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Effect of crop establishment methods on weed dynamics and productivity of rice under puddled condition

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Abstract
To study the effect of different crop establishment methods on weed dynamics, productivity and economics of rice, the experiment was conducted at Birsa Agricultural University, Ranchi, Jharkhand during *kharif* season, 2015. Results revealed that conventionally transplanted (31.48 m^{-2}) and drum seeded rice (34.33 m^{-2}) had similar weed density which were significantly lower than rice established through broadcasting of dry seeds (45.18 m^{-2}) and that of sprouted seeds (42.13 m^{-2}) whereas conventional transplanting was significantly 29.4% lower than mechanical transplanting. Conventional transplanting recorded minimum weed dry matter (187.08g/m^2) and was significantly lower by 18.5, 15.9 and 15% than broadcasting of sprouted seeds, broadcasting of dry seeds and mechanical transplanting, respectively. Conventional transplanting recorded highest grain and straw yield (4.42 and 6.84, respectively) which was on par with drum seeding of sprouted seeds and mechanical transplanting while B: C ratio (2.34) under drum seeding was significantly higher having edge by 20.6, 23.8, 30 and 55% over broadcasting of sprouted seeds, broadcasting of dry seeds, conventional transplanting, and mechanical transplanting, respectively.

Keywords: Weeds, rice, drum seeding, weed density, transplanting

Introduction
Rice (*Oryza sativa* L.), belonging to Gramineae family is normally cultivated as an annual crop and is consumed as staple food by more than 70 percent of the world's population (Yadav and Singh, 2006) [18, 13, 17]. In India, 42 million hectare area was under rice cultivation during 2015-16, accounting for about 103.61 million tonnes of the country's total foodgrain production (Anonymous, 2016) [1]. Rice is established countrywide by adopting the traditional method of transplanting, which is a cumbersome practice involving high water and labour requirement with lots of drudgery caused to women. However, in order to meet the demand of staple food of Jharkhand, rice was cultivated over 1.49 million hectares with a productivity of 2.57 t/ha during 2014-15 (Anonymous, 2015) [1]. Rice is largely grown in Jharkhand by transplanting seedlings under puddled soil, which is also labour, water, and energy intensive. This causes the cultivators to shift to another method of rice establishment in form of direct seeding. Although rice established through direct seeding is advantageous over transplanting in curtailing the cost of cultivation by reducing the labour cost, water usage, and conserving energy but weeds are the major threats which may ultimately reduce the yield of direct seeded rice up to 90% depending upon the severity of weed infestation (Yadav *et al.* 2009) [18]. The pre germinated seeds of crop and already existed weed seeds in soil weed seed bank grow simultaneously in direct seeded wet land rice, resulting in competition for resources like moisture, nutrients, light and space. This adversely affects the crop growth and accounts for yield loss on large scale. Rice is reported to be one of the highly weed invaded crop and is ranked as second highest pesticide consuming crop after cotton. Most of the introduced herbicides are selective and are specified to control only one or two types of weeds. Weeds have variable growth habits and life cycles and they even vary under different cultural practices. Therefore, the use of chemicals only cannot effectively control weeds in all situations (De Datta and Herdt, 1983) [4]. Hence, the present investigation was undertaken to observe the efficacy of different rice establishment techniques under puddled condition on weed density and weed dry matter at all the growth stages while bispyribac sodium was used as post- emergence herbicide in all the treatments to control the weed population.

Methodology
Field experiment was conducted at Birsa Agricultural University, Ranchi (Jharkhand) during *kharif* season of 2015 to study the influence of different establishment techniques on weed

dynamics, yield and economics of rice under puddled condition. The soil of experimental Site belongs to "Red-yellow-light grey catenary soil association group" representing the major soil group of Chhotanagpur plateau. The soil was clay loam with 38.1% sand, 30.6% silt and 31.3% clay. The soil was slightly acidic in reaction (pH 6.1), low in organic carbon (3.6 g/kg) as well as in available nitrogen (200.7 kg/ha), high in available phosphorus (33.54 kg/ha) and medium in potassium (187.04 kg/ha). The experiment was laid out in Randomized Block Design with four replication and the rice variety used was 'Naveen'. The treatments comprised of five different rice establishment methods – conventional transplanting (seedlings raised by wet nursery method, 2-3 seedlings/hill (21 days old) were transplanted at 20 x 15 cm spacing), mechanical transplanting (seedlings prepared on mat type nursery, 4-5 seedlings/hill (15 days old) were transplanted at 25 x 15 cm spacing), drum seeding of sprouted seeds (20 cm row spacing), broadcasting of sprouted seeds and broadcasting of dry seeds and Nominee Gold (Bispyribac-Na) was applied @ of 25 g/ha (10% SC) at 20 days after sowing/transplanting in the experimental plots as post emergence herbicide to control the weed population. The following formula was used to compute the dose of herbicide.

$$Q = \frac{R - 100}{P} X \frac{A}{1000}$$

Where, Q= Quantity of herbicides formulation required (g/ha)
R=Recommended rate of herbicide (g/ha)
P=Percentage of active ingredient (a.i.) in the formulated product
A=Area (ha)

Direct seeding was done on the same day i.e. the day seeds were placed in nursery. Puddling was done 5 days before as well as on the day of sowing/transplanting. Uniform fertilization (120: 60: 40 kg N: P_2O_5: K_2O / ha) was done for all the rice establishment methods through urea, diammonium phosphate and muriate of potash, respectively. Whereas, in nursery fertilizers was applied @ 12: 6: 4 kg N: P_2O_5: K_2O /1000 sq m. In case of conventional and mechanical transplanting, gap filling was done wherever required with left over seedlings. Irrigation were applied at the appearance of hair like cracks at the soil surface in direct seeded rice while submergence was maintained in transplanted rice throughout the crop period except 15 days before harvesting. The weed population in each plot was studied at 30, 60 and 90 days after sowing by randomly placing the quadrate of 25 x 25 cm at two spots. Weeds within the quadrate were counted and the observation thus made was computed to obtain weed density per m^2. The weed samples taken for population count were also used for weighing dry matter (g/m^2) at 30, 60 and 90 days after sowing. Samples were then sun dried for 2-3 days to remove any excess moisture and then kept in oven at 65 ºC ± 5 ºC. After complete oven drying the dry weight was recorded with an electronic balance and converted into g/m^2. All the data on yield and economics were recorded as per the standard methods.

Results and Discussion

Density and dry matter of weeds

Rice establishment methods under puddled and the use of herbicide had a significant impact on weed density and weed dry matter at all the growth stages (Table-1). Weed density increased with crop age and the maximum weed density was recorded at 90 days after sowing (DAS). At 30 and 60 DAS, rice established by conventional transplanting (10.45 m^{-2} and 22.25 m^{-2}, respectively) and drum seeding of sprouted seeds (11.65 m^{-2} and 24.95 m^{-2}, respectively) had minimum weed density per unit area and were significantly lower than broadcasting of either dry seeds (26.15 m^{-2} and 36.65 m^{-2}, respectively) or sprouted seeds (20.8 m^{-2} and 34.23 m^{-2}, respectively), and mechanical transplanting (15.33 m^{-2} and 35.40 m^{-2}, respectively). However, at 90 DAS, conventionally transplanted rice having minimum weed density (31.48 m^{-2}) was significantly 43.5, 33.8 and 29.4% lower than broadcasting of dry seeds, broadcasting of sprouted seeds, and mechanical transplanting respectively. Whereas drum seeded rice (34.33 m^{-2}) also recording minimum weed density was 31.6 and 22.7% lower than broadcasting of dry seeds and that of sprouted seeds, respectively. While recording the weed dry matter at 30 and 60 DAS, it was observed that the crop established through conventional transplanting and drum seeding of sprouted seeds accumulated lowest weed dry matter (20.15 g m^{-2} and 23.50 g m^{-2}, respectively) and were significantly lower than broadcasting of dry seeds (32.58 g m^{-2}) and mechanical transplanting (28.42 g m^{-2}). However, weed dry matter under drum seeding was similar to broadcasting of sprouted seeds (27.33 g m^{-2}). In contrast to this, at 60 DAS conventionally transplanted and drum seeded rice accumulated lowest weed dry matter (61.83 g m^{-2} and 67.38 g m^{-2}, respectively) and were significantly lower than broadcasting of sprouted seeds (91.38 g m^{-2}), broadcasting of dry seeds (88.35 g m^{-2}) and mechanical transplanting (88.33g m^{-2}). Conventional method of transplanting at 90 DAS, recorded the minimum dry matter of weed (187.08 g m^{-2}) and was significantly lower by 18.5, 15.9 and 15% than broadcasting of sprouted seeds, broadcasting of dry seeds and mechanical transplanting, respectively. Further, weed dry matter accumulated under rice established through drum seeding of sprouted seeds (201.59 g m^{-2}) was on par with all the establishment methods tested. Under submerged condition transplanting rice seedlings of 21 days was stouter and stronger in suppressing weed population as compared to 15 days aged seedlings in mechanical transplanting which in turn reduced the weed dry matter accumulation in case of conventional transplanting. Also the desired spacing in drum seeded rice produced more tillers per unit area, suppressing the weed population to thrive, resulting in reduced weed density and weed dry matter. Whereas, the total weed density and dry weight of weeds were higher under direct seeded rice (sprouted and dry seeds) under puddled condition which might be due to failure to maintain flooded conditions in field and non submergence of crop in the initial stages, as crop and weeds germinate simultaneously so competition exists (Parameshwari and Srinivas, 2014) [15]. This result is also in conformity with Chander and Pandey, (2001) [3]; Subbulakshmi and Pandian, (2002); Singh *et al*. (2006) [18, 13]; Yadhav and Singh, (2006) [18]; Subramanayam *et al.* (2007) [15] and Talla and Jena, (2014) [16].

Yield

Grain and straw yield differed significantly by various rice establishment methods and use of bispyribac-sodium under puddled soil except the harvest index of rice. Rice established through conventional transplanting, drum seeding and mechanical transplanting had similar grain and straw yield (Table 2). Conventional transplanting (44.18 q ha^{-1}) had edge by 19 and 21%, respectively over broadcasting of either sprouted (37.13 q ha^{-1}) or dry seeds (36.50 q ha^{-1}) whereas

drum seeding of sprouted seeds (43.70 q ha^{-1}) was significantly higher by 17.7 and 19.7%, respectively over broadcasting of either sprouted (37.13 q ha^{-1}) or dry seeds (36.50 q ha^{-1}) in grain production. Further, among the direct seeded rice, broadcasting of dry seeds being similar to broadcasting of sprouted seeds recorded the lowest grain yield. The comparatively low paddy yields in broadcasting of either sprouted or dry seeds as compared to transplanting could have been due to uncontrolled growth of weeds resulting in crop-weed competition (Dingkuhn *et al*. 1991) [5]. whereas, transplanting method and drum seeding recorded significantly higher paddy yield because desired planting distance ensures air circulation, water and light which are basic factors necessary for photosynthesis. Further, proper spacing increases tiller and yield (Baloch *et al*. 2002) [2]. The beneficial effects of uniform stand establishment, ideal rhizosphere environment and weed free condition might have contributed to higher nutrient uptake which resulted in the production of greater source and efficient translocation of photosynthates into the larger sink as indicated by higher yield attributes. Lack of uniformity in distribution and initial setback in taking early lead in the growth due to excessive weed infestation might be the probable reasons for poor performance of rice established by broadcasting seeds (Kanthi *et al*. 2014). This finding also agrees with Johnkutty *et al*. (2002) [8]; Singh and Singh, (2003) [12]; Singh *et al*. (2007 b) [11]; Mankotia *et al*. (2009) [9]. In case of straw yield, crop established through conventional transplanting (68.43 q ha^{-1}) and drum seeding of sprouted seeds (67.90 q ha^{-1}) showed significant edge by 15.3 and 14.5%, respectively over broadcasting of dry seeds (59.32q ha^{-1}). Further, rice established through broadcasting of dry seeds being similar to that of sprouted seeds recorded the minimum straw yield. Transplanting method of establishment recorded significantly higher straw yield compared to direct sowing of rice under puddled condition due to less crop weed competition in transplanting method which led to taller plants, more number of tillers and dry matter production which in turn resulted in higher straw yield (Parameshwari and Srinivas, 2014) [10]. Subramanyam *et al*. (2007) [15] also reported similar results. However, there was no significant effect of various establishment methods on the harvest index of rice. This confirms the findings of Jha *et al*. 2011 [6].

Economics

Rice crop established by drum seeding of sprouted seeds (Rs.49293.61 ha^{-1}) and conventional transplanting (Rs. 45704.42 ha^{-1}) had similar net return. Whereas, drum seeded rice was significantly higher by 23.9, 26.9 and 27.1% over broadcasting of sprouted seeds (Rs. 39769.40 ha^{-1}), mechanical transplanting (Rs.38844.37 ha^{-1}) and broadcasting of dry seeds (Rs.38778.40 ha^{-1}), respectively. The higher net return under drum seeded and conventionally transplanted rice might be due to higher grain and straw yield of the crop owing to low weed infestation due to desired spacing. Drum seeding of sprouted seeds gave significantly higher benefit: cost ratio (2.34) and showed significant edge of 20.6, 23.8, 30 and 55% over broadcasting of sprouted seeds (1.94), broadcasting of dry seeds (1.89), conventional transplanting (1.80), and mechanical transplanting (1.51), respectively.

Conclusion

In view of water and labour shortages, research undertaken has shown that rice can be established well by direct sowing into the main field under puddled condition rather than raising nursery and then transplanting. Direct seeding with drum seeder is a successful method of cultivation which not only saves labour but also aids in water conservation, and reports less weed infestation thereby increasing the water use efficiency and ultimately enhances the productivity. Comparing various establishment methods of rice it was found that crop established by conventional transplanting produced higher grain yield, straw yield and lower weed density and weed dry matter, which was statistically similar to that of direct sowing of sprouted seeds under puddled conditions by drum-seeder. Although transplanting has been a major traditional method of rice establishment in Asia, the economic factors and recent changes in rice production technology have enhanced the desirability of direct- seeding of rice. Therefore, it can be concluded that the desired spacing and use of bispyribac-sodium, a post emergence herbicide in drum seeding of sprouted seeds suppressed the weed growth as compared to other direct seeding methods of rice establishment, giving higher benefit : cost ratio, hence for higher productivity, establishment of rice through drum seeding can be a feasible alternative of conventional transplanting.

Table 1: Density of weeds and weed dry matter in rice as influenced by rice establishment methods

Treatments	Weed density(No./m^2)			Weed dry matter(g/m^2)		
	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
T_1 Conventional Transplanting	10.45	22.25	31.48	20.15	61.83	187.05
T_2 Mechanical Transplanting	15.33	35.40	40.73	28.42	88.33	215.08
T_3 Drum seeding of sproutedseeds	11.65	24.95	34.33	23.50	67.38	201.59
T_4 Broadcasting of sproutedseeds	20.83	34.23	42.13	27.33	91.38	221.26
T_5 Broadcasting of dry seeds	26.15	36.65	45.18	32.58	88.35	216.85
SEm ±	0.96	1.72	2.50	1.47	3.27	8.61
CD (P=0.05)	2.94	5.29	7.67	4.51	10.05	26.42

Note: Bispyribac –sodium @ 25 g/ha (10% SC) used as herbicide in all treatments

Table 2: Yield, Harvest index, Net return and Benefit cost ratio as influenced by rice establishment methods under puddled condition

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index %	Net return (Rs./ha)	Benefit: cost ratio
Conventional Transplanting	4.42	6.84	39.19	45704.42	1.80
Mechanical Transplanting	3.98	6.38	38.38	38844.37	1.51
Drum seeding of sprouted seeds	4.37	6.79	39.13	49293.61	2.34
Broadcasting of sprouted seeds	3.71	6.02	38.18	39769.40	1.94
Broadcasting of dry seeds	3.65	5.93	38.13	38778.40	1.89
SEm ±	1.90	2.62	0.60	2919.33	
CD (P=0.05)	5.82	8.05	NS	8958.96	0.39

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