Effects of different planting methods on rice (*Oryza sativa* L.) crop performance and cost of production

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ABSTRACT

A field experiment was conducted at ARDC-Samtenling research station in 2017 to study the performance of rice using different rice planting methods. Four planting methods, namely line transplanting, random transplanting, drum seeding and broadcasting were applied on rice variety, Bhur Kambja-I that is currently considered as the best improved variety released for the low altitude rice agro-ecosystem. Rice cultivation in general and transplanted rice in particular is beset with issues of farm labor shortage and high cost of production in Bhutan. The results of the experiment showed that the planting methods did not have any significant effects on the grain yield and yield components. Grain yields for the different planting methods ranged between 3.10 ton/ha to 4.03 ton/ha. There was also no effect on yield components such as number of productive tillers and filled grains per panicle. However, the planting methods had significant effect on the crop maturity duration by about two weeks. Direct seeded rice matured early (113 days) while transplanting took 123 days. Further, direct seeding using either drum seeder or broadcasting had comparative advantage over transplanted rice in terms of labor requirement and cost of production. The cost advantage was found to be as high as 53% for drum seeding and 42% for broadcasting methods compared against line transplanting method. Based on the study, direct seeded rice could be promoted since it showed potential for promotion.

Keywords: *Agro-ecosystem*; *Crop performance; Grain yield; Planting methods*

1. Introduction

Rice is the staple food for Asia (IRRI 2012) and is also considered as the most important crop for Bhutan. It is the most preferred staple food in Bhutan and the country accords top priority in increasing rice production for food security and rice self-sufficiency. However, Bhutan imports more than 50% of its rice requirement, mostly from India (Chhogyel et al 2015a). The country's production stands at 85,261 ton of rough rice (DoA 2015) while the import rose to 83,640 ton in the same year (PPD 2016). This situation has posed a huge challenge for the Department of Agriculture (DoA) to enhance rice self-sufficiency of 65% by the end of 12 Five Year Plan (FYP) in 2023. Globally, rice is largely grown in irrigated and rain-fed environments either through planting in puddle fields or direct seeded in both wet and dry conditions (GRiSP 2013).

While transplanting is the most common method of production, direct seeding is reported to be picking up worldwide. In Bhutan, farmers transplant rice in terraced fields wherein seedlings are randomly transplanted. The disadvantages of this method are that the crop

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density is not uniform and intercultural operations are inconvenient. The time required for the transplanting, harvesting and other management practices such as weeding is much higher. A shift from traditionally practiced transplanting to direct seeding method of rice cultivation could be one of the solutions to reduce the cost of cultivation. Therefore, considering high labor and management costs, it will be an essential intervention that is required to make the rice cultivation practices attractive. As is reported by the International Rice Research Institute (IRRI) that direct seeding is a low-cost method of rice establishment technology (IRRI, 2006), tapping its advantages and subsequent adoption of the technology is critical when Bhutan is striving to achieve rice self-sufficiency goal.

Bhutan by virtue of its location in rugged Himalayas, opportunity for farm mechanization is limited. Thus, labor shortage is one of the main constraints in rice farming in the country. According to the Agriculture Statistics (DoA 2016), farm labor shortage accounted for 53% of the farming constraints. Reports and field experiences show that fallowing of land in Bhutan mainly results from labor shortages, although there is no scientific study done to establish the fact.

In order to overcome such problems, there is a need to intensify labor saving technologies and farm mechanization where possible. Among the technological options in rice farming, direct seeding has tremendous potential and could be promoted. In Bhutan, majority of rice is transplanted and direct seeding is not popular which could be mainly due to lack of proper scientific experimentation in our situation.

Akhgari and Kaviani (2011) defined direct seeding of rice (DSR) as the process of establishing a rice crop from seeds sown in the field rather than by transplanting rice (TPR) seedlings from the nursery. They reported that the DSR either through dribbling, broadcasting and drum seeding can help rice farming communities bring down the labor cost. The only challenge confronted from using this method is reported to be the weed pressure. But, if weeds are well managed, DSR gives comparable yield to transplanted rice. Johnkutty (2002), through long term experiment proved that direct seeding could be a potential substitute for transplanted rice if proper and weed management techniques were followed. Mann (2007) in Pakistan also obtained rice yield of 3.70 ton/ha in a weed free direct seeded rice trial. Similarly, there are many literatures and studies that mention potential of direct seeded rice (Johnkutty 2002, Manjunatha et al 2009 and Sanusan et al 2010).

While direct seeding could be a potential method of rice production in Bhutan, there is a dearth of information and research in the country. Therefore, in order to promote direct seeding as an alternative method of rice cultivation, a location specific research and data was required. For this, four methods of planting viz. line transplanting, random transplanting, and direct seeding through broadcasting and use of drum seeders were evaluated. The objectives were to compare grain yield from different methods of planting for promotion as technology and to assess comparative advantage of direct seeded rice over transplanted rice in terms of labor cost.

2. Materials and Methods

2.1. Experimental design and materials

The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications at the research station of Agriculture Research and Development Centre, Samtenling, in Sarpang Dzongkhag, Southern Bhutan.

Each plot size measured 8 x 4 m^2 and the test variety used was Bhur Kambja-I. Seed of Bhur Kambja-I was pre-soaked for 24 hours and incubated for 36 hours prior to seeding. From the same pre-germinated seed, nursery for transplantation was raised under wet bed condition. The same pre-germinated seeds were also used for drum seeding and broadcasting. Twenty one days old seedlings were transplanted maintaining 20 x 20 cm plant to plant and row to row distance. A recommended dose of fertilizers at 70:40:30 NPK Kg/ha was applied. Half dose of nitrogen was applied as basal along with full doses of phosphorus and potassium. Another half dose of nitrogen was applied in two splits at active tillering and panicle initiation stages. All intercultural operations such as weed control and irrigation were applied as and when needed. Butachlor @ 1.5 a.i/ha was applied to control grasses and sedges in the initial stage of crop followed by one hand weeding after one month of planting in all the treatments. For labor cost comparison, total man days required from nursery raising till weed management for all the methods were recorded.

2.2. Data gathering

Data from the field were gathered following standard procedures (IRRI 2002) and care was taken to minimize error and bias. The experimental plots were monitored at regular intervals and data for plant height were gathered after flowering, while agronomic parameters such as number of productive tillers, number of filled grains per panicle, panicle length and yields were measured during the harvesting stage.

For planting and weeding time, a stop watch was used to record the timings and for yield analysis, a crop cut was conducted on an area measuring 3x2 m^2. Calculation of grain yield was done following the standard formula and grain yield adjusted to 14% moisture level as given below:

$$\text{Grain yield (ton/ha)} \quad = \frac{Plot\ yield\ (kg) x\ MC\ adj\ x\ 10{,}000}{plot\ size\ x\ 1000}$$

$$\text{Where MC adj} \quad = \frac{100-MC}{100-86}, \text{ and MC= grain moisture at harvest}$$

The research data were compiled in Microsoft excel spread sheet and were analyzed using statistical software ‘STAT-8’. The data were subject to the analysis of variance (ANOVA) at *P 0.05* level of significance for the comparison of treatment means.

3. Results and discussion

3.1.Grain yield and its components

Comparison among the different planting methods of planting rice showed that there was no significant difference in grain yield (P>F = 0.2258) and its yield components (Table 1). Grain yield varied between 3.10-4.03 ton/ha for the different treatments. Similarly, the number of productive tillers and number of filled grains varied between 9 to 12 and 165 to 177, respectively for different planting methods. The panicle length, however, showed significant difference (P>F = 0.00029) among the planting methods. Transplanted rice (line and random planting) gave the maximum length of panicles among the treatments.

Table 1. Effect of different planting methods on grain yield (ton/ha) and its components

Treatments	Grain yield (ton/ha)	Productive tillers/hill	No. of filled grains/panicle	Panicle length (cm)
Drum seeding	3.10a	12.00a	177.00a	22.00a
Broadcasting	3.92a	9.00a	172.00a	22.67bc
Random planting	3.90a	10.00a	165.00a	23.33ab
Line planting	4.03a	12.00a	168.00a	24.00a
P value	0.2258	0.1716	0.8978	0.0029
CV	14.31	14.32	11.64	1.62

3.2. Plant height

The plant height ranged between 117 cm to 120.33 cm among the different planting methods (Figure 2). The two transplanting methods (line and random) resulted in taller plants as compared to direct seeding using drum seeder and manual broadcasting. Mean plant heights in both broadcasting and drum seeding were 117 cm while the plant heights in random transplanting and line planting were 120 and 120.33 cm, respectively.

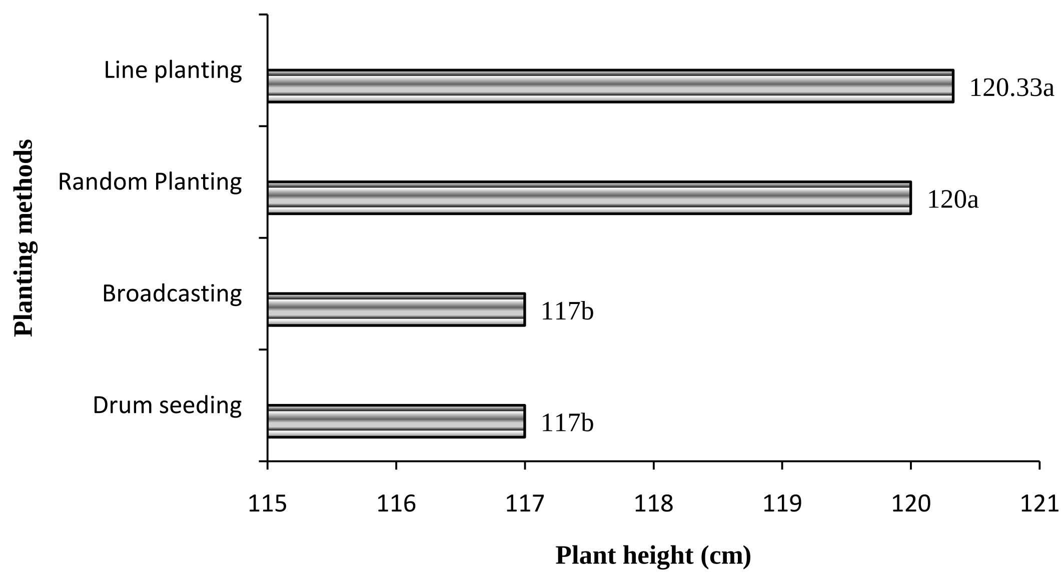

Figure 1. Plant height of rice as affected by different planting methods

3.3. Maturity duration

The test variety Bhur Kambja-I showed significant difference in days to maturity (DTM) using different planting methods. It took 127 days to mature in two transplanted plots while it took only 113 and 114 days in drum seeding and broadcasting, respectively (Figure 3). This difference could have been due to environmental shock imposed from uprooting of the seedlings until crop establishment for the transplanted rice. Overall, the direct seeded and the transplanted rice differed by about two weeks and drum seeded rice took the shortest number of days to mature at 113 days.

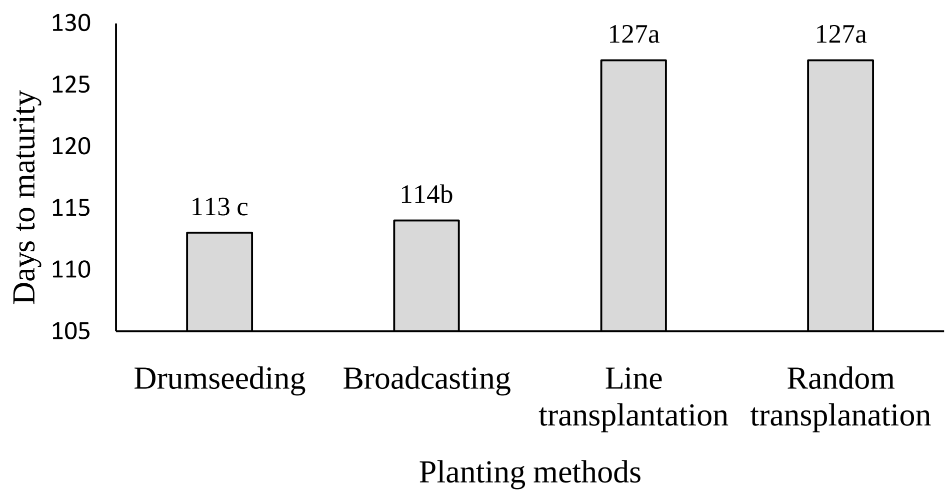

Figure 2. Days to crop maturity as affected by different planting method

3.4. Labor requirement and costs per Acre

The management practices other than seedling preparation and transplanting remain same for all methods. Practices such as seedling thinning and weeding were also taken into account for the cost comparison. In terms of labor requirement, the study showed that there is comparative advantage in direct seeded rice over transplanted rice. The direct seeding method drastically reduced labor requirement from 33 man days in line transplanting and from 29 man days in random transplanting to 15.5 and 19 man days in drum and broadcasting methods of planting, respectively (Table 2). There was higher cost of labor in transplanted rice as compared to the direct seeded rice. The cost of labor for line transplanting was Nu. 11,550/acre while it was Nu. 10,150/acre for random transplanting. Conversely, the labor cost for drum seeding and broadcasted methods were just Nu. 5,425/acre and Nu. 6,737/acre, respectively. Therefore, there is a cost advantage of 12% for random transplanting, 53% for drum seeding and 42% for broadcasting against the line transplanting method.

Table 2. Man-days requirement and cost of labor for different planting methods per acre

Cultivation practices	Different planting methods			
	Line transplanting	Random Transplanting	Drum Seeding	Broadcasting
Nursery development (Man-days)	3	3	0	0
Seedling uprooting (Man-days)	1	1	0	0
Field preparation (Man-days)	3	3	3	3
Transplanting (Man-days)	16	10	0.5	0.25
Seedling thinning (Man-days)	0	0	0	2
Weeding (Man-days)	10	12	12	14
Total labor required (Man-days)	33	29	15.5	19.25
Labor cost (Nu/head)	350	350	350	350
Total costs (Nu)	11,550	10,150	5,425	6,737.50
Percent cost advantage against land transplanting		12%	53%	42%

4. Discussion

4.1. Grain yield and its components

Though the planting methods did not show significant difference in grain yields, line transplanting produced the highest yield of 4.03 ton/ha followed by random transplanting at 3.92 ton/ha and broadcasting at 3.90 ton/ha. Insignificant difference in yield components such as number of productive tillers and number of filled grains per panicle further indicated that planting methods do not affect yield performance of rice. If management practices are applied correctly, a crop of rice could be produced using any methods of planting. This is in agreement with the research conducted by Rana et al (2014) in Bangladesh involving short duration Aman rice. Kumar and Ladha (2011) also reported that rice yields in transplanted and direct seeded rice were almost the same. Insignificant differences in other yield attributes among the different methods of planting further revealed that all methods have potential for sustainable rice production by skipping nursery to transplanting activities. Although not significant, the findings on the highest number of grains per panicle in drum (177) and broadcasted (172) method from this experiment agrees with the finding of Rana et al (2014) and Akhgari et al (2013). Thus, the germinated seeds when sown directly perform well and were comparable to transplanted rice which normally produces higher number of productive tillers. Higher number of productive tillers in transplanted rice could be due to proper spacing and uniformity which is not the case in direct seeded rice. In transplanted rice, there is no overcrowding of seedlings and less weed pressure, thus leading to higher number of tillers. Singh et al (2008) reported that lower number of tillers in direct seeded rice is attributed to higher level of weed pressure as compared to transplanted rice. In all the parameters, the coefficients of variations (CV) were within 15 which are normal for agricultural experiments.

4.2. Plant height

The difference in plant height (cm) among the different planting methods could be attributed to increased crop competition in both direct seeded methods (broadcasting and drum seeding). Taller plants in transplanted rice (120 cm and 120.33 cm) could be due to deeper rooting system as seedlings were firmly planted into the puddled soil. However, in direct drum seeding and broadcasting methods, seeds were sown at the surface thus leading to reduced rooting system. Research by Naresh et al (2013) on direct seeded and transplanting methods by Naresh et al (2013) showed that plants were taller in transplanted rice as compared to direct seeded method.

Plant height in rice is an important agronomic trait and has tremendous effect on the yield potential of the crop. Moreover, it has marked influence over the varietal choice in Bhutan since rice straw is used as off-season cattle feed in winter besides the grain yield. Bhutanese farmers prefer varieties that produce good yield and also more straw for their cattle (Chhogyel et al 2015b). In modern rice variety development, plant height is one of the breeding objectives (De Datta 1981) where rice varieties of shorter height with sturdier culm carrying heavier panicle heads that do not lodge are preferred.

4.3. Maturity duration

The difference in days to maturity among the various methods of planting could be due various factors such as rooting depth, nutrition, weed pressure and inter-crop competition. Longer maturity days for transplanted rice in both random and line planting could be attributed to transplanting shock and recovery. In transplanted rice, the seedlings were uprooted and re-planted thereby directly exposing them to physical stress which requires a week or two to recover and perform normal physiological functions. In direct seeded rice, the seedlings were not disturbed and hence took just 113-114 days to mature. The crop in direct seeded rice establishes earlier as compared to transplanted rice, thus leading to faster physiological maturity since there is no transplantation injury. Overall, the plants showed a difference of 14 days to mature. Similar findings were reported in the review works of Farooq et al (2006a, b; Farooq 2010). It has also been reported that rice matures about 7-10 days earlier and have less methane emissions (Balasubramanian and Hills 2002). Thus, the direct seeded paddy may be harvested early thereby giving time for the following crop.

Crop maturity duration is one of the most important agronomic parameters in all rice ecosystems. For Bhutan, maturity duration is more important since the crop has to fit within a single growing period. Crop growing period in Bhutan's condition is short and therefore has to time it properly to optimize yield potential. Normally, the people prefer medium crop maturity group of 130-160 days for normal season (Chhogyel et al 2013).

4.4. Labor requirement and costs

For the labor requirement and costing analysis, the main field operations until weeding was considered since rest of the practices would involve more or less same labor. The field operations considered for the current study included nursery development, seeding preparation, field preparation (bund plastering and puddling), planting and weeding Among the different methods of planting, line planting required the highest number of labor at 33 man-days followed by random planting at 29 man-days due to additional man power required for nursery, and transplanting operations. In case of direct seeded rice using drum and broadcasting methods, there was no nursery development and thus, no transplanting of seedlings was required. Thus, direct seeding showed drastic reduction in labor requirement. However, direct seeding method specially the broadcasting method showed additional labor requirement for seedling thinning and weeding operation. Overall, transplanting method had higher labor requirement. While there are no literatures or studies on direct seeded rice in Bhutan, studies in other countries have shown that direct seeded rice has a comparative advantage over transplanted rice mainly due to reduction in labor cost (Farooq et al 2010, Gill et al 2014). This led to labor cost difference of Nu. 4,000-6,000 per acre between the transplanted and direct seeded rice. There was also a slight difference in labor cost between line planting and random planting due to additional labor required for guiding with ropes during transplanting. The cost advantage of direct seeding was as high as 53% for drum seeding and 42% for broadcasting method. Gill et al (2014) also reported that direct seeding reduced cost of production by about 9%. Study by Naresh et al (2013) in India also showed that direct seeded rice is more economical than transplanted rice. Further benefit cost ratio of 1.11 was obtained by Yanous et al (2016) who made an economic comparison between direct seeded and transplanted rice involving super basmati rice in Pakistan. This shows that direct seeding method of planting is one potential method of rice production requiring less labor.

5. Conclusion

Based on the findings from on-station research at ARDC, Samtenling (Sarpang), direct seeded rice is a potential method of production for promotion in the country. The crop performance in terms of grain yield and its components including basic agronomic parameters showed that direct seeding method, either through drum seeding or broadcasting is comparable to transplanted rice. The grain yield from different methods of planting ranged between 3.10 ton/ha to 4.03 ton/ha without showing any significant difference. Similarly, there was no difference in yield components, thus, indicating that direct seeding does not reduce grain yield as perceived by many farmers in the country. Based on number of labor required for different cultivation practices, direct seeding was found to be better since it required less labor compared to transplanting. This contributed to reduction in labor cost, thus enhancing profitability of rice farming through direct seeding. Direct seeded rice required just 15 and 19 man-days for the two methods of direct seeding as against 33 and 29 man-days in transplanted rice. Therefore, there is additional cost difference of Nu. 4,000 to 6,000 in transplanted rice. The overall results indicate that the labor intensive and costly method of transplanting could be substituted by direct-seeding without compromising productivity. The research proved that direct seeded rice is worth promoting in the southern rice agro-ecosystem as one of the strategies to overcome labor shortage in rice farming.

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