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Effect of Planting Methods on Grain Yield and Crop Management in Finger Millet

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ABSTRACT

A field experiment on two planting methods (direct seeding and transplanting) in finger millet was conducted using two cultivars; Samtenling Memja 1 (SM1) and IE4425 at the Agriculture Research and Development Centre (ARDC), Samtenling from July to December 2020. The study aimed to determine the best planting method that gave better yield and economic advantage in crop production. The results of the experiment showed that the transplanted finger millet recorded the highest yield (0.81 Mt ha^{-1}) compared to directed seeded (0.65 Mt ha^{-1}) but statistically not significant. There was a percent yield difference of 19.7 % between the two methods. Similarly, there was no significant effect between planting methods and yield components such as plant height, productive tillers, and finger numbers; but there were varietal significant effects on plant height and length of the fingers (P=0.00). However, a significantly shorter maturity duration was observed in direct-seeded millet (120 days) as compared to transplanted millet (126.5 days). Moreover, economic analysis indicates that net returns for direct seeding were considerably greater (>25%) than that of the transplanting method. Based on the study, direct-seeded finger millet could be promoted in farmers' fields considering the economic advantage and early maturity.

Keywords: *Finger millet, Planting methods; Days to maturity; Grain yield; Economic analysis*

1. Introduction

Finger millet (*Eleusine coracana* L) is generally a small-seeded cereal known for its high nutritive value. It is a staple food for the tribal and lower-income groups (Kumar, Tomer, Kaur, Kumar et al., 2018). Generally, finger millet is the only millet that occupies the largest area under cultivation among other small millets. The global millet production was estimated at 28.4 million metric tons in 2019, with India being the largest global producer with 41.0% global market share followed by Africa (FAO, 2019). In Bhutan, millets are cultivated over an area of 7,313.45 hectares (ha) with a production of 1,240.45 Mt and average productivity of 0.0058 Mt ha^{-1} (RSD, 2019). The global recorded accession of finger millet is about 25,707 and Bhutan has around 84, which constitutes 0.33 % of the total accessions (Sood et al., 2016). Even though

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finger millet is categorized as a neglected and underutilized species (NUS) (Chadha & Olouch, 2006; Kahane, Hodgkin, Jaenicke, Hoogendoorn et al., 2013) and it is grown for its superior nutritional properties and minimal inputs (Gupta et al., 2017). A unique feature of finger millet is that it has the highest productivity among millets due to its resilience and adjustability to adverse agro-climatic conditions (Seetharam, 2006) as a result of its C4 photosynthetic pathway (Wafula, Korir, Ojulong, Siambi et al., 2016). It tolerates salinity better than most cereals (CABI, 2003). Finger millets are cultivated for strengthening nutritional security rather than for food security purposes directly (Puranik, Kam, Sahu, Yadav et al., 2017). Globally, finger millets are cultivated both in irrigated and dry land. However, only dryland cultivation is practised in Bhutan hitherto.

Bhutan is a mountainous country where the arable land is only about 2.83%, i.e., 1,08,534 ha from a total area of 38,394 km^2 (RSD, 2019). Farm mechanization is limited and traditional farming still predominates. Traditional farming is laborious and entails more drudgery. Moreover, labour shortage is one of the main farming constraints in the country. According to the report by the Department of Agriculture (DoA, 2016) and Dendup and Chhogyel (2018), about 53% of the farming constraint in Bhutan is accounted for by farm labour shortage. Planting methods vary among farmers according to their choice of where the crop is cultivated. The most common practice is to transplant where nurseries are raised by broadcasting the seeds. The transplanting method is the dominant method of finger millet establishment in all of Asia (Pandey, 1995). Despite transplanting being a major traditional method for raising millets, the economic factors and recent changes in millet production technology have provided an increased impetus to direct seeding methods (Pandey & Velasco, 2005).

The direct seeding method is defined as the seeding method which involves the sowing of seeds directly into the soil where the plants are let to eventually mature (Bareja, 2021). Plants bear no transplanting stresses, and the crop is seen to develop faster. The primary economic motives for switching to direct seeding are to reduce the labour cost and explore the possibility of crop intensification. According to Mortimer, Riches, Mazid, Pandey et al. (2008), the major forces driving the spread of direct seeding methods were the rising cost of agricultural labour, the need for intensifying crop production, the development of high-yielding short-duration modern varieties, and the availability of chemical weed control methods that largely promoted this change as evidenced in Malaysia and Thailand in the late 1980s and 1990s. Direct seeding offers the advantage of faster and easier planting, reduced labour and less drudgery, and 7–10 days' earlier crop maturity (Balasubramanian & Hill, 2002). Moreover, Pandey (1995) has also reported that in developing countries, direct seeding is adopted because of the migration of farm labour to nonfarm jobs and the consequent shortage of labour and high wages. Accordingly, the rise in population pressure, scarcity of water and agricultural land, and the continuing shortages of labour will continue to pressure a shift toward direct-seeding methods.

De Datta and Flinn (1986) reported that Asian farmers are shifting to direct seeding given the primary advantage that the crop can be established in time so that better crop stands can be achieved for higher productivity. With the same available farm power and labour, much larger acreage can be brought under cultivation in much less time through direct seeding. A similar advantage was reported by Balasubramanian and Hill (2002). The productivity of the direct-seeded crop is found at par with those raised through the transplanting method while the net profit obtained was higher (Y. Singh, Singh, Johnson, & Mortimer, 2005). However, the drawbacks of the direct-seeded method are the lack of uniformity in crop density and the difficulty at times in undertaking intercultural operations. One of the most critical challenges reported in the direct-seeded method is weed stresses. Yet, if the weed pressure is managed well, farmers could still obtain yields comparable to the transplanting method (Rana, Al Mamun, Zahan, Ahmed et al., 2014).

Among agronomic practices, planting methods are one of the important operations to realize higher productivity. Suitable planting methods and selection of improved cultivars play a critical role in exploiting the yield potential of the crop under agro-climatic conditions. Among the possible technological options in finger millet farming, direct seeding has immense potential, and this could be promoted. In Bhutan, finger millet is mostly transplanted, and direct seeding is not popular. This could be largely due to a lack of knowledge and the absence of proper scientific documentation on the different planting methods available. Therefore, it is important to study the effect of planting methods on finger millet varieties under Bhutan’s sub-tropical conditions. The objectives of this study were to compare grain yield from different planting methods with two varieties for promotion as new technology and to assess the comparative advantage of the two methods in terms of labour input and cost.

2. Materials and Method

2.1 Evaluation/trial site

Field experiment was conducted at ARDC, Samtenling, in Sarpang (Figure 1). The site is located at 26° 54’-14’ N latitude and 90°26’-20’ E longitude. It falls under the wet sub-tropical agro-ecological zone of Bhutan by latitude between the elevations (375 <600masl), temperature (max 35°C, min 12°C), and rainfall (2,500-5,500mm). The average monthly precipitation is 1,032mm with a relative humidity of 86.13% (NCHM, 2020). The texture of the soil at the experimental site is sandy loam. The soil is inherently infertile with gentle slopes and good drainage for crop production. Crop grown includes rice, maize, groundnuts, sesame, millets, and oilseeds.

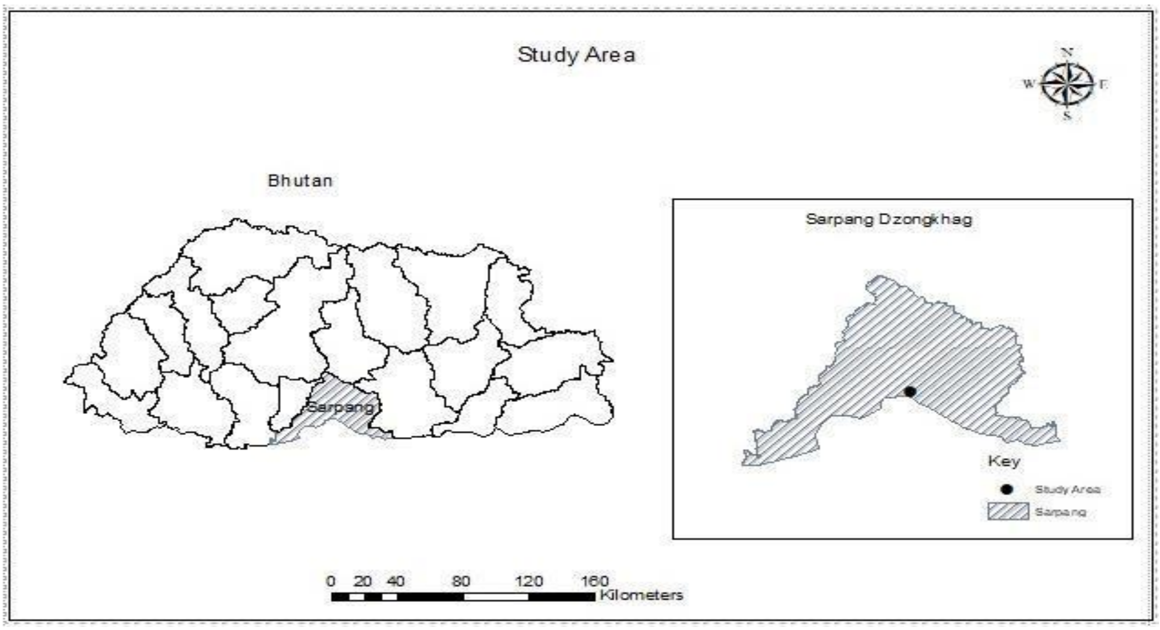

Figure 1. Study site (ARDC research station) in Sarpang

2.2 Evaluation methods

The experiment was laid out in a split-plot design with three replications. The main plot factor consisted of two planting methods (direct-seeded and transplanting) and the sub-plot factor consisted of two varieties *viz.*, SM 1 and IE 4425. This experiment had a total of twelve plots covering an area of 75 m^2. Slope/vertical gradient was a blocking factor. The plot size of 2.25 m x 3 m per treatment was used. The distance between blocks and interspacing for the individual plot was 0.5 m. A spacing of 0.2 m row to row and 0.1 m plant to plant were maintained. Farmyard manure (FYM) at the rate of 5 t ha^{-1} was applied to all the experimental plots uniformly. A fertilizer dose of 40:20:20 NPK kg ha^{-1} was applied. Nitrogen was applied in a split dose (0.352 kg) as basal along with 1.012 kg of phosphorus and 0.27 kg of potassium. Another 0.352 kg of nitrogen was applied 35 days after sowing (DAS) in direct-seeded plots and 30 DAT in transplanted plots. The nursery was raised during the first week of August and transplanted in the third week of August 2020. To suppress the weed pressure, two hand-weeding for direct-seeded plots were performed at 25 DAS and 40 DAS, and for the transplanted plot at 25 DAT and 40 DAT, respectively. The crop received a total recorded rainfall of 2,645 mm during the study period.

2.3 Data collection

The data were recorded adopting standard procedure using UPOV (International Union for the Protection of New Varieties of Plants) guidelines for finger millet. The data observations on yield attribute *viz.* plant height, number of tillers, days to 50% flowering, number of fingers, leaf shape, length of flag leaf, days to maturity, plot yield, and harvest index (%) were recorded. Five plants were randomly selected to measure plant height which was recorded before harvesting while maturity days were calculated from the day of sowing until the grains attended physiological maturity. The harvested plant samples were dried for a week before threshing and threshed grains were weighed using a digital weighing balance. Grain and straw yields were calculated based on the yield obtained from each net plot and converted to t ha^{-1}. Before recording the straw yield, the plot-wise bundles of straw were sun-dried for a week to remove excess moisture.

1. Harvest index was calculated as per the formula given below, (Huhn, 2008)

$$\text{H.I.} = \text{Economic yield} / \text{biological yield} \times 100$$

Where, Economic yield = grain weight (g)
Biological yield = Total plant yield (g)

2.4 Cost of Production

Cost of production and economic returns were estimated as per the existing farmer's wages. The cost for millet grains and straw per kg was taken at the existing farmer's rate. A man-day or working hours was assumed to be eight hours a day, based on which the calculations were made. Cost of cultivation was done considering the management practices including land preparation, weeding, thinning, and transplanting.

2.5 Statistical analysis

Data were collected and entered in MS Excel and analyzed at a 5% level of probability and were subjected to analysis of variance (ANOVA) using STAR (Statistical Tool for Agricultural Research) version 2.0.1 and IBM SPSS Statistics version 22. The results were expressed in tabular form by generating response surfaces.

3. Results and Discussion

3.1 Effect of planting methods on grain yield

The results (Table 1) show that planting methods had no significant effects on most of the growth attributes of finger millet such as plant height, number of fingers, flag leaf length, and number of productive tillers. However, planting methods had a significant effect on finger length and days to maturity. Finger millets raised from the transplanting method recorded a higher yield at 0.81 t ha^{-1} whereas finger millet from direct seeding showed a low yield (0.65 t ha^{-1}) with a percent yield difference of 19.7 % between the two methods. The SM 1 produced an average grain yield of 0.83 t ha^{-1} compared to IE 4425 with 0.63 t ha^{-1}. The percent yield difference between the two varieties was 24%. Similarly, the highest straw yield was found in SM 1 under the transplanted method (1.60 t ha^{-1}) and the lowest in the direct seeded method in the variety IE 4425 (1.3 t ha^{-1}). The higher yield obtained in the transplanted method could be attributed to the cumulative effect of increased tiller production due to the combined effects of abiotic factors such as light, temperature, relative humidity, bright sunshine hours coupled with optimum day length that possibly led to increased photosynthesis efficiency. This in turn could have contributed to increased dry matter production.

Gavit, Rajemahadik, Bahure, Jadhav et al. (2017) have reported that the increased yield attributes in the transplanted method might be due to increased growth and plant development. Nigade, Bagade, and Bhilare (2020) and Hebbal, Ramachandrappa, and Thimmegouda (2018) have reported higher millet yield in the transplanted method as compared to the direct-seeded method. The higher yield could be ascribed to the involvement of increased weed and other management practices, which also agree with the findings of Rana et al. (2014). In addition, Fayisa, Welbira, and Bekele (2016) reported similar results where the increase in spacing led to an increase in tillering, panicle number, and grain yield. On the contrary, the low yield in the direct-seeded crop may be due to the slow initial growth rate as seeds were broadcast, followed by weed stresses later. This might also be due to the adverse effect of competition between plants associated with closer spacing, as well as the poor yield from those that ended in scattered stands. Nonetheless, the broadcast method is considered one of the best planting options compared to drill and spot planting as it returns a higher yield. These results align with those of Adeyeye, Ahuchaogwu, Shingu, Ibirinde et al. (2014) and Shinggu and Gani (2012).

The interaction effects between the planting method and varieties were found to be non-significant (*P*=0.48). This indicates that there was no combined effect of planting methods and varieties on grain and straw yield. The non-significant differences in other yield attributes between the planting methods further reveal that these methods have the potential for sustainable millet production by skipping nursery to transplanting operations that involve cost. If the management practices are applied correctly, any of these methods can produce a credible millet crop. Therefore, a direct-seeded method can be adopted and promoted for a sustainable millet production system.

Table 1. Effect of different planting methods on finger millet grain yield

Treatments	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Days to maturity	Harvest Index (%)
Planting methods (Main plot)				
Direct seeding	0.65	1.30	120.00	30.90
Transplanted	0.81	1.60	126.50	49.43
S. E*	0.06	0.10	0.45	2.67
CD* (*P*=0.05)	0.25	0.02	0.00	0.00
Varieties (Sub plot)				
SM 1	0.83	1.57	123.50	43.81
IE 4425	0.63	1.33	123.00	36.52
S. E	0.09	0.15	0.64	3.77
CD (*P*=0.05)	0.17	0.76	0.59	0.20
Interaction (Main x Sub plot)				
S. E	0.13	0.21	0.91	5.34
CD (*P*=0.05)	0.48	0.19	0.13	0.75

Note: S. E: Standard Error, CD*: Critical Difference (P-value at 5% probability)*

3.2 Effect of planting methods on days to maturity

Crop phenology and maturity duration are some of the most important agronomic parameters in all millet growing ecosystems. Transplanted millet involves uprooting and replanting seedlings that directly expose them to physical and mechanical stresses, which in turn requires days to recover before the plants can perform normal physiological functions like any other growing plant. Transplanting therefore is associated with transplanting injury, hardening, and increased crop period leading to a longer duration for crop maturity.

The results (Table 1) of the study reveal that planting methods had a significant effect on days to maturity (*P*=0.00). However, there was no significant effect of variety on days to maturity and no statistical interaction effects for both the treatments. The direct seeded record (120 days) compared to transplanted millet (126.5 days). This may be due to the ability of the plant in a direct-seeded method to germinate easily and establish earlier as they are devoid of the stresses that transplanted millets are subjected to. This result agrees with the findings of Dendup and Chhogyel (2018). It could also be due to various factors such as root depth, nutrient use efficiency, weed pressure, and inter-crop competition. A difference of 6.5 days in maturity days is observed between the two planting methods.

Alterations in crop maturity and plant stature offer new cropping system opportunities. Early maturity is an excellent drought escape mechanism in the drought-prone finger millet growing areas. Many farmers around the world prefer crops with environmental adaptability that demonstrate yield stability with early maturing traits in cultivars that help mitigate erratic rainfalls and abiotic stresses (Asrat, Yesuf, Carlsson, & Wale, 2010). Thus, the direct-seeded millet can be harvested early, thereby providing a sufficient time window for the following crop. Generally, direct-seeded finger millets suffer from intensive weed pressure if intercultural operation is delayed. Fufa and Mariam (2016) have reported that there was an 82% yield reduction from weedy plots which in turn delayed the physiological growth and maturity period. In a mountainous country like Bhutan where cropping periods are rather short, maturity duration is more important since the crop has to fit in within a single growing period (Dendup & Chhogyel, 2018). Hence, the crop should be sown in time to optimize its maximum yield potential.

3.3 Effect of planting methods on finger millet plant height

Our analysis (Table 2) revealed that the plants did not show any significant differences in their heights under the different planting methods (*P*=0.24). However, a significant height difference was observed between the two varieties (*P*=0.02). The mean plant heights recorded in transplanted and direct-seeded millets were 82.85 cm and 79.15 cm, respectively. Taller plant height in transplanted millet could be due to the deeper root system as seedlings were planted into the soil directly, while the direct-seeded millet is sown at a surface leading to a shallow and reduced root system. This also conforms to the findings of Naresh, Misra, and Singh (2013) who reported taller plant heights in transplanted rice compared to those directly seeded. The transplanting method is always associated with better moisture utilization, nutrient supply, and optimum growth condition during nursery leading to better performance in growth parameters, including taller plant heights. Similar results were also reported by Hebbal et al. (2018).

Plant height is a central part of the plant ecological system that strongly correlates with its life span, seed mass, and time to maturity. It is also a major determinant of a plant's ability to compete for light and is directly correlated to the yield of a crop (Moles, Warton, Warman, Swenson et al., 2009). An increase in plant height is always advantageous as it intercepts more light resulting in increased dry matter production per unit area. Transplanted millet is associated with uniform and wider spacing compared to the direct-seeded method, and its interaction effect with desirable genotype results in taller plant growth. The results of this present investigation are further substantiated by similar findings by Kalaraju (2007) and Nandini and Sridhara (2019) in foxtail millet. Kalaraju, Kumar, Nagaraja, and Ningappa (2009) have also noticed that the increased plant height and larger number of tillers lead to more leaves, thereby resulting in increased straw yield in pearl millet. Further, the interaction effect between planting methods and varieties was also found to be non-significant (*P*=0.91). This indicated that there was no combined effect on plant height. The taller plant height, however, could be attributed to the varietal effect where the height differences were also observed between the two planting methods.

Table 2. Effect of different planting methods on plant height and growth parameters

Treatments	Plant Height (cm)	Productive tiller hill^{-1}	No. of finger earhead^{-1}	Length of finger (cm)	Length of flag leaf (cm)
Planting methods (Main plot)					
Direct seeding	79.15	2.65	4.00	6.83	22.66
Transplanted	82.85	3.16	4.33	8.00	25.16
S. E	1.47	0.18	0.14	0.20	0.75
CD (*P*=0.05)	0.24	0.21	0.28	0.02	0.13
Varieties (Sub plot)					
SM 1	85.00	3.16	4.66	8.16	24.16
IE 4425	77.00	2.66	3.67	6.67	23.66
S. E	2.07	0.26	0.20	0.28	1.07
CD (*P*=0.05)	0.02	0.21	0.00	0.02	0.75
Interaction (Main x Sub plot)					
S. E	2.93	0.37	0.28	0.40	1.15
CD (*P*=0.05)	0.91	0.66	0.28	0.06	0.46

3.4 Effect of planting methods on productive tillers per plant

The results (Table 2) of this study revealed no significant difference (*P*=0.21) between the planting methods on the productive tillers hill^{-1}. Nevertheless, a greater number of productive tillers was observed in the transplanted method (3.16) compared to the direct-seeded method (2.65). Statistically, the interaction effects between planting methods and varieties on productive tiller numbers were non-significant (*P*=0.66). The varietal effect on productive tillers per hill was greater compared to the planting methods. The transplanting method usually involves a larger space, distributed uniformly in that it helps in the effective utilization of available resources such as land, light, and nutrients. The greater number of productive tillers in the transplanted method could be attributed to the larger space between the plants. Wider spacing and more nutrient availability in the transplanting method contribute to a greater number of tillers per plant as also observed by Kalaraju (2007). Sarawale, Rajemahadik, Shendage, and Mane (2016) reported that tillering in cereal grains could be induced by transplanting shock as well as through wider spacing between the individual plants. This is consistent with the results obtained by Maobe, Nyang'au, Basweti, Getabu et al. (2014) where transplanted finger millet had higher tiller formation which in turn influenced productive panicle formation and increased the overall grain yield. Similar results were obtained by Awan, Ali, Safdar, Ashraf et al. (2007), and Sakadzo, Bvekwa, and Makaza (2019).

On the other hand, direct-seeded millet recorded a lower number of productive tillers (2.65 tillers/hill) which could be due to higher weed pressure during the initial growth stages. This conforms with the earlier works of V. P. Singh, Singh, Singh, Kumar et al. (2008). The higher number of productive tillers in transplanted finger millet could be due to proper spacing and uniformity which was not the case in direct-seeded millet. In transplanted millet, there was no overcrowding of seedlings, and weed pressure was considerably less. Hebbal et al. (2018) also reported similar findings. Therefore, we can safely conclude that germinated seeds when sown directly perform well and are comparable to transplanted millet which normally produces a higher number of productive tillers.

3.5 Effect of planting methods on finger number per earhead of finger millet

Among the two planting methods used, transplanted finger millet resulted in a greater number of fingers per earhead than the direct-seeded millet, although the results were not statistically significant (*P*=0.28). A higher number of fingers were produced in the transplanting method (4.33) as compared while direct-seeded millets (4.00). However, there was a significant effect (*P*=0.00) on the number of fingers per earhead between the varieties (Table 2). Variety SM 1 produced a higher number of fingers per earhead (4.66) than IE 4425 (3.67). These results are also corroborated by earlier findings of Kumari and Singh (2015) who reported that the greater the productive tillering, the more would be the finger numbers. Further, similar results were also observed in the research work of Gavit et al. (2017) who evaluated the effect of establishment techniques and sowing time on yield and yield attributes of Proso millet. This is also supported by the results obtained by Hebbal et al. (2018) in India where they showed that transplanted finger millet recorded higher finger numbers as compared to the direct-seeded method.

3.6 Effect of planting methods on finger length per earhead of finger millet

Finger length is one of the important yield parameters in finger millet. The panicle length is positively correlated to the number of grains per plant, and ultimately to the grain yield of the crop (Chandan, 2018). Our results (Table 2) showed that the interaction effects between the planting method and the length of fingers were non-significant *(P*=0.06). Longer finger lengths were observed in transplanted millets (8.00 cm), while direct-seeded recorded a mean finger length of 6.86 cm. Moreover, SM 1 (8.16 cm) recorded a greater number of finger lengths than IE 4425 (6.67 cm). Statistically, the planting method and variety had a significant effect on the finger length (*P*=0.02), but their combined interaction effect did not. The main effect of planting methods on the finger length was more in transplanted SM 1millets than in direct-seeded SM 1 millets. Similar results were obtained for the IE 4425 variety as well. As indicated earlier, this can be due to the higher moisture and larger space available in the transplanted method that aid in the efficient use of water, air, and nutrients, resulting in better growth and development. This is supported by the findings of Sakadzo et al. (2019) and Michaelraj and Shanmugam (2013) where mean finger length was recorded as the highest in transplanted millets as against their broadcast counterparts. A study by Tamilmozhi, Karthikeyan, Sakthivel, and V Ravichandran (2020) on the influence of seedling age, planting pattern, and the number of seedlings per hill on the growth and yield of finger millet under Tamil Nadu conditions in India also supports these results.

3.7 Labour requirement and cost of production

The field operations considered for this study include nursery development, field preparation, planting, weeding, and thinning. These all incur costs. The ultimate objective of any agricultural technology is to realize the maximum returns per Ngultrum (Nu.) invested. Any farming technology to be adopted under farmer conditions should be economically viable.

Table 3. Man-day's requirement and cost of labour for different planting methods per hectare

Cultivation practice	Unit	Planting methods of Finger millet	
		Direct Seeded	Transplanting method
Nursery development	(Man-days)	0	6
Seedling Uprooting	(Man-days)	0	5
Field preparation	(Man-days)	6	6
Seed sowing	(Man-days)	1.5	0
Transplanting (manual)	(Man-days)	0	24
Seedling thinning	(Man-days)	4	0
Weeding (Hand weeding)	(Man-days)	16	10

Total labour required	(Man-days)	27.5	51
Labour cost incurred	(Nu/head)	450	450
Total costs	(Nu)	12,375/-	22,950/-
Cost percent advantage against transplanting method	%	46%	

Table 4. Gross return, net return, and cost-benefit ratio analysis for different planting methods per hectare

Particulars	Planting methods	Quantity (t ha^{-1})	Rate kg^{-1} (Nu.)	Amount (Nu.)
Produce/Grains (t ha^{-1})	1	0.6	30/-	18,000
	2	0.8	30/-	24,000
Straw (t ha^{-1})	1	1.3	5/-	6,500
	2	1.6	5/-	8,000
Gross returns (A) (Nu.)	1			24,500
	2			32,000
Cost of production (B) (Nu.)	1			12,375
	2			22,950
Net returns (A-B) (Nu.)	1			12,125
	2			9,050
C: B ratio	1			1:1.98
	2			1:1.39
Profitability (%) against transplanting				25%

Note: 1 = Direct seeded, 2*= Transplanted method*

To examine the labour requirement and undertake cost analysis, the main field operations such as seedling thinning, and weeding was considered. Management practices other than seedling preparation and transplanting were the same for both methods. The study results showed that the transplanting method in finger millet requires 51 man-days due to the additional manpower required for nursery, seedling uprooting, and transplanting operations (Table 3). Transplanting alone required 24 man-days, while these activities were not necessary for the direct-seeded crop. Thus, direct seeding showed a drastic reduction in labour requirements. The transplanting method required higher labour resulting in a higher cost of cultivation. The results (Table 4) show that the gross returns (Nu. 32,000/-) and total cost of production (Nu.22,950/-) was higher in the transplanted method whereas net returns (Nu. 12,125/-) and cost-benefit ratio (1: 1.98) was higher in the direct-seeded method. This confirms the findings of Hebbal et al. (2018) who reported that transplanting methods of planting recorded the highest cost of production and gross returns compared to the direct-seeded method in finger millet under Bangaluru conditions in India.

There was a labour cost difference of Nu. 10,575/- per ha between transplanted and direct-seeded methods. Additionally, the cost advantage of the direct-seeded method against the transplanting method was as high as 46%. The direct seeded method again recorded a higher net profit of 25%. Similar findings were made by (Y. Singh et al., 2005) who argued that the productivity of the direct-seeded crop is at par with the transplanting method and the net profit remains higher as well. Gill, Walia, and Gill (2014) also reported that direct seeding reduced the cost of production by about 9%. Many farmers still adopt the transplanting method since the high labour inputs were often offset with higher yields. Many studies have reported that the direct seeded method is more economical than the transplanted method (Bhardwaj, Singh, Singh, & Singh, 2018; Jaiswal, Pradhan, Kumar, Sharma et al., 2020; Naresh et al., 2013) due to the minimal costs involved. Direct-seeding method of planting, therefore, offers potential for millet production with fewer labour requirements.

4. Conclusion

The study indicated that the direct seeding method in millet is a potential alternative approach to millet cultivation that could be promoted in the country. Though the growth parameters of millet *viz.,* plant height, tiller number per hill, number of fingers per plant, and grain yield were found to be insignificant between the planting methods, it has a numerical difference in grain yield and other yield attributes. Based on the yield and yield attributes, the transplanting method is worth adopting. However, based on the cost advantage and number of labourers required for different cultivation practices, direct-seeding was found to be better since it required less labour. This contributed to the reduction in labour cost, and in turn, enhanced the profitability (25%) of millet farming. Direct-seeded millet required 27.5 man-days compared to 51 man-days in transplanted millet. Thus, there is an additional cost difference of Nu. 10,575/- in transplanted millet. Based on the overall results, the transplanted method which is labour-intensive and associated with higher cost can be replaced by direct seeding without compromising the productivity of the crop. The direct-seeded method could be, therefore, recommended for finger millet production for optimum growth, higher yield, and early maturity at a lower cost of production. This study recommends the direct-seeding method in millet cultivation as a potential technology to be incorporated as a part of the strategy to overcome farm labour shortage and reduce costs in finger millet farming.

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