height was recorded at 10 tagged plants from the ground level to the tip of the top-most panicle. Total number of tillers was also counted on tagged hills and the values were averaged and multiplied by total number of hills in 1 m² area to express it in number of tillers/m². To record shoot dry matter, randomly 4 hills from sample row were clipped just above the ground level with the help of sickle. After sun drying for 3–4 days, these were kept in plant direr at 65 ± 5 °C temperature till the samples attained a constant weight and then average

weight was multiplied with total hills in 1 m² area.

For recording root-dry matter, 1 hill from second row from both sides of the plot was dugout separately up to a depth of 15 cm along with soil mass with the help of core sampler of diameter 10 cm, as the maximum root activity of rice (shallow rooted crop) occurs in top layer of soil. Soil mass was removed under running water and after thorough cleaning the roots were cut-off from the shoots. Roots were dried in oven at 65 ± 5°C until a constant weight was obtained. Then, oven-dry weight of roots was recorded and average root dry weight was calculated. Average root-dry weight was multiplied by total number of hills in 1 m² area to express it in g/m². Root-weight density was calculated by dividing root dry weight by volume of core. At maturity, 10 representative panicles randomly selected from marked plants were used for estimation of yield attributes. After leaving the border rows and plant sampling area, the net plot area was used for yield estimation. Harvest index (HI) was calculated as:

$$HI (\%) = \frac{\text{Grain yield (kg/ha)}}{\text{Total biological yield (kg/ha)}} \times 100$$

Total irrigation depth was calculated by summing up the total amount of irrigation water applied in each treatment. Water saving was calculated against conventional method of puddled transplanting. Irrigation water-use efficiency (IWUE) was calculated as:

$$IWUE \text{ (kg/ha - cm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total irrigation applied (cm)}}$$

Plant-growth parameters, viz. plant height, tillers/m², shoot-dry matter/m², root-dry matter/m² and root weight density, were significantly affected by crop-establishment methods (Table 1). The maximum plant height (82.3 cm) was observed when rice was transplanted in puddled condition at 25 cm × 20 cm followed by conoweeding operation. It was at par with unpuddled transplanting at 25 cm × 20 cm with conoweeding (81.0 cm) and double-square planting (79.0 cm). More plant height in widely spaced

treatments may be attributed to less competition for nutrient, moisture and space.

The number of tillers/m² was the highest in double-square transplanting treatment (417/m²). It was significantly superior to ridge planting (376/m²) and wide furrow transplanting (345/m²). Increase in number of tillers with close spacing was also reported by Reuben *et al.* (2016). It might be because in wider spacing there is less competition for nutrients, air and light which created a better environment for plant growth. Widely spaced treatments and double-square treatment produced more number of tillers owing to conoweeder operation which promotes healthy growth of the root-system and improves root growth leading to better moisture and nutrient uptake. The lowest number of tillers/m² was obtained in wide furrow transplanting (345/m²). In ridge and furrow transplanting and wide furrow treatment, the seedling establishment took relatively more time owing to non saturated conditions. In wide furrow, the growth remained poor during the entire season due to removal of top soil from the furrow and closer spacing among the rows (average 15 cm).

The maximum plant dry matter/m² was obtained from double-square method (289 g/m²). It was significantly higher than ridge planting (238.8g/m²) and transplanting in wide furrow (205.9g/m²), but statistically at par with rest of the treatments. It was probably due to relatively higher plant height (79.0 cm) as well as number of tillers (417/m²) under double-square transplanting. Further, better root growth in all conoweeded plots increased the plant height, tillers/m², which subsequently led to more dry-matter accumulation in shoot².

The highest root dry matter/hill was obtained under puddled transplanting at 25 cm × 20 cm (1.68 g) which was statistically at par with unpuddled transplanting at 25 cm × 20 cm with conoweeder (1.63 g). It can be attributed to higher availability of space coupled with use of conoweeder. Conoweeder-treated plots produced heavier roots due to vigorous growth of roots as conoweeder cuts

Table 1. Shoot and root growth parameters of rice as affected by different crop-establishment techniques at 50 days after transplanting

Treatment	Plant height (cm)	Tillers/m ²	Shoot dry matter (g/m ²)	Root dry matter (g/hill)	Root dry matter (g/m ²)	Root weight density (g/cm ³ of soil)
Conventional transplanting	76.5	410	257.6	1.33	33.10	1.30
Unpuddled transplanting	77.3	396	256.9	1.35	33.79	1.32
Puddled transplanting at 25 cm × 20 cm + conoweeding	82.3	400	279.1	1.68	33.59	1.65
Unpuddled transplanting at 25 cm × 20 cm + conoweeding	81.0	405	272.9	1.63	32.59	1.60
Double-square planting (25/15 cm)	79.0	417	289.0	1.44	35.96	1.41
Ridge and furrow (20/25 cm)	78.0	376	238.8	1.46	32.48	1.43
Wide furrow planting (35/25 cm)	73.6	345	205.9	1.18	29.41	1.14
SEM±	1.4	10.7	11.7	0.044	1.0	-
CD (P=0.05%)	4.2	38	36.5	0.13	3.1	-

the old roots and encourages the growth of new roots. Increased soil aeration in these treatments further led to favourable environment for root growth. Conoweeder was also used in double-square method, which produced more root dry matter/hill than rest of the treatments, but magnitude of increase was non-significant. Rice grown under double-square pattern got lesser space than other 2 conoweeded treatments, thus root-dry matter/hill noted was lower. The root-dry matter/m² was found maximum with double-square method which was significantly higher than puddled transplanting at 25 cm × 20 cm and unpuddled transplanting at 25 cm × 20 cm. The highest root-dry matter (35.96 g/m²) in double square planting was due to better root growth per hill coupled with higher population (25 hills/m²). It can be inferred that more number of hills/m² in double-square method compensated for decrease in root-dry matter/hill. The highest root-weight density was observed in puddled transplanting (25 cm × 20 cm) with conoweeding, while the lowest was observed in wide furrow transplanting.

Yield attributes like panicles/m², filled grains /m², filled grain weight/m², unfilled grain /m² and unfilled grain weight/ m² were found to be the maximum in double-square transplanting (Table 2). Panicles/m² and filled grains/m² were statistically similar to puddled transplanting (25 cm × 20 cm) with conoweeding and unpuddled transplanting (25 cm × 20 cm) with conoweeding. Higher number of panicles/m² in widely spaced conoweeded plots may be attributed to higher tiller production; however, panicles/m² in conventional puddle transplanting were also at par with widely spaced conoweeded treatments. Significantly higher number of grains/m² in widely spaced conoweeded treatments can be attributed to more dry matter in these treatments during tillering stage. Chen *et al.* (2012) reported positive linear relationship between total dry matter during tillering stage and grain number/m². Filled grain weight/m² in double-square transplanting was significantly higher than unpuddled transplanting and wide furrow

transplanting but at par with rest treatments. There was no significant difference in unfilled grain numbers/m², unfilled grain weight/m², panicle length and 1,000-grain weight (Table 2). The maximum panicle length was observed for unpuddled transplanting (25 cm × 20 cm) with conoweeding and the minimum in wide furrow transplanting. Small panicles under wide furrow transplanting might be due to the less height of plants which might have resulted in less interception of solar radiation. The highest 1,000-grain weight was observed for puddled transplanting (25 cm × 20 cm) with conoweeding and the lowest for wide furrow transplanting. In wide furrow transplanting, less accumulation of dry matter might have caused poor grain size and ultimately resulted in the lowest 1,000-grain weight.

The highest grain yield was recorded with double-square planting of rice (6.7 t/ha), followed by puddled transplanting at 25 cm × 20 cm with conoweeding (6.6 t/ha). The grain yield is an outcome of number of productive tillers and grain weight per effective tiller. In the present study, both these parameters were favourably improved by conoweeder and wider spacings. The maximum grain yield in double-square treatment may be attributed to use of conoweeder along with optimum plant population. Since conoweeder helps in proliferation of roots which might have helped in better nutrient availability, consequently resulted in higher grain yield. Positive impact of conoweeder use on yield has been reported by Poonam *et al.* (2016). Transplanting of rice in wide furrows resulted in the lowest grain yield (5.6 t/ha). Lower grain yield in wide furrow transplanting may be attributed to poor growth and yield parameters. Ridge transplanting and conventional transplanting had a meager difference (3.1%). Non-significant yield difference between these treatments is in conformity with Sandhu *et al.* (2012). The highest straw yield was recorded with double-square transplanting, which was significantly higher than ridge and furrow transplanting and wide furrow transplanting. Harvest index did not vary

Table 2. Yield attributes of rice as affected by different establishment techniques

Treatment	Panicles/ m ²	Filled grains/ m ²	Filled grain weight (g)/m ²	Unfilled grains/ m ²	Unfilled grain weight (g)/m ²	Panicle length (cm)	1,000-grain weight (g)
Conventional transplanting	241	31,037	780	5,895	65.3	30.2	25.8
Unpuddled transplanting	234	29,851	733	5,023	56.2	29.8	25.2
Puddled transplanting at 25 cm × 20 cm + conoweeding	245	33,043	818	5,388	61.5	30.3	26.8
Unpuddled transplanting at 25 cm × 20 cm + conoweeding	244	32,530	795	6,245	76.8	30.9	26.6
Double square planting (25/15cm)	258	33,789	841	6,774	83.7	30.2	26.0
Ridge and furrow (20/25cm)	236	30,379	778	6,054	74.1	30.5	26.4
Wide furrow planting (35/25 cm)	208	26,301	657	5,658	71.4	29.2	24.6
SEm±	5.33	571.4	23.0	357.2	5.82	0.41	0.94
CD (P=0.05)	17	1,780	72	NS	NS	NS	NS

Table 3. Yields and water-use parameters of rice under different establishment techniques

Treatment	Yield (t/ha)		Irrigation depth (m ³)	Irrigation water saving (%)	IWUE (kg/ha-cm)
	Grain	Straw			
Conventional transplanting	6.5	7.3	7,600	–	85.2
Unpuddled transplanting	6.5	7.1	7,400	2.6	87.3
Puddled transplanting at 25 cm × 20 cm + conoweeding	6.6	7.2	7,600	–	87.2
Unpuddled transplanting at 25 cm × 20 cm + conoweeding	6.5	7.1	7,400	2.6	87.5
Double square planting (25/15 cm)	6.7	7.3	7,600	–	87.9
Ridge and furrow planting (20/25 cm)	6.3	6.7	5,100	32.9	123.0
Wide furrow planting (35/25 cm)	5.6	5.9	5,100	32.9	108.9
SEm±	0.17	0.17	–	–	–
CD (P=0.05)	0.52	0.54	–	–	–

IWUE, Irrigation water-use efficiency

significantly among the treatments (Table 3).

Ridge and furrow transplanting method resulted in the highest irrigation water-use efficiency (123 kg/ha-cm) followed by wide furrow transplanting (108.9 kg/ha-cm). Ridge and furrow transplanting gave good yield even with less amount of water (5,100 m³), thus resulted in the maximum irrigation water-use efficiency. The lowest irrigation water-use efficiency was observed in conventional puddled transplanting, as it needed more amount of irrigation water than other puddled treatments but had relatively lower yield. In comparison to puddled transplanting, irrigation water saving was observed in unpuddled transplanting to the extent of 2.6 and 32.9% in ridge transplanting and wide furrow transplanting (Table 3). Naresh *et al.* (2014) observed that, rice transplanting on beds resulted in statistically similar yield with conventional transplanting, despite of increase in water productivity in bed transplanting (0.222 kg/m³) than conventional transplanting (0.199 kg/m³).

Thus, it can be concluded that among flatbed treatments, double-square transplanting recorded the highest grain yield. Ridge transplanting (20/25 cm) is the most water-efficient production system. Unpuddled transplanting can be next suitable option for water saving.

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