EVALUATION OF MECHANICAL RICE TRANSPLANTER IN COLD SEASON AT FARMERS' FIELD

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Executive summary

Rice transplanting is the most important agricultural operation which demand considerable amount of labor. Due to shortage of human labor, farmers are compelled to practice delayed planting which results in yield loss. In this regard, mechanical transplanting could lead to make cultivation more profitable and to maximize production. Mechanical transplanting is an emerging technology in Bangladesh agriculture. It is imported from South Korea and China. The performance of this machine needs to be thoroughly investigated in local condition. This experiment was conducted in Boro (2015) season in the farmers' field at Gosaidanga in Shailkupa upazila under Jhenaidah district and at Rashidpur in Mithapukur upazila under Rangpur district. Two treatments, i.e. T1 = Hand transplanting (HT) and T2 = Mechanical transplanting (MT) were used in the experiment. The experiment was carried out in randomized complete block design (RCBD) and replicated in six plots in each location. Rice variety BRRI dhan28 was used to conduct the experiment in both locations. Fuel consumption of 4-row walking type mechanical transplanter was 5.25 litre per hectare. The field capacity and field efficiency of rice transplanter was 0.11-0.12 ha/hr and 64-70 percent, respectively. Conventional seedbed preparation required 37-55 man-hr/ha whereas 71-77 man-hr/ha required in mat type seedling suitable for mechanical transplanting. Labor requirement in manual and mechanical transplanting ranged from 123-150 and 9.0-10.5 man-hr per hectare which was 19-22 and 1.65-2.00 percent of total labor requirement in rice cultivation, respectively. Number of seedling tray requirement ranged from 215-230 per hectare. Calibration should be done on space and seedling density setting before operation in each plot to get optimum plant spacing and seedlings tray requirement. Missing hill obtained 1-2 percent in mechanically transplanted plot. Mechanically transplanted plot showed significantly higher grain yield (9-14%) than hand transplanted method due to use of infant seedling and better planting efficiency. The input cost in the form of labor and material obtained similar in manual transplanting whereas in mechanical transplanting, labor cost was 12 percent lower than material cost. The cost of growing mat type seedling for mechanical transplanter was 53 percent whereas the cost of raising traditional seedbed was 34 percent of the cost of manual transplanting. The cost of machine transplanting obtained Taka 80,379 per hectare in comparison to Taka 81,893 per hectare for manual transplanting. Mechanical transplanting reduced 1.8 percent input cost than manual transplanting in crop cultivation. BCR of MT and HT showed 1.18-1.19 and 1.03-1.06, respectively. Mechanical intervention in crop production drastically reduced the labor requirement which can offset the peak labor demand. Mechanical transplanting systems increased yield, improved labor efficiency, ensured timeliness in operation and faster transplanting.

Background

Rice (*Oryza sativa* L.) is the leading food crops of 164 million people of Bangladesh with a total paddy production of about 48 million Mt on an area of 10.8 million ha. It covers 77% (10.71 Mha) of the total cropped areas (BBS, 2011). At present, rice alone constitutes about 92% of the total food grains produced annually in the country. It provides about 75% of the calorie and 55% of the protein intake (Bhuiyan *et al*., 2002). It also ensures a sense of food security of the country. Rice grown under irrigated, rain fed and deep water conditions in the three distinct seasons namely; Aus, Aman and Boro. Aus rice is grown in March to August. Transplanted Aman (T. Aman) is growing from July to December, while Boro rice is grown mainly under irrigated conditions and planted in December-January and harvested in April-May.

Transplanting of crops is the most important agricultural operations. There are many ways to transplant seedling-manual, mechanical, throwing. Transplanting of seedlings into heavy puddled soils is the common practice of rice cultivation in Bangladesh. Soil puddling is a capital and energy-intensive process and requires a large volume of water although it has a number of advantages including better weed control, reduces water percolation losses and enhances nutrient availability (Sharma and De Datta, 1986). Manual paddy transplanting is the tedious, laborious and time consuming operations requiring about 250-300 man h ha^{-1} which is roughly 25% of total labor requirement of rice production (Singh *et al.,* 1985). It was reported that a delay in transplanting by one month reduces the yield by 25% and a delay of two month reduced the yield by 70% (Rao and Pradhan, 1973).

There is a very limited time between harvesting of one crop to sowing/transplanting of the next one. Due to shortage of human labor, farmers are compelled to practice delayed planting which results in yield loss. Farm labor is decreasing due to shifting on-farm to off-farm activities. Farm owners have been facing an acute crisis of labor in the peak time of transplanting due to shortage of laborers and excessive cost in this season. Crisis of labor has created an unusual situation. The farm owners have to find the labors going door to door or they have to wait for the labors to finish the work in the nearby fields. Sometimes, they have to hire labor offering extra wages with additional facilities. As a result, the scheduled time of transplanting paddy expires in many places.

Rice production area is decreasing in day by day due to high population pressure. Moreover, Bangladesh does not have any additional land for expanding cultivation. In this context, farm mechanization with small, low cost and easy operational farm machinery could lead to make cultivation more profitable and to maximize production. Further, due to rapid industrialization and migration to urban areas, the availability of labor became very scarce and with hike in the wages of labor, manual transplanting found costly leading to reduced profits to farmers. Under such circumstances a less expensive and labor saving method of rice transplanting without yield loss is the urgent need of the hour (Tripathi *et.al.,* 2004). It is therefore essential to adopt the mechanical transplanter to ensure the timeliness in planting. Mechanization will bring a fundamental change in agricultural labor and cultivation process in Bangladesh.

Mechanical rice transplanting method generates employment and alternate sources of income for rural youth through custom services on nursery raising and transplanting. The mechanical transplanting of rice has been considered the most promising option, as it saves labor, ensures timely transplanting and attains optimum plant density that contributes to high productivity. However, rice transplanters are considerably expensive for almost all Asian small-hold farmers. It is popular in industrialized countries where labor cost is high, for example in South Korea.

Seedlings age is an important factor because it has a tremendous influence on the plant height, tiller production, panicle length, grain formation, grain per panicle and other yield contributing characters. Mechanical transplanter use infant seedlings. The farmer of Bangladesh does not give attention to the age of seedlings at transplanting and use 30 or more day's age of seedling. For optimum yield, age of seedlings at transplanting of a particular variety at a particular season may not be suitable for other varieties at that season. Therefore, it is very important to find out the optimum age of seedlings of a particular variety for a particular season. The growth, development, yield and yield components of rice all are greatly influenced by plant spacing. Optimum plant spacing ensures the plants to grow properly with their aerial and underground parts utilizing more solar radiation and nutrients.

There is a significant trend to mechanization of rice production resulting in reducing the labor work and time consuming. Rice planting is one of the important stages in this viewpoint particularly in transplanting method. According to above and necessity of time saving and crop yield, in recent years, farmers were encouraged to adopt mechanized methods of rice transplanting.

1.1 Justification

Mechanical transplanter has high field capacity and farmers can transplant rice seedlings within very short time by using mechanical transplanter. Mechanical transplanters use infant seedlings and do not require extra land to raise seedlings. Recently, mechanical transplanter is introduced in our country. As a new technology, this machine needs to be evaluated in different agro-ecological zone and in different crop season. Therefore, the present study was undertaken with the following objectives.

1.2 Objectives

- To evaluate the field performance of mechanical rice transplanter
- To estimate the yield and yield contributing character
- To compare the cost of mechanized cultivation over traditional method

Review of literature

Rice is one of the most important food crops and staple food of about 135 million people in Bangladesh. In Bangladesh more than 78 percent of her population lives in the villages (BBS, 2008) and agriculture is the major occupation of the people. Especially they are directly involved in rice production and trade. Almost all of the 13 million farm families of the country grow rice. During this period in Bangladesh the total rice area is about 10.5 million hectares (Web: https://www.knowledgebank-brri.org). But the area will also shrink to 10.28 million hectares for many reasons. Due to pressure urbanization, industrialization and non-crop development activities, cultivated land has been degrading and shrinking at a rate of eight thousand hectares per year (Alam *et. al.*, 2004 and Mondol, 2005). Farmers faced many problems during cultivation. Labor crisis in the peak period for transplanting is the major one.

Rice is grown either by direct seedling i.e. broadcasting, drilling, sowing, transplanting. In India, higher and more stable yield was obtained from transplanted rice than direct seeded rice. In most provinces of India, transplanted rice had 10 to 20% higher yield than broadcasted rice (Grag, 1997).

Baruah *et. al.* (2001) reported that the cost of machine transplanting was found to be only Rs. 1310/ha in comparison to Rs. 2463/ha for manual transplanting. The cost of growing mat type nursery for mechanical transplanting was about forty percent whereas the cost for raising conventional nursery was only 25% of the cost transplanting.

Rice transplanting is highly labor intensive farm operation. The total labor requirement for rice production in one hectare of land was 156.2 man-days of which 44.5 man-days were consumed by seedling raising and transplanting which is 28.24% of the total labor requirement (Rahman, 1997).

Chaudhury *et. al.* (2005) stated that the self-propelled rice transplanter gave net profit of Rs. 1146 and Rs. 1319 per hectare when annual use of machine was 300h (one season) and 500h (two season), respectively, over the manual transplanting.

Singh *et. al.* (2011) recently reported in their research the yield in traditional method was 4.83 t/ha and it was 5.7 t/ha in self-propelled paddy transplanting method. Paddy is grown in India by transplanting under wetland conditions or direct sowing depending upon availability of water. The main difference between the two methods are in direct seedling method, the seeds are shown directly in wet or dry field, whereas in the transplanting method, seedlings are first raised in a seedbed in the nursery and uprooted for transplanting either manually or mechanically. The transplanter are classified on the basis of nursery used i.e. machine using wash root seedling and machine using mat type seedlings. Mat type seedlings are raised on a polythene sheet with the help of farmers. 20-30 days seedlings were found most suitable for transplanting. The mat thickness for best results should be about 2 cm. Transplanting mat type seedlings is becoming more popular due to its superior performance and reduced labor requirement (50 man ha/ha). The 6-row manually operated machine was found to be the most economical. (Anoop Dixxit, 2007).

Rao *et. al.* (1973) reported that a delay in transplanting by one month reduced the yield by 25% and a delay of two month reduced the yield by 70%.

Aslam *et. al.* (2008) noted that the labor shortage at the time transplanting which results in low plant population and eventually low rice yield. Now a days, the availability of labor becoming scarce and increasing the wages of labor, manual transplanting found laborious and costly leading to reduce profits to the farmers.

Alizadeh *et. al.* (2011) stated that the average labor input in the rice transplanter was 30 man h/ha compared to 126 man h/ha in hand transplanting.

GBK (2012) explained that the manual transplanting is labor intensive, time consuming and expansive, large number of workers required. About 25-40 man-days/ha are required to transplant with manual transplanting method where an operator with the help of an assistant can do the same work with self-propelled rice transplanter and it is possible to transplant more than 2 ha/8hrs.

Materials and methods

This section represents the details of various materials and methods related to manual and mechanical transplanting of rice seedlings. This section was conducted for studying the yield performance of mechanical transplanted rice over manual transplanted rice in boroseason.

3.1 Experimental location

This experiment was conducted in the farmers' field at Gosaidanga in Shailkupaupazila under Jhenaidah district and at Rashidpur in Mithapukurupazila under Rangpur district.

3.1.1 Experimental design and treatment

The experiment was carried out in randomized complete block design (RCBD) and replicated in six plots. Twelve plots within one kilometer radius were selected to conduct this study (Appendix 1a and 1b).

3.1.2 Treatment

Two treatments were used to conduct the experiments, which is

T1 = Hand transplanting (HT)

T2 = Mechanical transplanting (MT)

3.1.3 Rice variety

Rice variety BRRI dhan28 were used to conduct the experiment in both locations.

3.2 Specification of rice transplanter

Self-propelled four rows walking-type rice transplanter (DP-480) was used to transplant seedling (Photo 3.1). It has a fixed row spacing of 30 cm and has provisions for adjustments of planting depth, number of seedlings per hill, floats pressure against soil, hill spacing and planting speed. The specification of the transplaner is shown in Appendix 2

Photo 3.1: 4-row walking type rice transplanter

3.3 Land preparation

The field was prepared using common tillage practice, which was first plowing (primary tillage) once, followed by puddling (secondary tillage) twice and leveling using two-wheel tractor under the flooding conditions (Photo 3.2). After first rotary tilling, the field was flooded with water and kept as such for 7 days and then second rotary tilling was done on 8th day and the field was leveled by a plank.

Photo 3.2: Land preparations using two wheel tractor in flooding condition

3.4 Seedlings raising

3.4.1 Seedlings tray preparation

The plastic trays were used to raise mat-type seedlings. Dry soil was filled in tray in such a way that the soil was free from any stone, stubble and grass. Sprouted seeds were spread uniformly over the tray. The seed rate per tray for mechanical transplanting was 130-140 gm dry seed. To protect the seeds from the birds, the mats were covered with straw. Water was sprinkled twice a day by rose cane until there was complete emergence of seedlings. The mat seedlings were ready to transplant when they had 3-4 leaves and 10-12 cm height (Photo 3.3).

a. Sprouted seed

b. Filling tray with dry soil

c. Spreading seed on tray

d. Uniform distributed seed on tray

e. Watering

f. Seedlings on tray

Photo 3.3: Rice seedlings on plastic tray

3.4.2 Traditional seedbed preparation

Seedbed preparation often involved secondary tillage using spade and puddling was done after inundating the field. Drainage canals were constructed for proper water removal. Puddled soil was leveled and raised to 5 to 10 cm height. Sprouted seeds were broadcasted manually. Organic manure (decompose) and a small amount of inorganic fertilizer were applied as basal dressing to increase seed vigor and allows easier uprooting for transplanting (Photo 3.4). The seed rate for manual transplanting was 37.5 kg/ha.

Photo 3.4: Seedlings at field in the conventional method

3.4.3 Seedlings uprooting

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 9th January 2015 without causing much mechanical injury to the roots and immediately transferred to the main field (Photo 3.5).

Photo 3.5: Uprooting of the rice seedlings

3.5 Fertilizer application

During final land preparation, all cares were taken for uniform leveling of the land. A fertilizer dose per hectare of 136 kg triple super phosphate (TSP), 111 kg muriate of potash (MOP), 111 kg gypsum and 11.25 kg Zn were applied at final land preparation in Rangpur site and 90 kg TSP, 112 kg MOP, 90 kg gypsum and 7.5 kg Zn were applied at final land preparation in Jhenaidah site.

3.6 Water management

Irrigation water was applied time to time as when required uniformly in manual and mechanical transplanted plots for proper growth and development of crops. Maximum irrigation was needed at the panicle initiation stage.

3.7 Transplanting

3.7.1 Manual transplanting

Forty two days (for Rangpur site) and forty six days (for Jhenaidah site) old seedlings were uprooted carefully from the nursery field and transplanted in each of the well puddled unit plots on two different days (Photo 3.6). The date of manual transplanting for Boro rice was 10th January in Rangpur site and 30th January in Jhenaidah site (after harvesting mustard).

Photo 3.6: Seedlings establishment

3.7.1 Mechanical transplanting

Thirty three days (for Rangpur site) and twenty eight days (for Jhenaidah site) old seedlings were used for mechanical transplanting (Photo 3.7). Before starting the transplanter, seedling mat was rolled and fed to the mechanical transplanter and all the required adjustments such as hill spacing, number of plant per hill and planting depth were done based on the machine operator's manual. The date of transplanting for Boro rice was 9th January in Rangpur site and 30th January in Jhenaidah site. In mechanical transplanter, line to line distance was fixed at 30 cm and plant to plant spacing can be varied and set at 17 cm.

Photo 3.7: Transplanting operation using mechanical transplanter

3.7.2 Labor requirement

The amount of human labor involved in each operation was investigated through field measurements.

3.8 Performance Parameter

3.8.1 Theoretical field capacity

The theoretical field capacity of a machine is the rate of field coverage that would be obtained if the machine performs its function 100% of the time at the rated forward speed and always covers 100% of its rated width. Therefore,

$$TFC = \frac{W \times S}{C} \qquad (1)$$

Where,

TFC= Theoretical field capacity, ha/hr

W = Operating width of the transplanter, m

S = Transplanting speed, km/hr

C = Constant, 10

3.8.2 Actual field capacity

It is the ratio of actual average rate of field coverage by the machine to the total time during operation. Therefore,

$$AFC = \frac{A}{T} \qquad (2)$$

Where,

C= Actual field capacity, ha/hr

A= Total transplanted area, ha

T= Total operating time required for transplanting, hr

3.8.3 Field efficiency

It is the ratio of effective field capacity to the theoretical field capacity of a machine under field conditions and the theoretical maximum productivity and it can be calculated by the following equation:

$$Eff = \frac{AFC}{TFC} \times 100 \quad (3)$$

Where,

Eff = Field efficiency, %

AFC = Actual field capacity, ha/hr

TFC= Theoretical field capacity, ha/hr

3.8.4 Fuel consumption

Fuel consumption was measured by filling the fuel tank twice, before and after each operation. Re-filled volume was the actual fuel consumption according to the following equation:

$$FC = \frac{Fr}{t} \quad (4)$$

Where,

Fc = fuel consumption, l/hr

Fr = re-filled volume of fuel, l

t = operating time, hr

3.8.5 Percent missing hills

It is the ratio of the total number of hills without seedlings to the total number of hills expressed in percentage and it can be calculated by the following equation:

$$H_{pm} = \frac{H_m}{H_t} \times 100 \quad (5)$$

Where,

H_{pm}= Percent missing hills, %

H_m= Total number of missing hills in the sampling area

H_t= Total number of hills in the sampling area

3.9 Comparative inputs

Comparative inputs in two practices are given in Table 3.1a and 3.1b. Inputs were almost similar in both practices. Seedling age was higher in MT than HT. Seedling were raised in tray for mechanical transplanter whereas, farmers raised seedling in traditional seedbed. Rice variety, fertilizer rate, cultural practices, disease infestation depended on rice season. Micronutrient was applied in both practices. Proper care was taken and agronomic services was provided regularly in MT and HT.

Table 3.1a Comparative input in two practices at Rangpur site

Sl. No.	Parameters	MT	HT
1	Variety	BRRI dhan28	BRRI dhan28
2	Date of Seedings	06/12/14	28/11/14
3	Seed rate	120 gm dry seed/tray	37.5 kg/ha
4	Seedling raising stechnique	Plastic tray method	Traditional seedbed
5	Transplanting	Mechanical	Manual
6	Date of transplanting	09/01/15	10/01/15
7	Age of seedlings	33 days	42 days
8	Spacing	30 × 17 cm	Almost line sowing
9	Tray requirement	230 tray/ha	-
10	Seedlings density setting	Medium	-
11a	Basal Fertilizer	TSP@136kgha^{-1} MOP@111kgha^{-1} Gypsum@111kgha^{-1}	TSP@136kgha^{-1} MOP@111kgha^{-1} Gypsum@111kgha^{-1}
11b	Micro Nutrient	Zn@11.25kgha^{-1}	Zn@11.25kgha^{-1}
12	Weedicide	Superclean@0.75kg ha^{-1}	Superclean@0.75kg ha^{-1}
13	Time of application	12/01/2015	13/01/2015
14	Weeding	one time	2 times
15	Top dressing	Urea 272 kgha^{-1}	Urea 272kgha^{-1}, DAP 50 kgha^{-1}
15a	1st top dress	Urea 99 kgha^{-1}	Urea 99 kgha^{-1}
15b	2nd top dress	Urea 124 kgha^{-1}	Urea 124 kgha^{-1}
15c	3rd top dress	Urea 49 kgha^{-1}	Urea 49 kgha^{-1}
16	Insecticide	Virtako one time @ 75 g ha^{-1}	Virtako one time @75 g ha^{-1}
17	Fungicide	Nativo one time @ 300 g ha^{-1} Trooper one time @ 2.25 kg ha^{-1}	Nativo one time @ 300 g ha^{-1} Trooper one time @ 2.25 kg ha^{-1}
18	Date of maturity	24/04/15	28/04/15

Table 3.1b Comparative input in two practices at Jhenaidah site

Sl. No.	Parameters	MT	HT
1	Variety	BRRI dhan28	BRRI dhan28
2	Date of Seeding	02/01/15	15/12/14
3	Seed rate	120 gm dry seed/tray	37.5 kg/ha
4	Seedling raising technique	Plastic tray method	Traditional seedbed
5	Transplanting	Mechanical	Manual
6	Date of transplanting	30/01/15	30/01/15
7	Age of seedling	28 days	46 days
8	Spacing	30 × 17 cm	Almost line sowing
9	Tray requirement	215 tray/ha	-
10	Seedling density setting	Medium	-
11a	Basal Fertilizer	TSP@90kgha^{-1} MOP@112kgha^{-1} Gypsum@90kgha^{-1}	TSP@90kgha^{-1} MOP@112kgha^{-1} Gypsum@90kgha^{-1}
11b	Micro Nutrient	Zn @7.5kgha^{-1}	Zn @7.5 kg ha^{-1}
12	Weedicide	Pyrogold@ 124kgha^{-1}	Pyrogold@ 124kgha^{-1}
13	Time of application	04/02/2015	04/02/2015
14	Weeding	One time	2 times
15	Top dressing	Urea 198 kgha^{-1}	Urea 198 kgha^{-1}
15a	1st top dress	Urea 74 kgha^{-1} at 25 DAT	Urea 74 kgha^{-1} at 25 DAT
15b	2nd top dress	Urea 124 kgha^{-1} at 55 DAT	Urea 124 kgha^{-1} at 55 DAT
16	Insecticide	Virtako one time @ 75 g ha^{-1}	Virtako one time @75 g ha^{-1}
17	Fungicide	Nativo one time @ 300 g ha^{-1} Trooper one time @ 2.25 kg ha^{-1}	Nativo one time @ 300 g ha^{-1} Trooper one time @ 2.25 kg ha^{-1}
18	Date of maturity	13/05/15	14/05/15

3.10 Cultural practices (weeding)

Weed infestation was not severe due to application of weedicide. Few weeds were grown in the plot. For the removal of weeds, weeding was done manually by hand once at 55 days after transplanting (DAT). After that no other weeding operation was done up to harvest.

3.10 Cultural practices (weeding)

Weed infestation was not severe due to application of weedicide. Few weeds were grown in the plot. For the removal of weeds, weeding was done manually by hand once at 55 days after transplanting (DAT). After that no other weeding operation was done up to harvest.

Photo 3.8: Manual weeding in the rice field

3.11 Pesticide andInsecticide application

Pest infestation was severe and controlled by a single application of Virtako and Nativo at the vegetative growth stage.

3.12 Harvesting

The crop was thought to be matured when about 85-90% of the grains become golden yellow. The crops established by different planting methods attained maturity at different dates. The crops were harvested at maturity level (Photo 3.9). The harvested crop of each plot was separately bundled, properly tagged and then brought to threshing floor.

Photo 3.9: Manual harvesting

3.13 Yield and yield contributing character

3.13.1 Grain yield

Grain yield were recorded from pre-selected 10 m^2 land area and adjusted moisture content of 14%. For computing aboveground biomass and yield contributing characters, 4 hills were collected from the outside of the selected area. The dry weight of straw was determined after oven-drying at 70°C to constant weight. Panicle number of each hill was counted to determine the panicle number m^{-2}.

Plant samples were separated into straw and panicles. Panicles were hand-threshed and the filled spikelets were separated from unfilled spikelets. Aboveground total biomass was the total dry matter of straw, rachis, and filled and unfilled spikelets. Spikelets per panicle, grain-filling percentage (100× filled spikelet number/total spikelet number), and harvest index (100 × filled spikelet weight/aboveground total biomass) were calculated. Border areas of all sides of the plot were excluded to avoid border competition effects.

3.13.2 Plant height and panicle length

The plant height was measured from the base of the hill to the tip of the longest panicle. Length of the panicle was taken from the basal node of the rachis to the apex of each panicle.

Photo 3.10: Measuring the plant height and panicle length

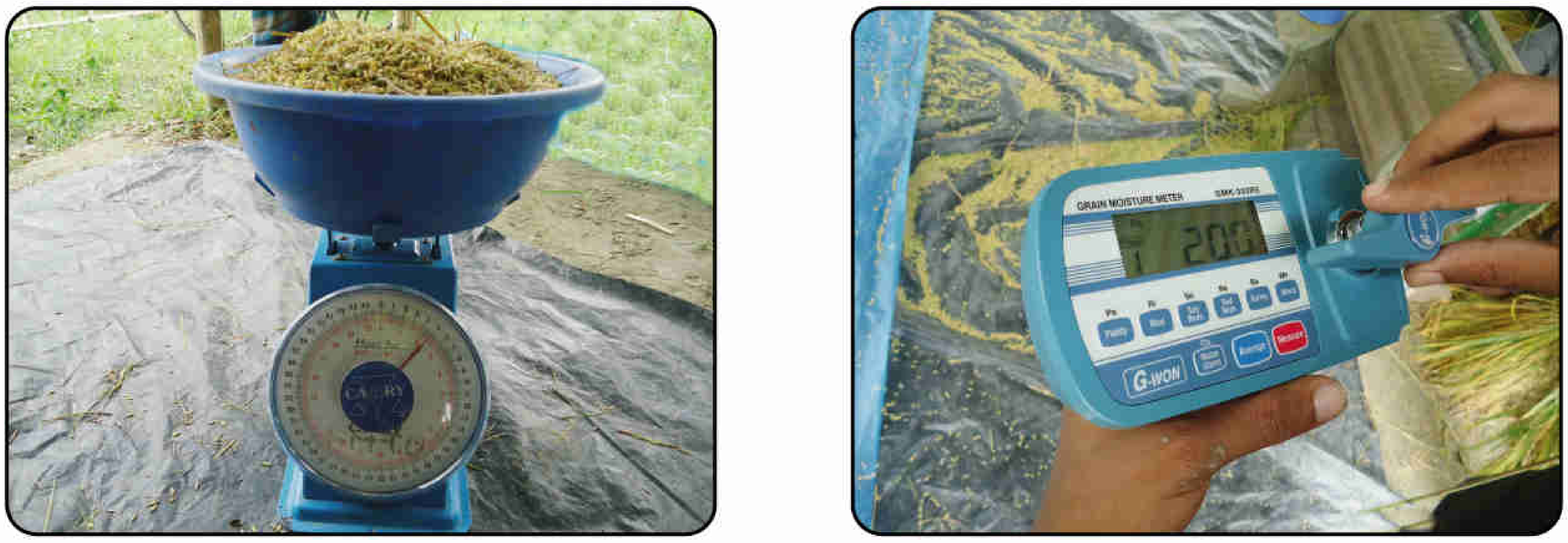
3.13.3Effective tillers, non-effective tillers and total tillers per hill

Three hills from each of the plots were collected randomly. The panicles that had at least one grain were considered as effective tillers. The panicles that had no grain were considered as non effective tillers. The number of effective and non effective tillers of each hill was noted and the total number of tillers was counted for each hill.

Photo 3.11: Counting of effective and total tillers per hill

3.13.4 Weight of 1000 grains

One thousand clean, dried seeds were collected and weight was measured by an electric balance. The moisture content was determined by digital moisture meter.



(a) (b)

Photo 3.12: (a) Moisture meter and (b) weight meter

3.13.5 Weight of straw per hill

Twelve hills from each plot were collected and then the straws were dried by an electric oven and dry weight was measured with the help of a digital balance and the weights of straw were recorded.

3.13.6 Harvesting index

It is the ratio of grain yield to biological yield and harvesting index (HI) was calculated by the following formula stated below.

$$HI = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Where,

HI= Harvesting index, %

3.14 Economic analysis

In order to estimate the production cost, the data on working speed, total time and labor involvement and materials inputs to complete the operation were recorded. Rental charge of the machines was also included in the cost estimation. Land rental value and interest on investment were considered to calculate the total input cost. Price of the produce was collected from the local markets to compute total production cost, gross return, gross margin and benefit-cost ratio. The benefit-cost ratio (BCR) was computed as follows:

$$BCR = \frac{\text{Gross return}}{\text{Production cost}} \times 100$$

3.15 Statistical analysis

Statistical analysis was done by using software Statistix 9.0. Least significant difference was used to compare the means. The results obtained in this study have been presented and interpreted in this chapter under relevant headings and sub-headings

4.1 Fuel consumption

Daily fuel consumption varied from 4.50 to 6.00 (Rangpur site) and 5.00 to 5.50 (Jhenaidah site) litre per hectare. The fuel consumption varied in two locations due to soil type, water height, plot size and shape. Average fuel consumption obtained 5.25 litre per hectare.

4.2 Seedling age

In mat type seedling, 25-30 days age found optimum for transplanting whereas farmers transplant 45 days-old seedling in cold season. Seedling age obtained higher in cold season than warm season.

4.3 Field capacity of mechanical transplanting

Field capacity is an important factor for any kind of machine operation. The Fig. 4.1 shows that, mechanical transplanter transplanted 0.10 hectare per hour at Rangpur site and 0.12 hectare per hour at Jhenaidah site. The field efficiency of transplanter was 64 and 70 percent at Rangpur and Jhenaidah site, respectively.

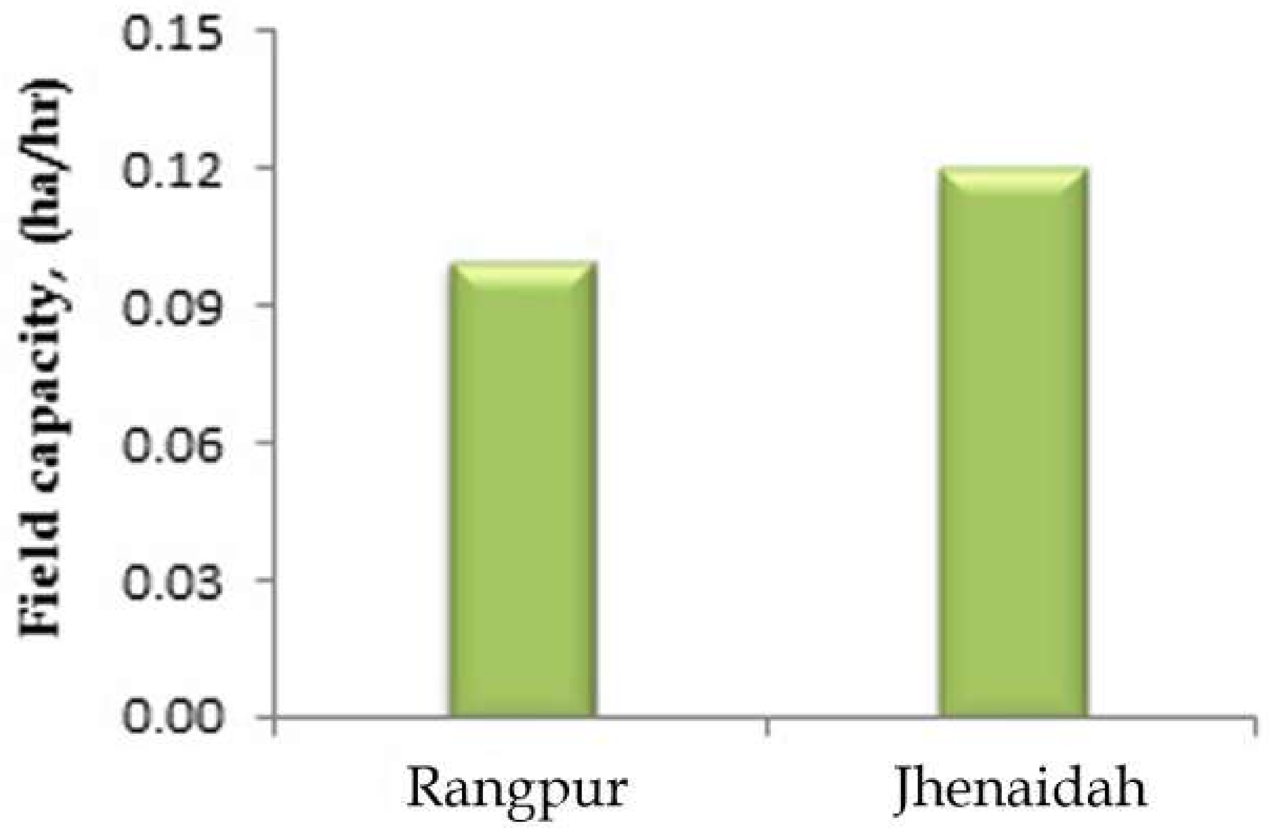


Fig. 4.1a : Field capacity of MT

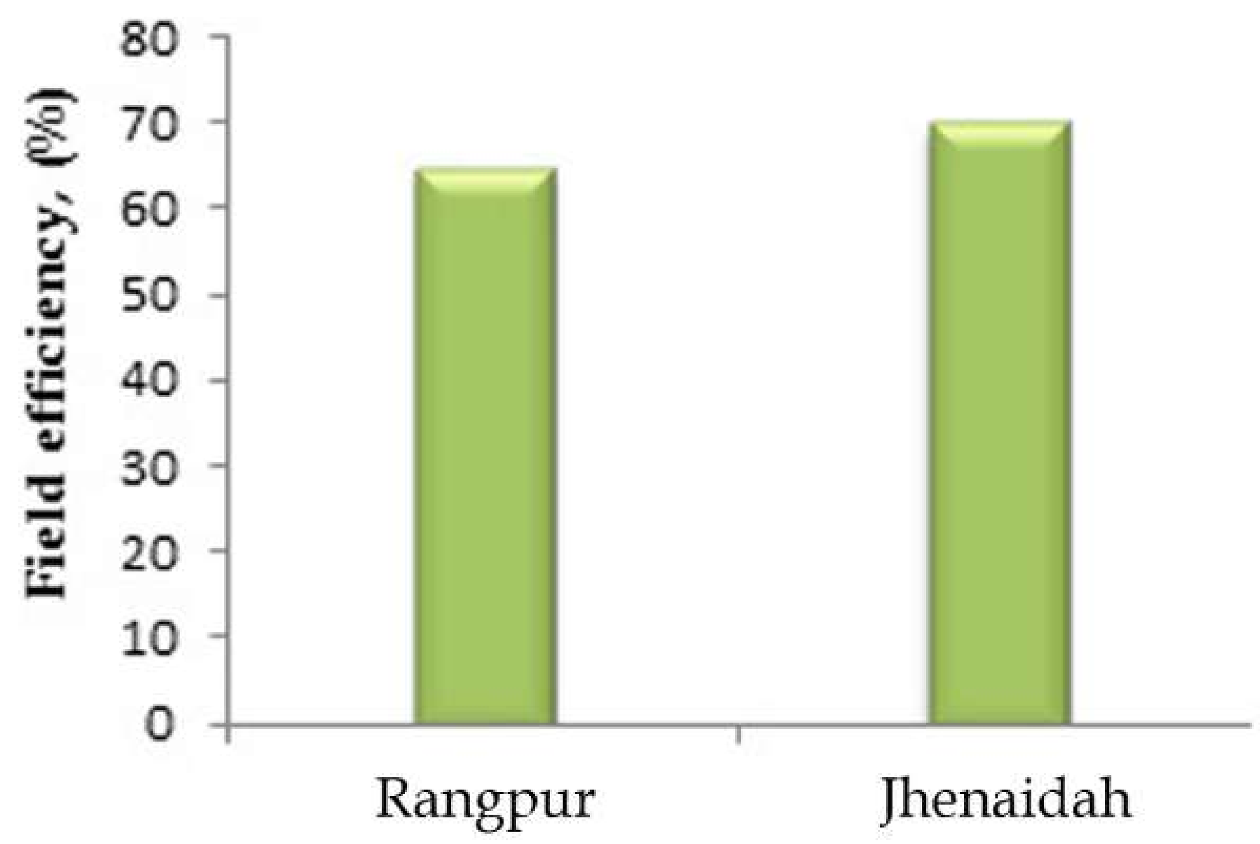


Fig. 4.1b : Field efficiency of MT

4.4 Seedlings tray requirement

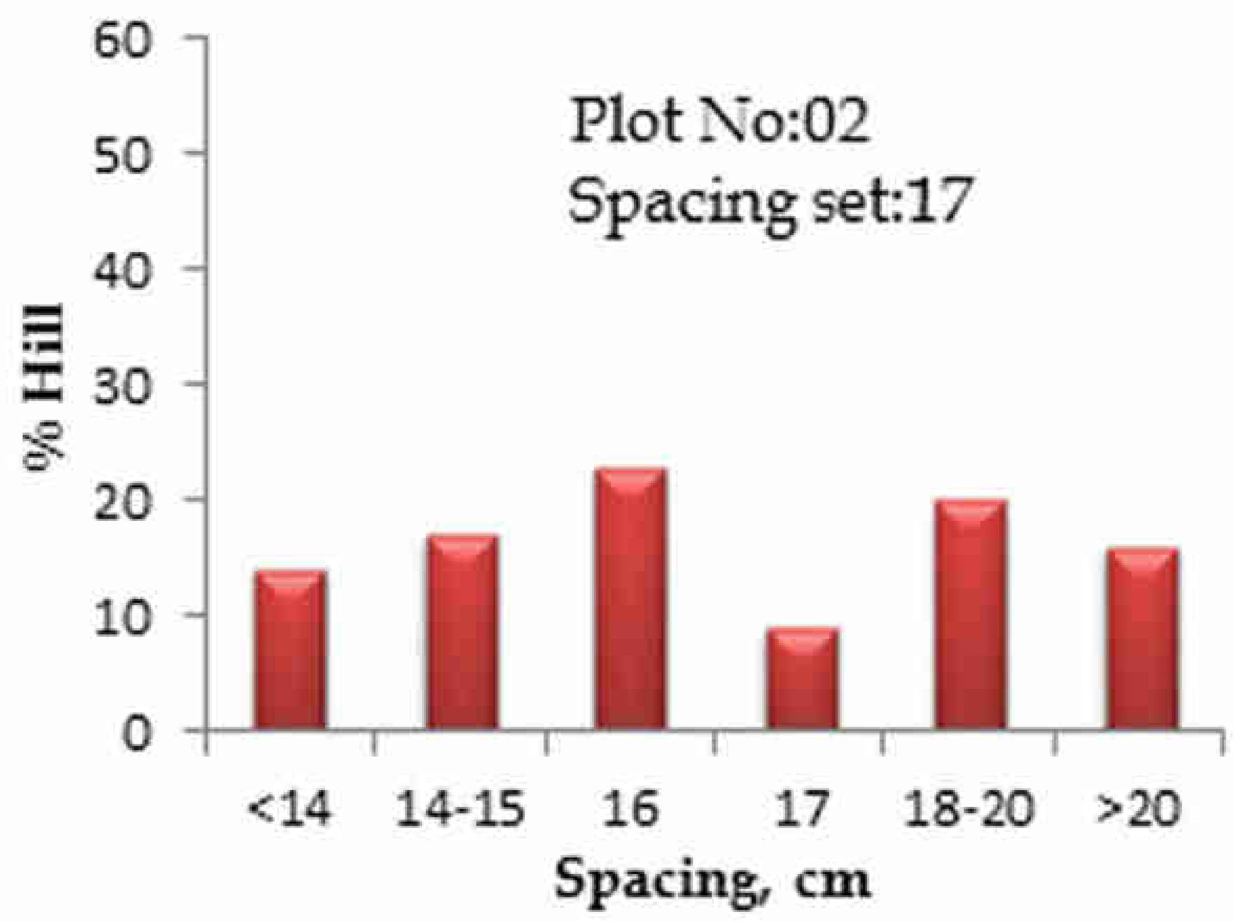
Seedling tray requirement depended on space setting. Seedlings tray requirement in mechanical transplanting ranged from 215-230 number per hectare in both locations. Calibration should be done on seedlings density setting to optimize seedlings tray requirement.

4.5 Plant to plant spacing

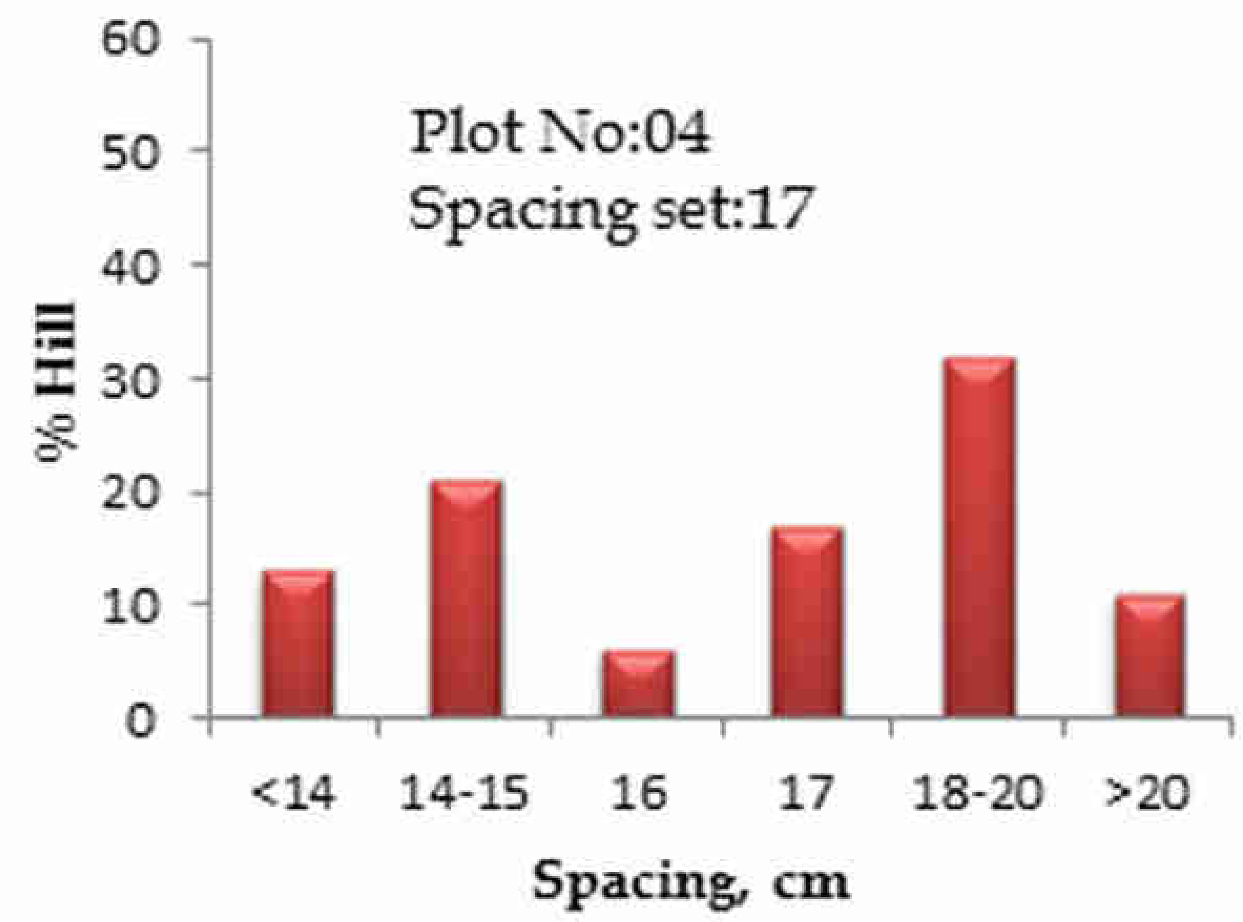
In mechanical transplanter, line to line spacing was fixed at 30 cm whereas, plant to plant spacing can be varied. Plant to plant spacing was set 17 cm. In practical situation, most of the places plant to plant spacing was not consistent and sometimes higher than 17 cm. This might be due to skidding of the transplanter as a result of water height and depth of puddled soil. Fig. 4.2a and 4.2b also show the histogram of plant spacing where spacing was set at 17 cm. Most of the places, plant to plant spacing was higher than 17 cm. This might be due to slippage of the transplanter. It was the common phenomenon which occurred frequently in the field. Calibration should be done on space setting before operation in each plot to get optimum plant spacing.

3.13.4 Weight of 1000 grains

One thousand clean, dried seeds were collected and weight was measured by an electric balance. The moisture content was determined by digital moisture meter.



(a)



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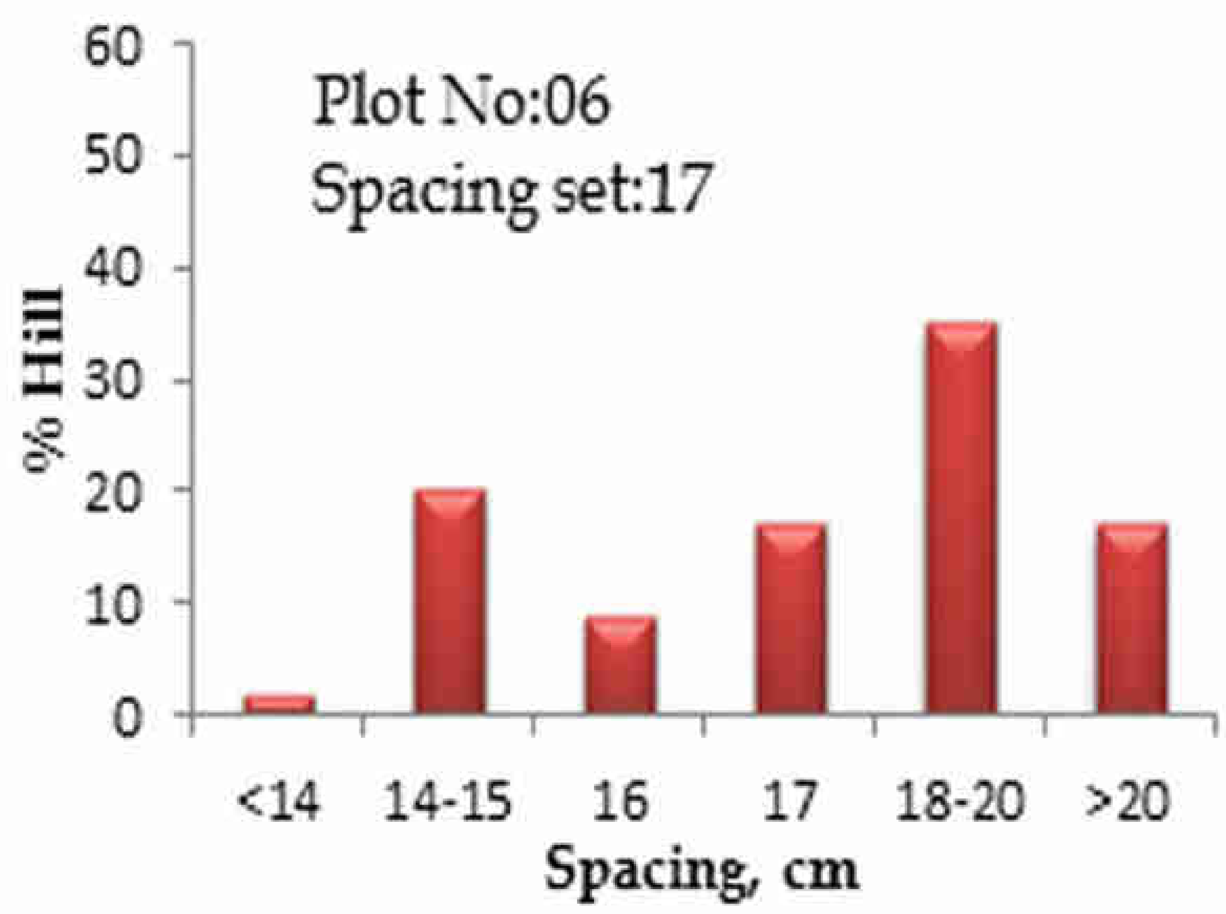

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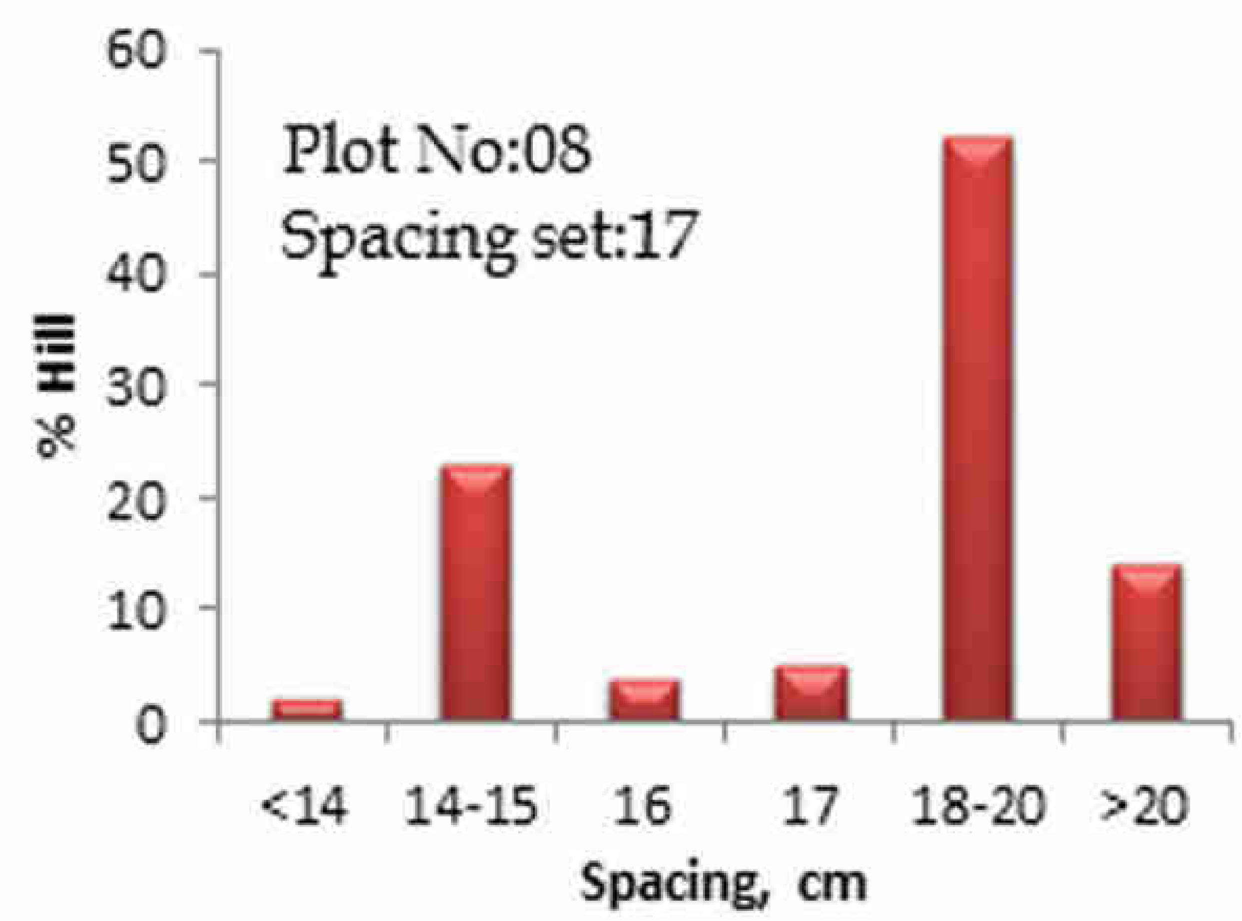

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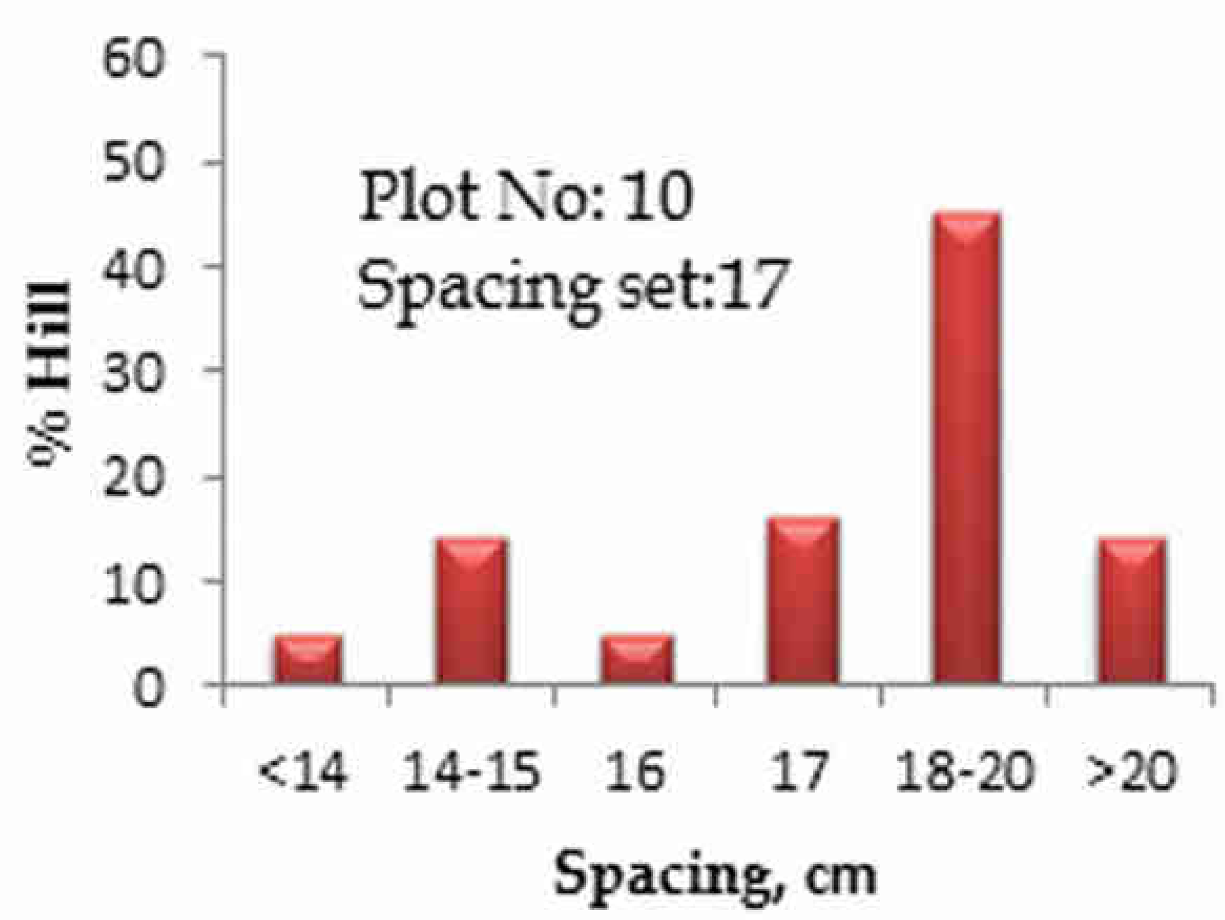

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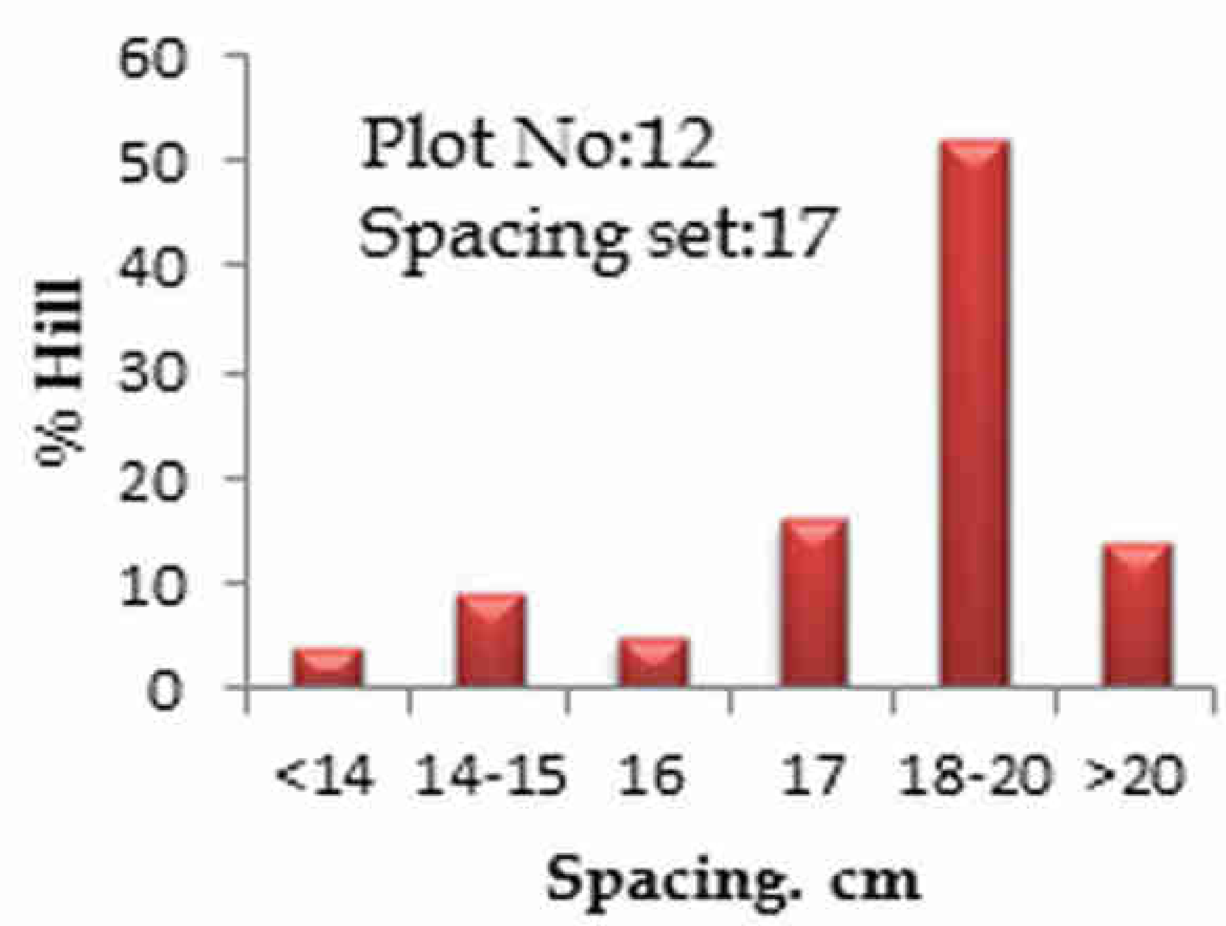
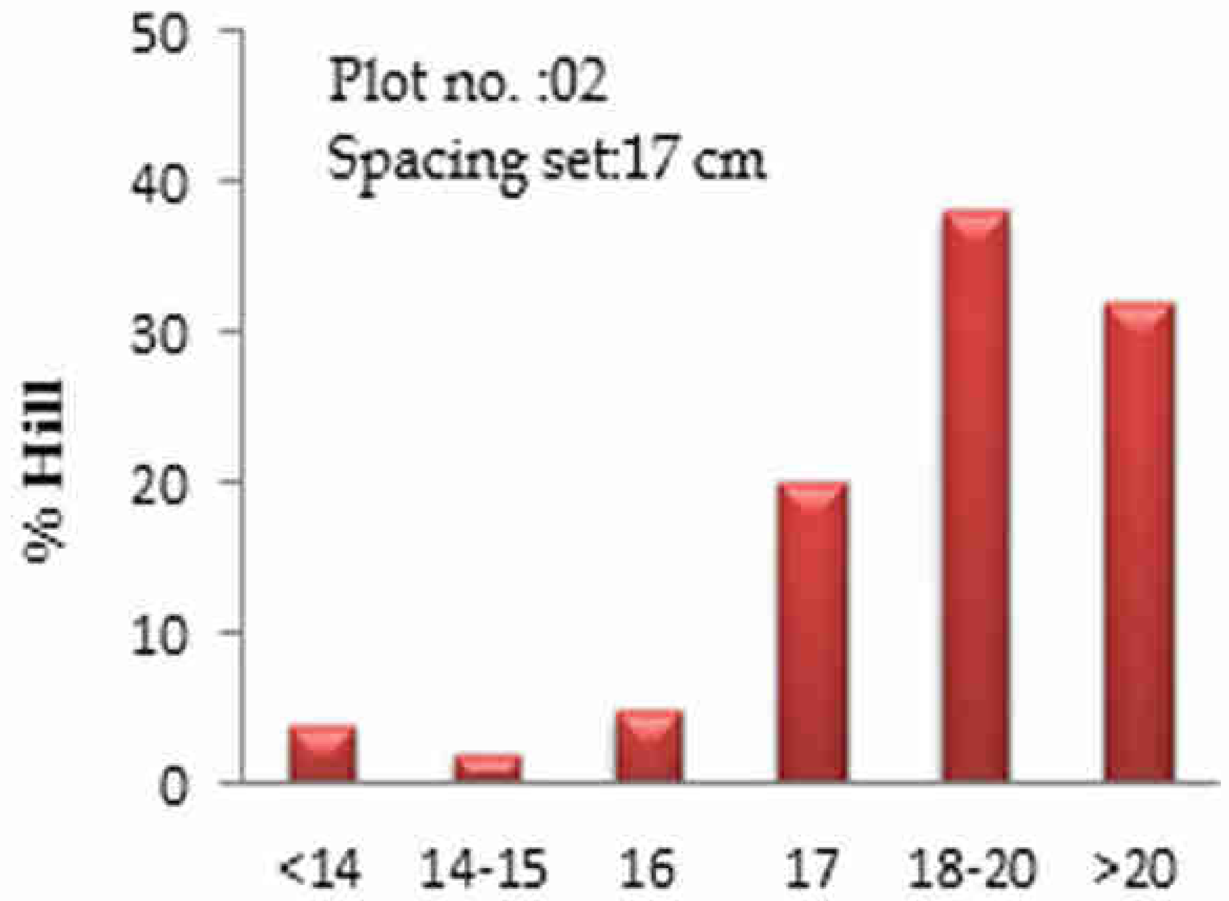


(f)

Fig. 4.2a: Distribution of seedlings spacing under plant space setting at Rangpur site



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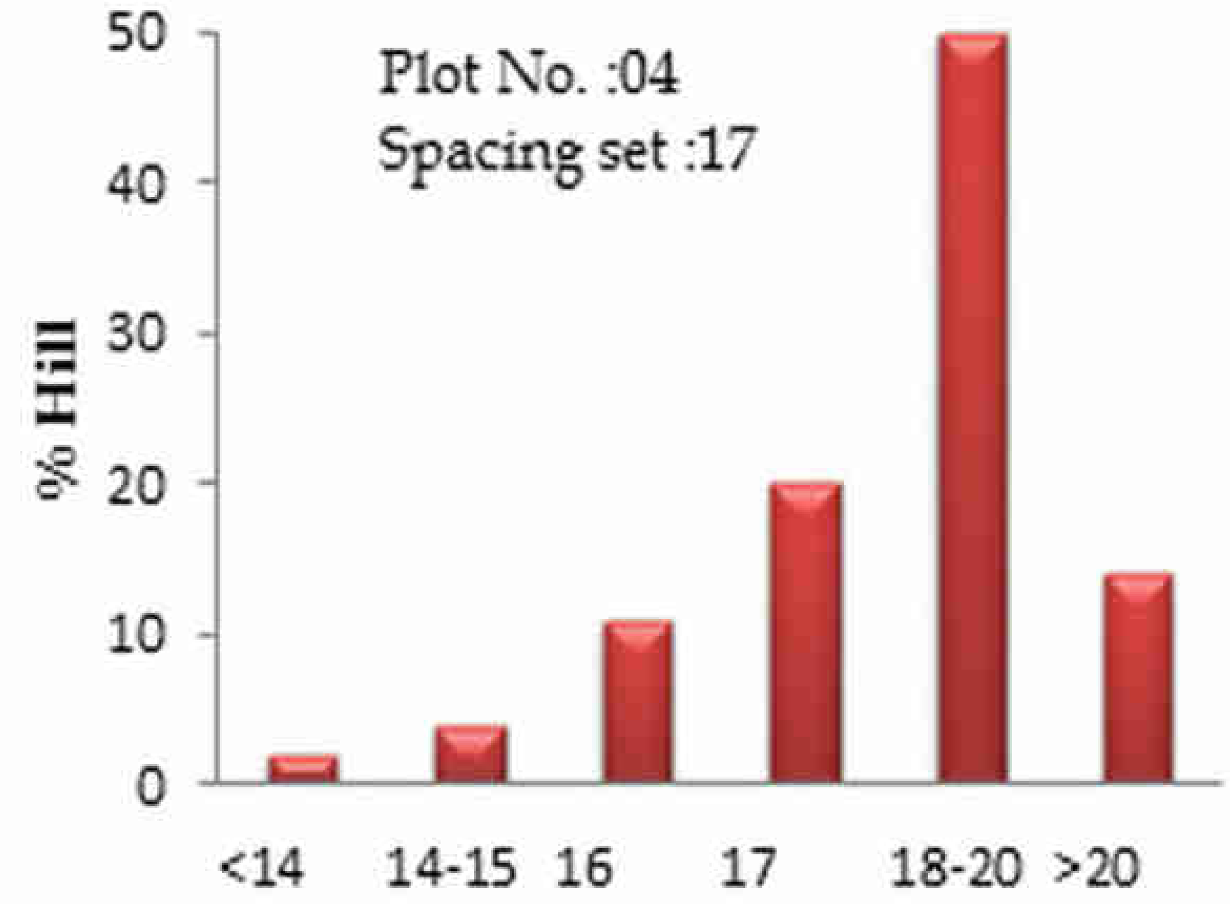

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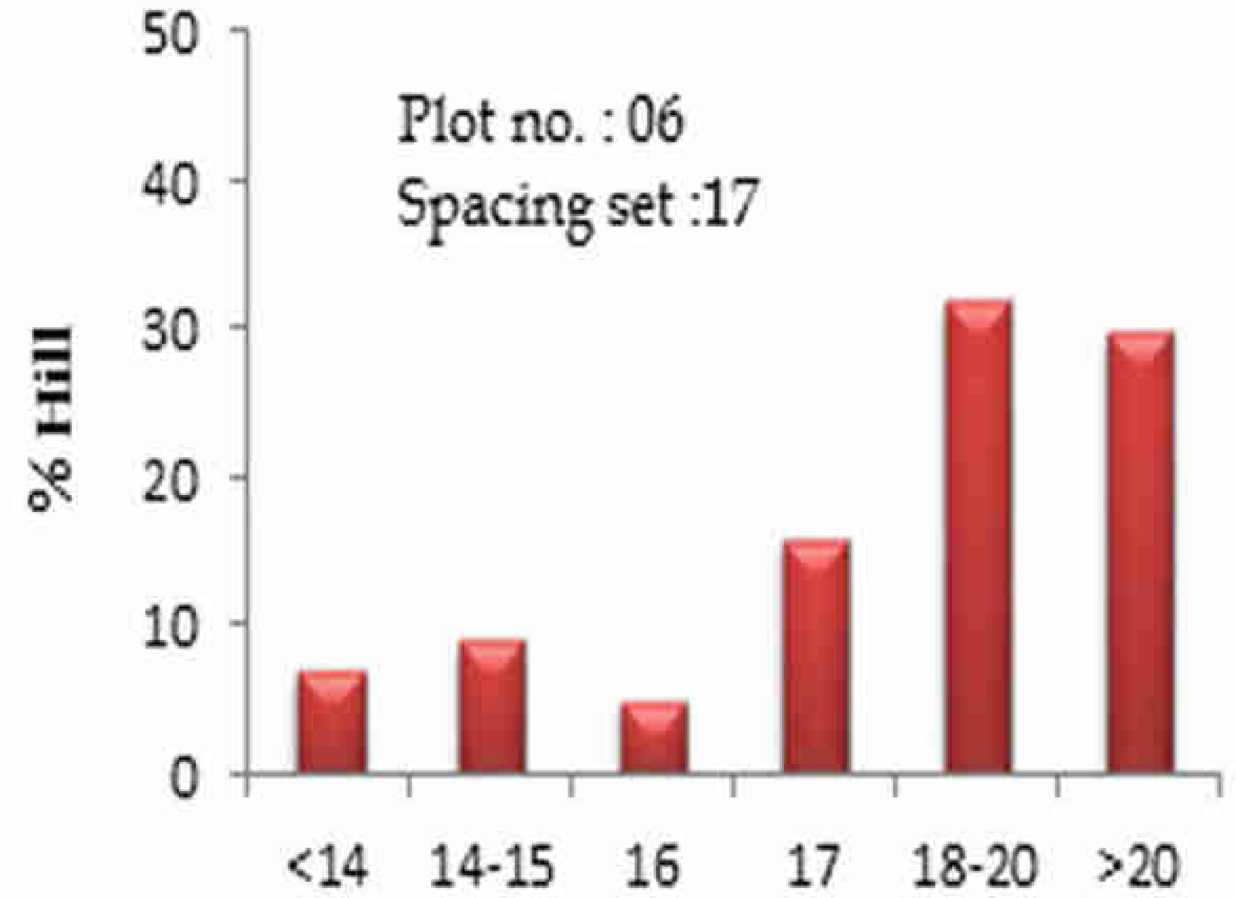

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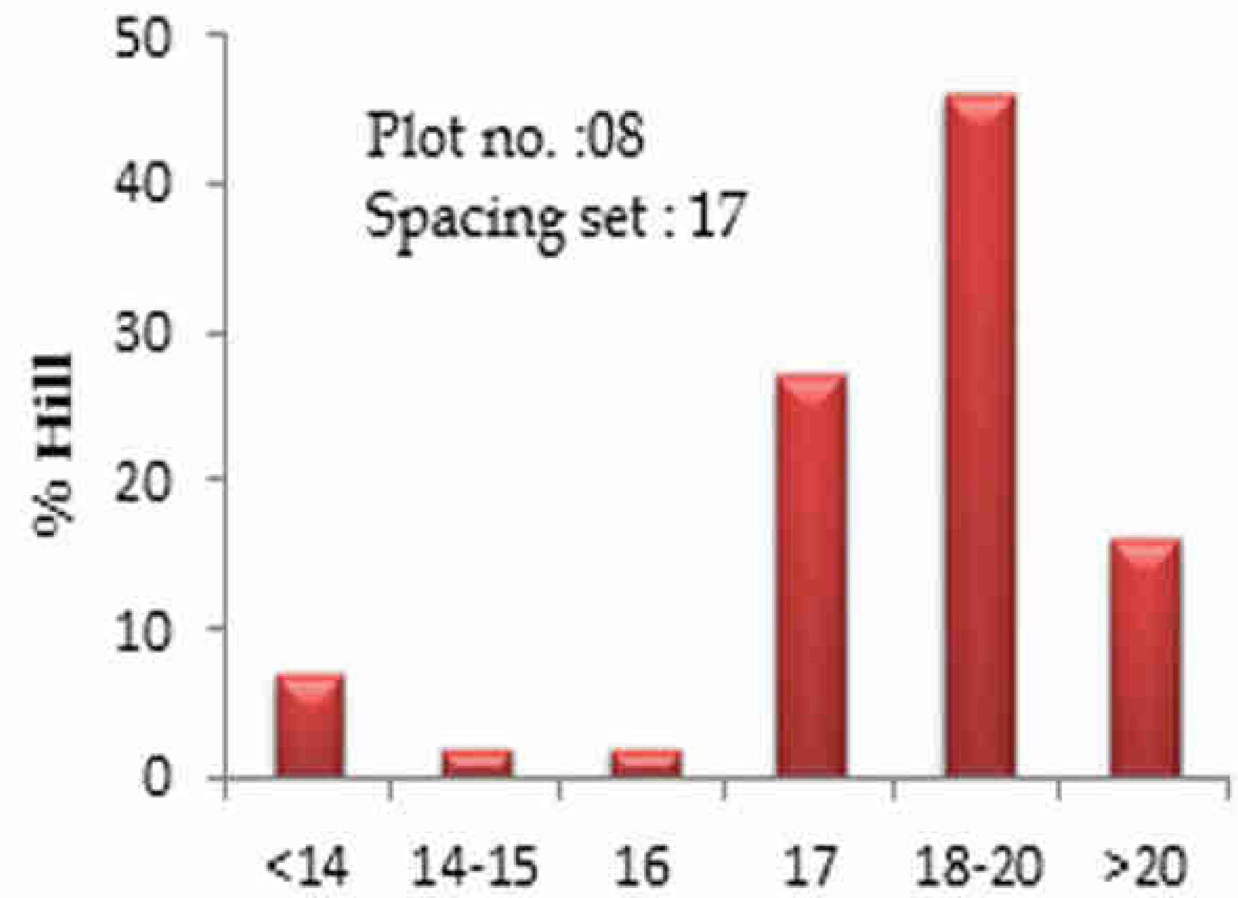

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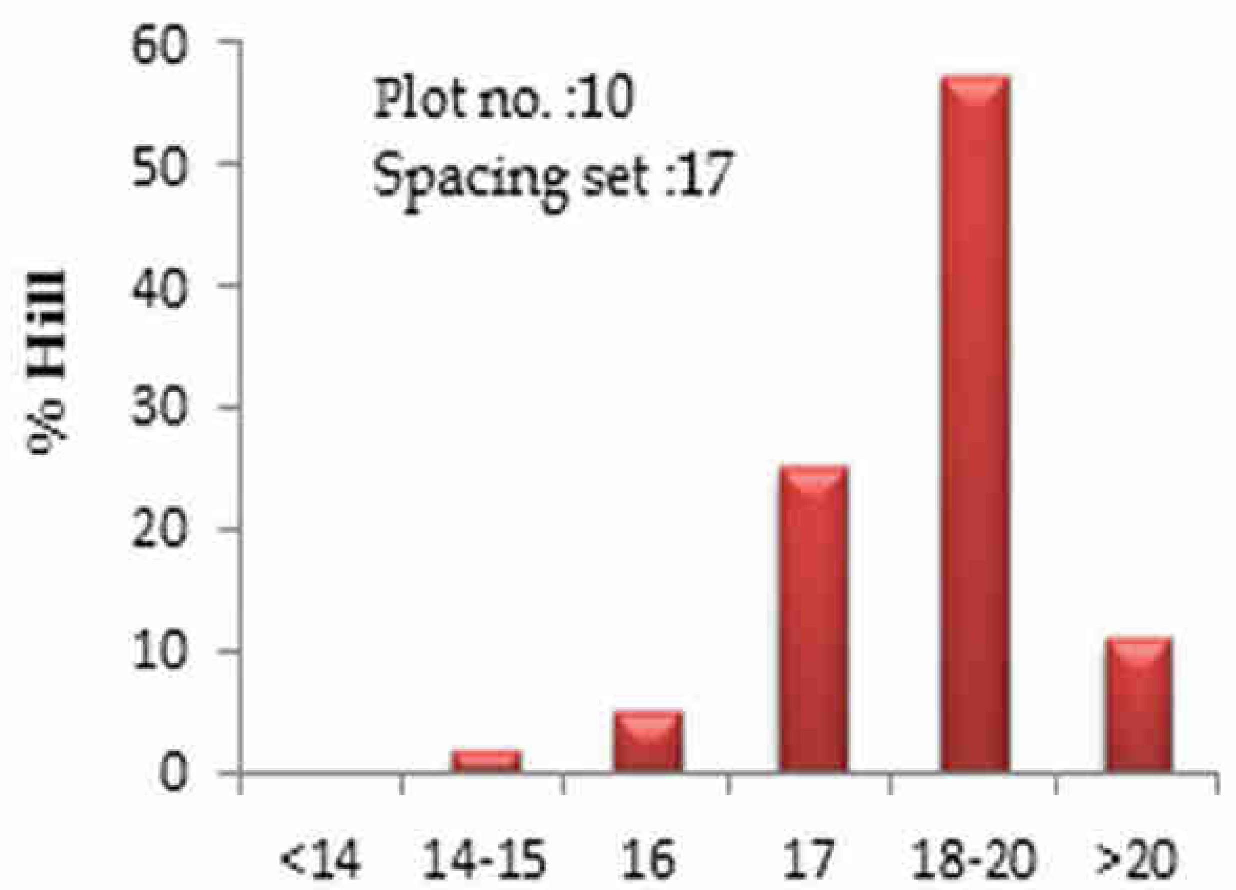

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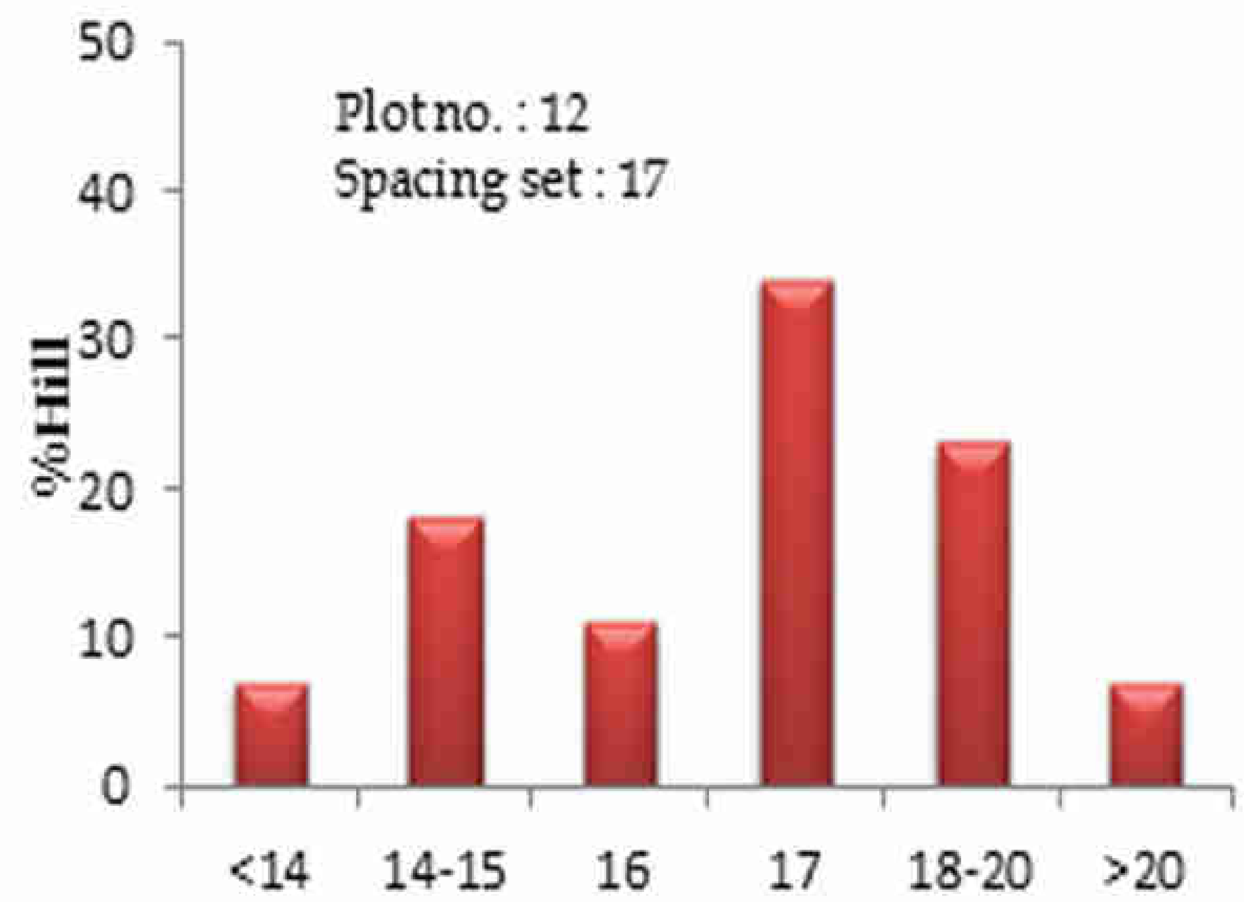


(f)

Fig. 4.2b: Distribution of seedlings spacing under plant setting at Jhenaidah site

4.6 Missing hill

In mechanical transplanting, missing hill observed 1-2% in both sites. Missing hill was insignificant in mechanically transplanted plot. Gap filling was done 3-4 days after transplanting.

4.7 Hill density

Fig. 4.3a and 4.3b showed the hill density of MT and HT. In mechanically transplanted plot, hill density obtained higher in Rangpur than Jhenaidah site. Hill density of MT was inconsistent in both locations. It might be due to slippage and skidding of the machine caused by water height, puddled depth and land leveling. In HT, hill density showed higher in Jhenaidah which might be due to laborers transplanted seedling by eye estimation and unable to maintain proper plant spacing. In both locations, plant to plant spacing observed highest and line to line spacing observed lowest in HT than MT.

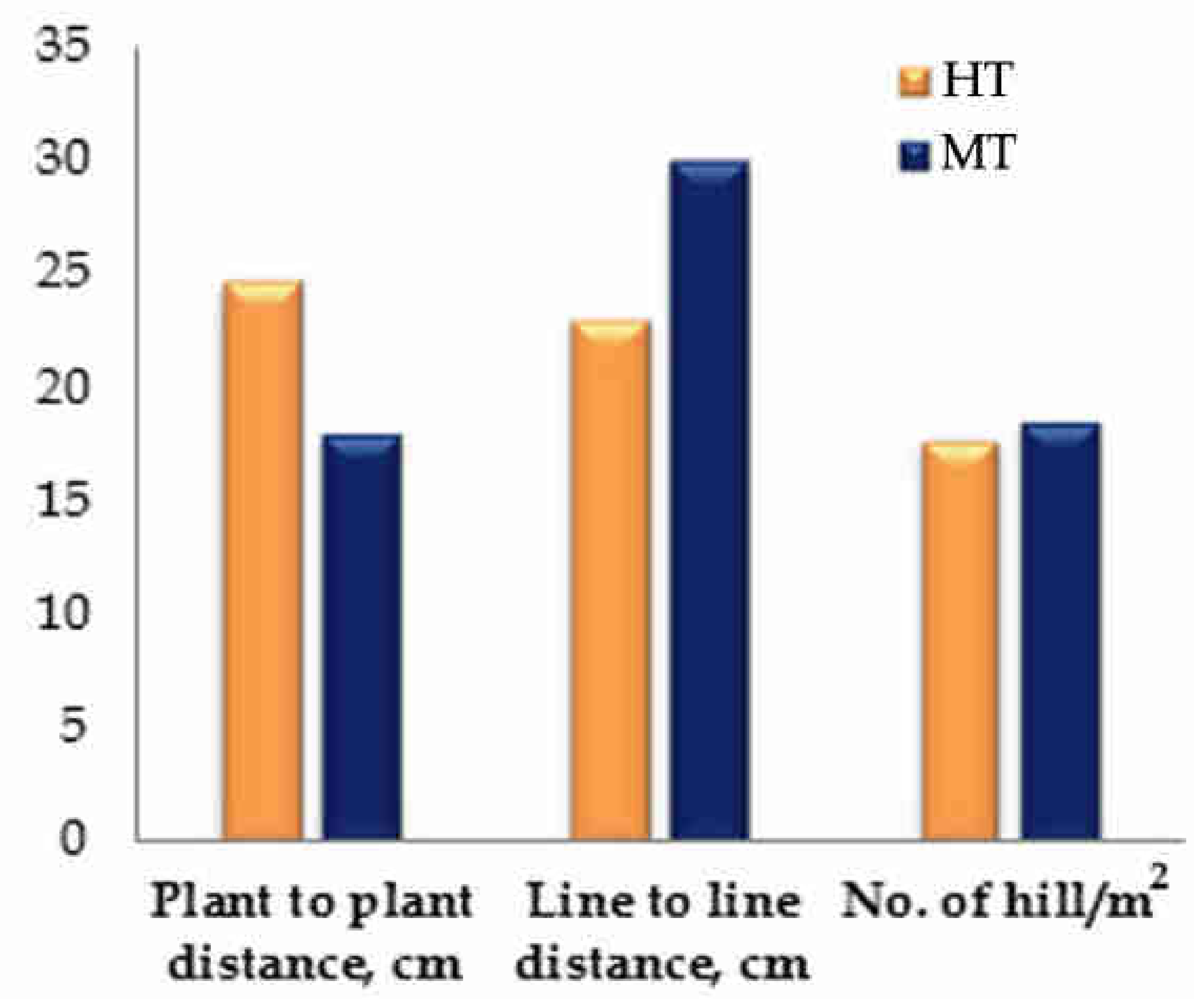


Fig. 4.3a: Hill density at Rangpur site

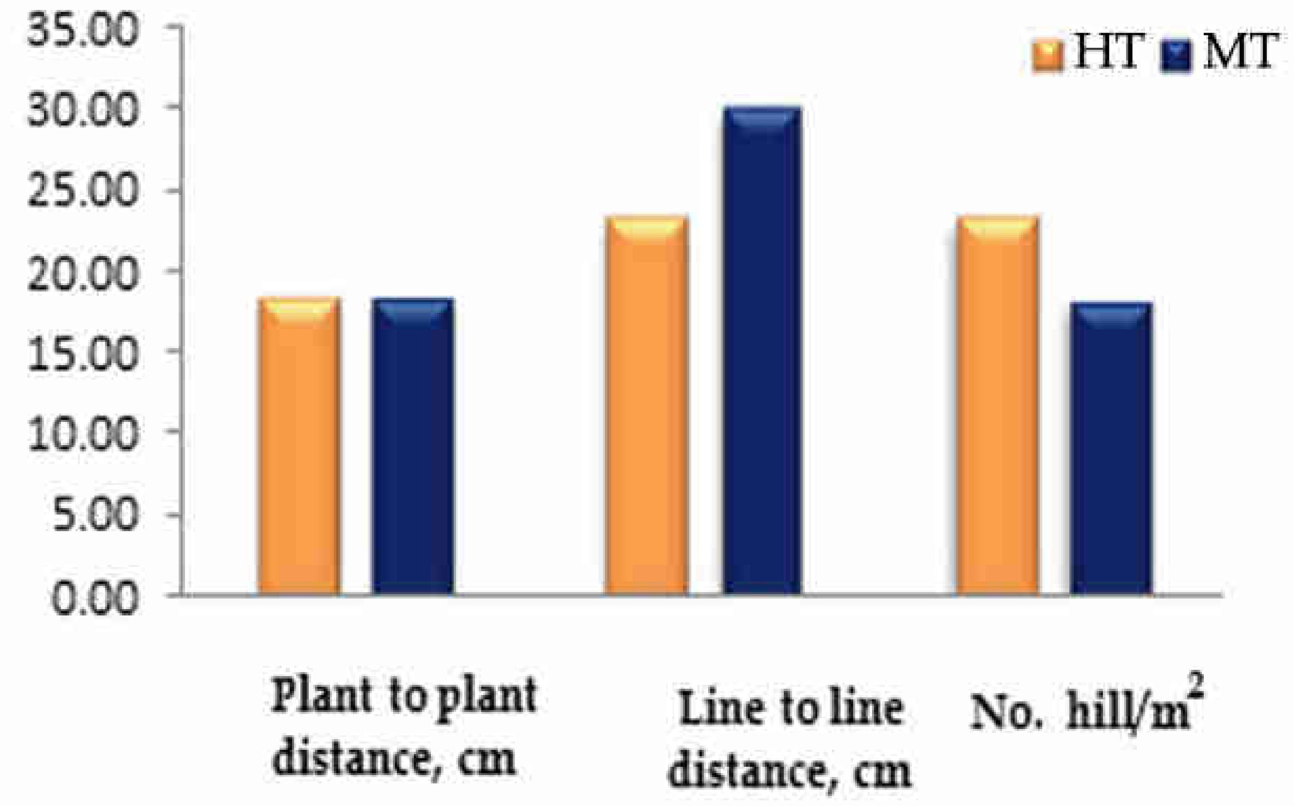


Fig. 4.3b: Hill density at Jhenaidah site

4.8 Number of seedlings dispensed per hill

Numbers of seedlings dispensed per hill in mechanically transplanted fields are given in Fig. 4.4a and 4.4b. Number of seedling dispensed per hill depends on the seedling density in tray and seedling density setting. Number of seedlings dispensed per hill varied in different plots. In most of the cases, 3-4 numbers of seedlings dispensed per hill. Single vigor seedling is enough to satisfy agronomic requirement. To avoid missing hill, number of seedling dispensed should be more than one.

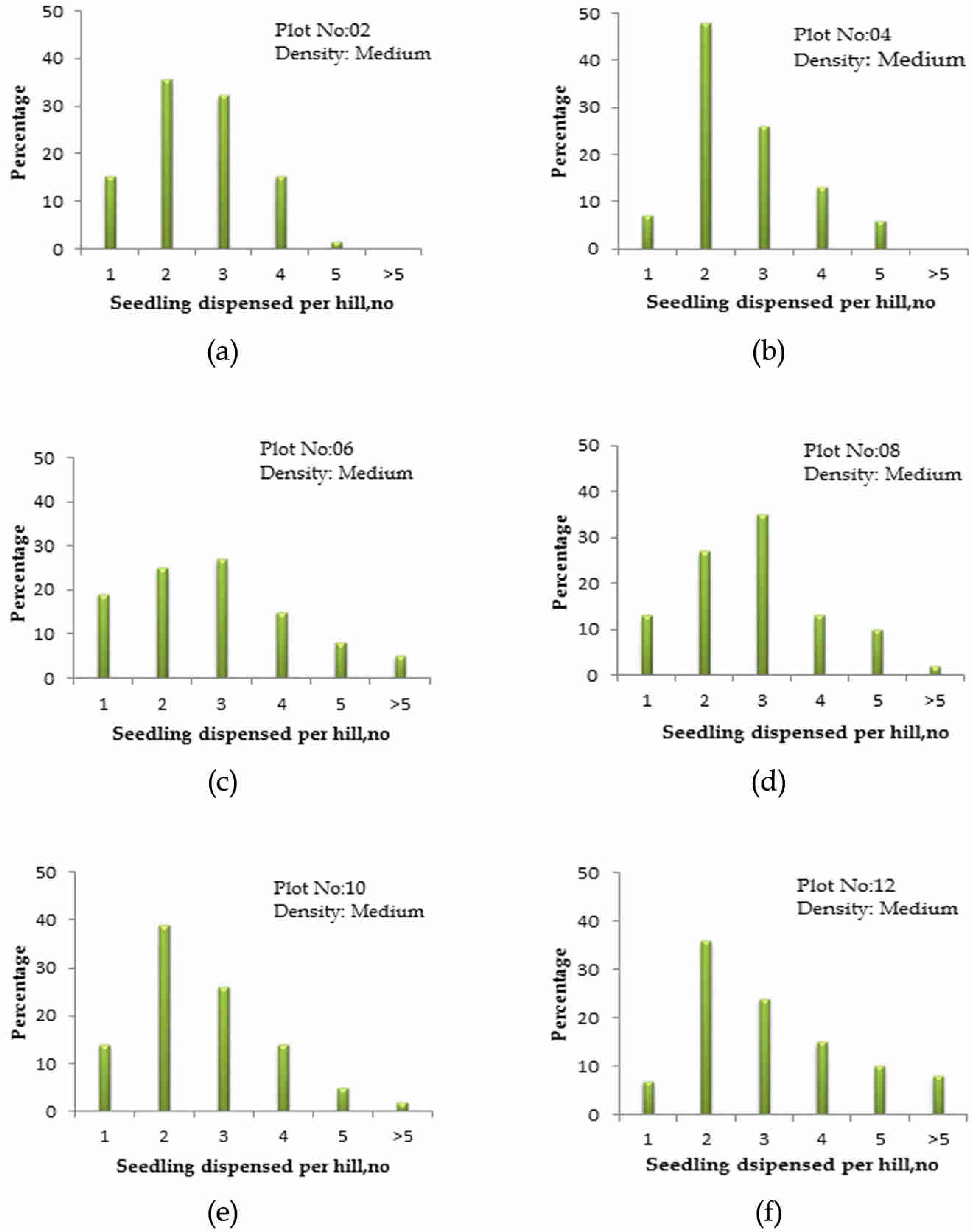


Fig. 4.4a: Seedling density in mechanical transplanted field at Rangpur site

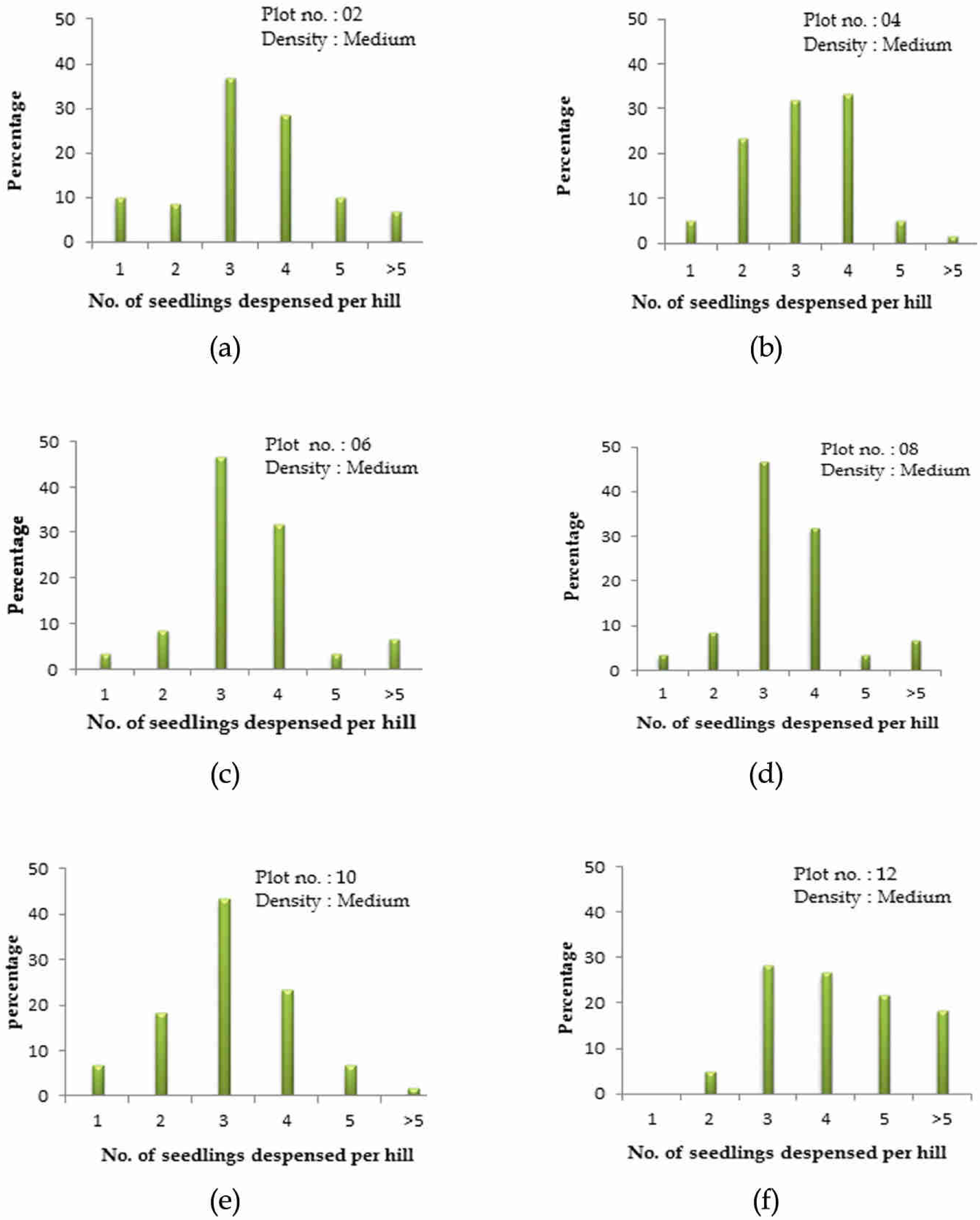
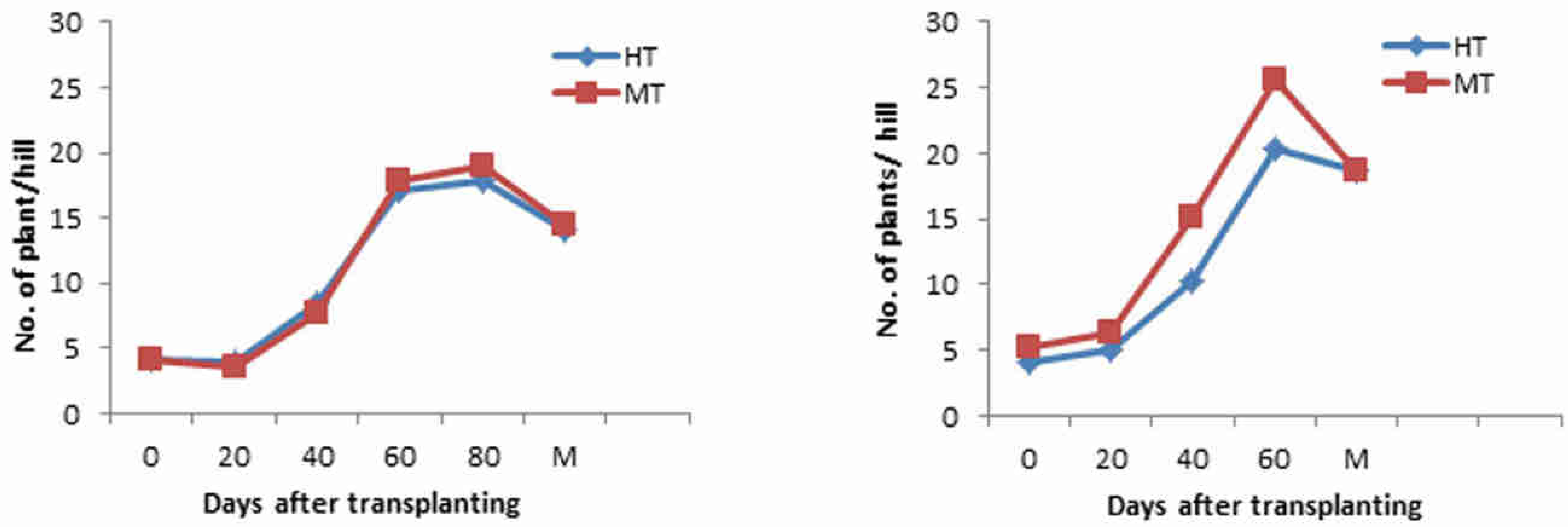


Fig. 4.4b: Seedling density in mechanical transplanted field at Jhenaidah site

4.9 Plant population per hill

Yield is closely related to plant population. Figure 4.5 shows that, plant populations followed increasing with time in both practices. Plant population showed higher in mechanically transplanted plots than hand transplanted plots up to 60 DAT.

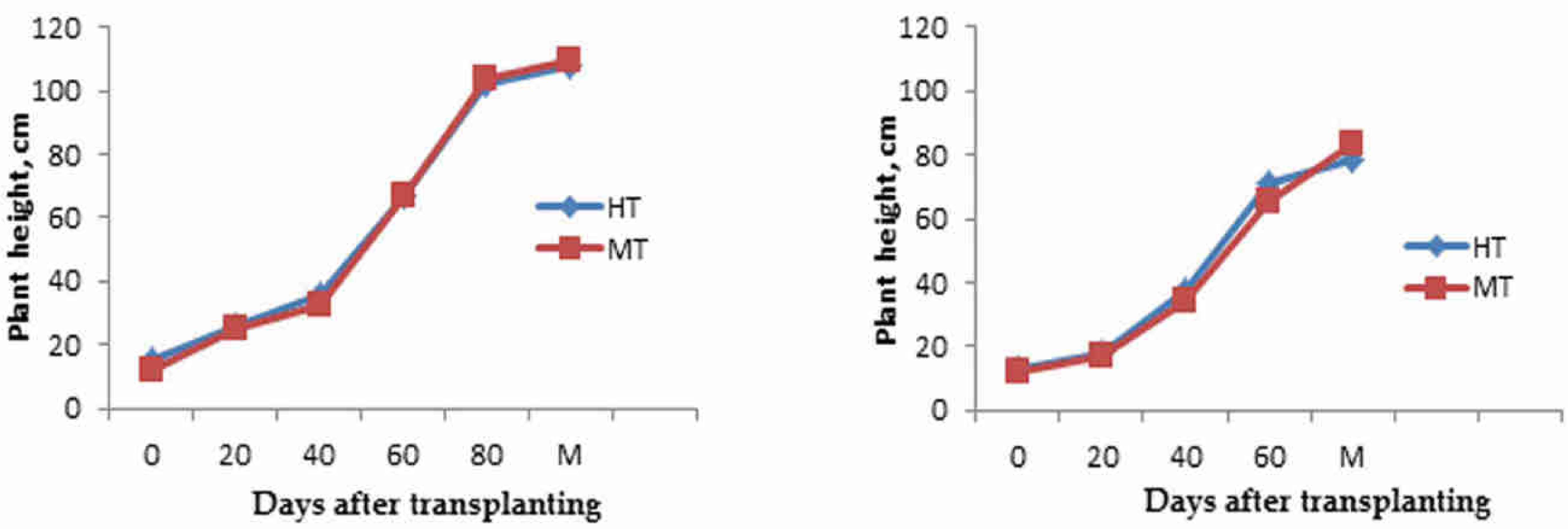


a. Rangpur **b. Jhenaidah**

Fig. 4.5: Hill density of mechanical and manual transplanting

4.10 Plant height

The effects of management practices at different days after transplanting gave significant effect on plant height. Plant height observed similar in both practices (Fig. 4.6). Plant height increased progressively overtime. Plant height followed rapid growth from 20 to 60 DAT in both practices.

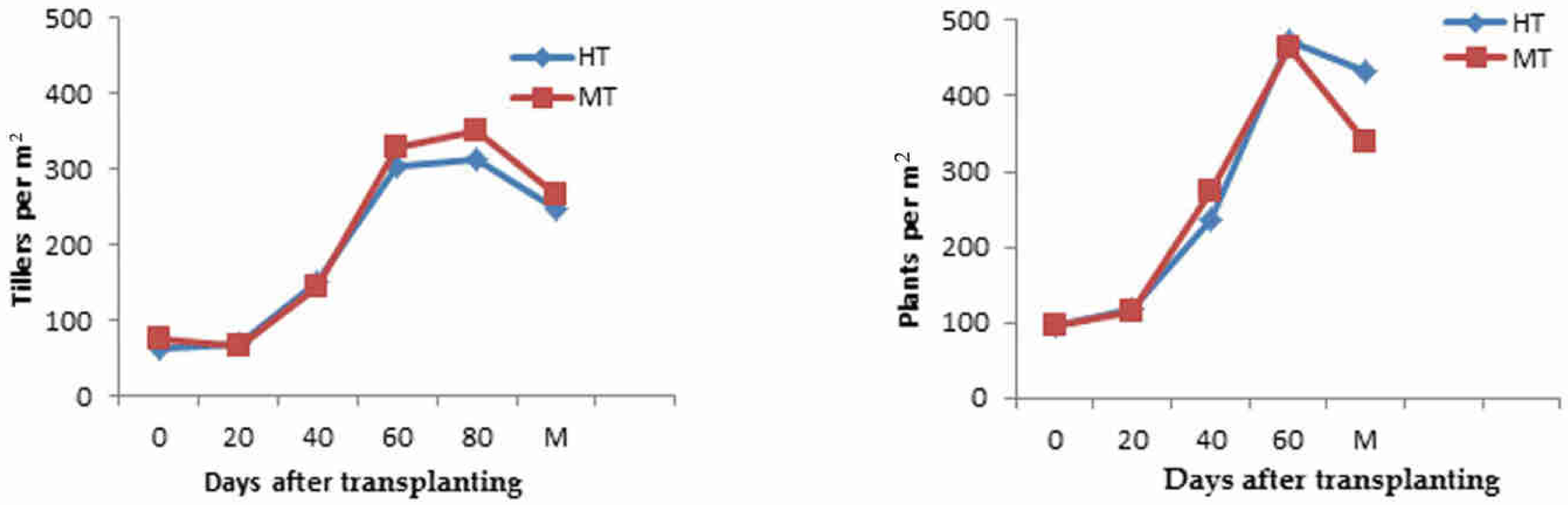


a. Rangpur **b. Jhenaidah**

Fig. 4.6: Plant height mechanical and manual transplanting

4.11 Tillering pattern

Tillering in rice (*Oryza sativa* L.) is an important agronomic trait for grain production. The effect of transplanting method on tillering pattern boro season rice in both method is shown in Fig. 4.7. In both practices, the tiller production sharply increased from 20 DAT and the maximum tillering stage reached in 60 DAT.

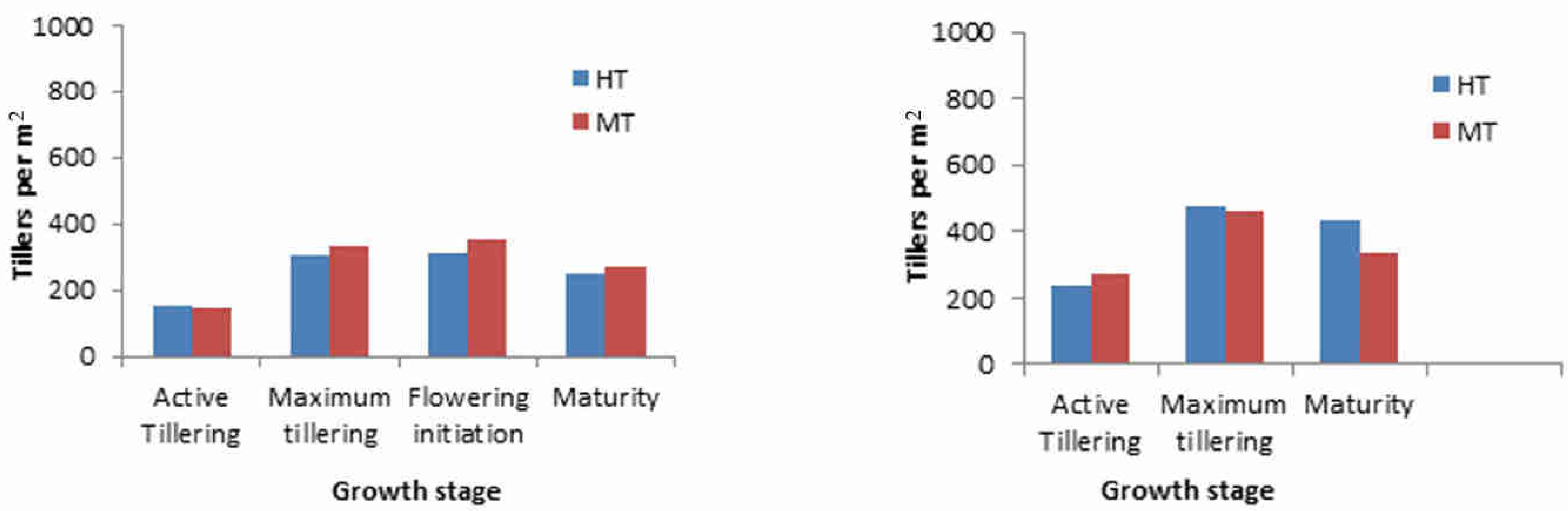


a. Rangpur **b. Jhenaidah**

Fig. 4.7: Tillering pattern of mechanical and manual transplanting

4.12 Stage-wise plant population

Fig. 4.8 showed the stage-wise tiller production under different practices. MT produced higher tillers at all the studied stages and it was more pronounced at maximum tiller stage.



a. Rangpur **b. Jhenaidah**

Fig. 4.8: Stage-wise plant population in mechanical and manual transplanting

4.13 Yield and yield contributing character

Grain yield is a function of interplay of various yield components such as number of productive tillers, grain per panicle and 1000-grain weight (Hassan et al., 2003). Data were statistically analyzed on treatments over location. Table 4.1 shows the yield and yield contributing character under two transplanting methods. MT produced significantly highest grain yield (9-14%) than HT in both locations due to use of tender age seedling. Grain yield of both practices showed less in Jhenaidah due to damage crop by hail storm. Hail storm occurred after maximum tillering stage (after 60 days of transplanting, 06-04-2015) and some crops revived within the panicle initiation stage. Transplanting methods showed significant effect on panicle length. MT produced longest panicle than HT in both site. Sterility percentage showed significantly higher in HT than MT. Combined effect of location and treatment showed insignificant on panicle number, grain per unit area and 1000 grain weight.

Table 4.1a Yield and yield contributing character

Location	Treatment	Grain yield, t/ha	Panicle, no./m²	Panicle length, cm	Grain, no./m²	Sterility, %	1000-grain mass
Rangpur	HT	5.05	211.50	21.21	18647.00	31.97	22.40
	MT	5.57	237.33	22.90	21305.50	29.68	22.32
Jhenaidah	HT	3.93	332.33	19.19	25461.30	26.47	23.06
	MT	4.50	265.50	20.79a	23223.50	17.83	22.11
CV, %		7.98	18.21	6.55	16.91	13.75	8.01
$LSD_{0.05}$	L	0.33	41.46	1.20	3260.82	3.17	NS
	T	0.33	NS	1.20	NS	3.17	NS
	L x T	NS	58.64	NS	NS	4.48	NS

4.14 Labor requirement in crop production

Effect of transplanting method on labor requirement is very important. Table 4.2 showed the labor requirement from seedbed preparation to winnowing in rice production. Total labor requirement for production of one hectare rice transplanting was 642-708 person hours for transplanting by hand and 542-606 person hours for mechanical transplanting. Labor requirement in manual transplanting ranged from 123-150 man-hr per hectare. It indicated that manual transplanting appeared as labor intensive works in rice production. Labor requirement in manual transplanting showed higher in Jhenaidah site due to maintain exact line to line and plant to plant spacing. It is not the common scenario whole over the country. In mechanical transplanting, labor requirement ranged from 9.5-10.5 man-hr per hectare in both sites. The labor requirement from seedling establishment to transplanting showed 179-187 man-hr/ha in HT and 81-87 man-hr/ha in MT i.e. 53-55% labor can be saved in mechanical transplanting if all other applications remain same.

Figure 4.9 shows that traditional seed preparation required 5-9% labor whereas 12-13% required in seedling raised in tray suitable for mechanical transplanting. Among the crop production stages, manual harvesting using sickle required highest (20-25%) labor. Manual transplanting required the second highest labor requirement (19-22%) in crop production whereas 1.65-2% labor required in mechanical transplanting. Mechanical intervention in crop production drastically reduced the labor requirement which can offset the peak labor demand.

Table 4.2 : Labor requirement in Hand and mechanical transplanting in two locations

Activity	Rangpur, man-hr/ha		Jhenaidah, man-hr/ha	
	Hand	Mechanical	Hand	Mechanical
Seedbed preparation	1.96	-	1.82	-
Seeding	0.35	-	3.59	-
Irrigation	24	-	24.01	-
Seedling uprooting	29.01	-	8.13	-
Seedling raising	-	-	-	-
Sieving,	-	6.93	-	10.73
Tray preparation	-	41.58	-	42.93
Seeding	-	4.79	-	10.31
Irrigation	-	18.07	-	13.3
Subtotal	55.32 (8.61%)	71.37 (13.15%)	37.55 (5.31%)	77.27 (12.76%)
Land preparation				
Tillage	8.53 (1.33%)	10.23 (1.88%)	9.04 (1.28%)	9 (1.49%)
Leveling	4.35 (0.68%)	4.74 (0.87%)	2 (0.28%)	2.02 (0.33%)
Transplanting	123.59 (19.24%)	9.86 (1.82%)	149.92 (21.19%)	10.02 (1.65%)
Weeding	99.99 (15.57%)	100.01 (18.43%)	170.01 (24.02%)	170.04 (28.08%)
Insecticide spray	9.96 (1.55%)	5.89 (1.09%)	5.01 (0.71%)	5.04 (0.83%)
Fertilizer application	3.68 (0.57%)	3.67 (0.68%)	3.97 (0.56%)	4 (0.66%)
Harvesting	129.97 (20.23%)	130.01 (23.95%)	149.95 (21.19%)	150.03 (24.78%)
Carrying	45.01 (7.01%)	44.99 (8.29%)	41.99 (5.93%)	42.02 6.94%
Threshing	109.99 (17.12%)	110.01 (20.27%)	80.35 (11.35%)	80.07 (13.22)
Winnowing	51.99 (8.09%)	51.96 (9.57%)	57.87 (8.18%)	56.04 (9.25%)
Total	**642.38**	**542.74**	**707.66**	**605.55**

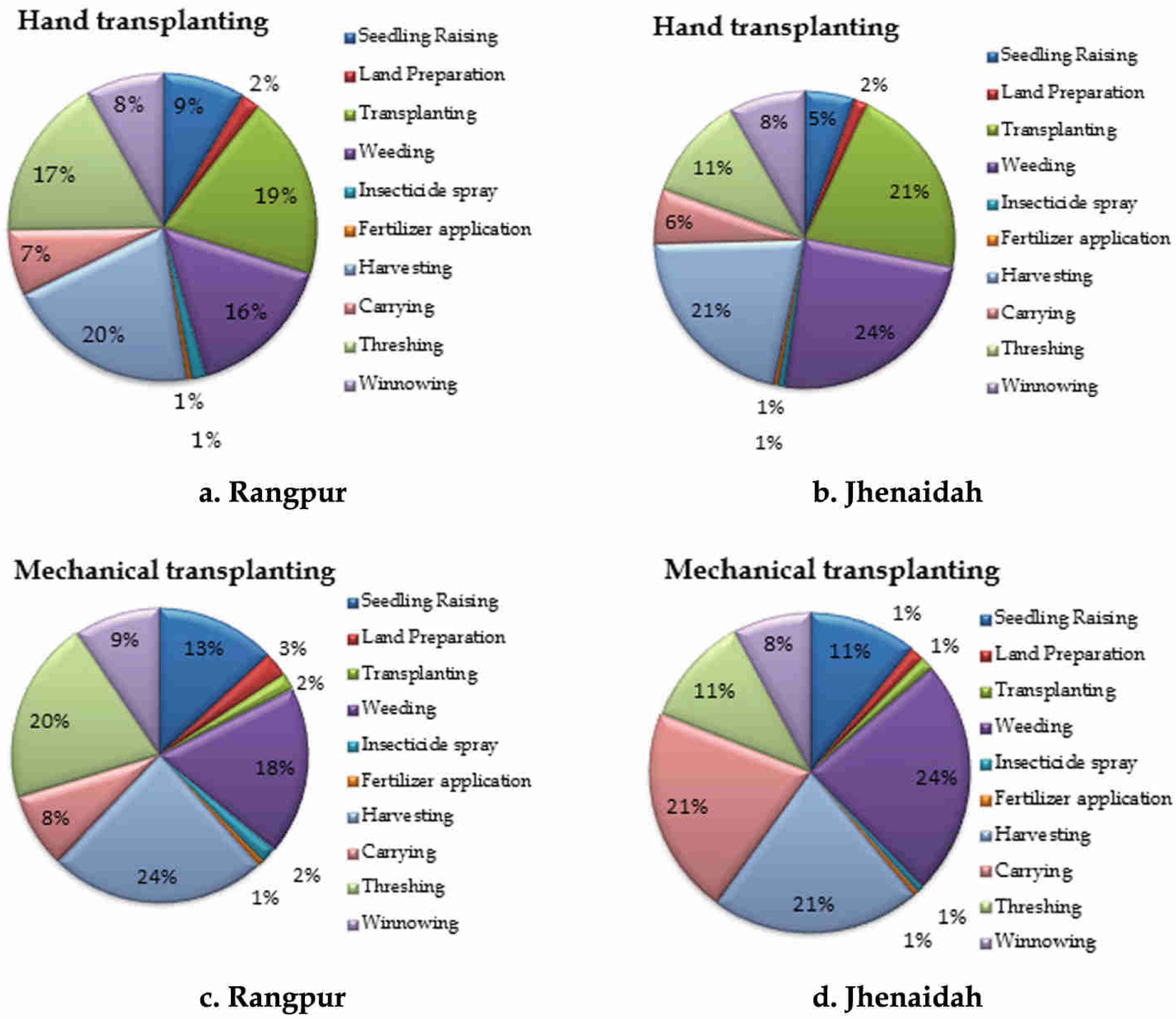


Fig. 4.9: Labor distribution in different activities

4.15 Economic analysis

4.15.1 Production cost

Table 4.4a and 4.4b showed the item wise costs of crop establishment and total production costs. Land preparation, irrigation, weeding, fertilizer, harvesting, carrying, threshing and winnowing costs were nearly same for both the transplanting method on both sites. Market price of the inputs and outputs are given in Appendix 3a-3c. Seed and transplanting cost varied depending on the transplanting method. Seedling raising cost in traditional method ranged from Taka 3174-4061 per hectare whereas, seedling raising cost in tray ranged from Taka 4516-5602 per hectare for mechanical transplanting. Seedling raising cost showed 10% higher in tray type than traditional method. Cost of Hand transplanting ranged from Taka 6179-7496 per hectare in both sites whereas, cost mechanical transplanting ranged from Taka 4013-4896 per hectare. Mechanical transplanter significantly reduced the transplanting cost. The total production cost in Hand and mechanical transplanting ranged from Taka 75,309-88,075 per hectare and Taka 75,133-86,338 per hectare, respectively.

Table 4.4a Cost of production under different transplanting methods in Rangpur

Activity	MT, Tk/ha	HT, Tk/ha
Seedlings raising	4,516	4,061
Land preparation	7,956	7,956
Transplanting	986	6,179
Machine rental charge	2,594	-
Fuel	433	-
Basal fertilizer	11,419	11,419
Urea application	184	184
Insecticide application	3,779	3,779
Weeding	5,000	5,000
Irrigation	10,500	10,500
Harvesting	6,498	6,498
Carrying	2,250	2,250
Threshing	5,500	5,500
Winnowing	2,600	2,600
Subtotal	**64,215**	**65,926**
Land value	20,000	20,000
Interest on investment	2123	2,149
Subtotal	**22,123**	**22,149**
Total production cost	**86,338**	**88,075**

Table 4.4b Cost of production under different transplanting methods in Jhenaidah

Activity	MT, Tk/ha	HT, Tk/ha
Seedlings raising	5,602	3,174
Land preparation	7,767	7,767
Transplanting	1,059	7,496
Machine rental charge	2,786	-
Fuel	1,051	-
Basal fertilizer	9,600	9,600
Urea application	200	200
Insecticide application	432	432
Weeding	8,500	8,500
Irrigation	1,500	1,500
Harvesting	7,500	7,500
Carrying	2,100	2,100
Threshing	3,210	3,210
Winnowing	1,993	1,993
Subtotal	**53,300**	**53,472**
Land rental charge	20,000	20,000
Interest on investment	1,833	1,837
Subtotal	**21,833**	**21,837**
Total production cost	**75,133**	**75,309**

4.15.2 Effect of transplanting method on labor and material cost

The input cost in the form of labor and material from seedling establishment to winnowing for mechanical and Hand transplanting are shown in the table 4.4. In Rangpur site, labor and material cost was almost similar in Hand transplanting whereas in mechanical transplanting, labor cost is 12% lower than material cost. In Jhenaidah, labor cost of both system showed highest compared to material cost due higher labor requirement in weeding and higher labor price.

Table 4.4: Cost comparison of mechanical and Hand transplanting in two locations

Parameter	Rangpur		Jhenaidah	
	Hand	Mechanical	Hand	Mechanical
Labor cost (Tk/ha)	33070 (50.16)	28629 (44.58)	35157 (65.75)	31148 (58.44)
Material cost (Tk/ha)	32855 (49.84)	35586 (55.42)	18315 (34.25)	22152 (41.56)
Total cost	**65973**	**63887**	**53819**	**52950**

*Figure in the parentheses indicate the percentage

4.15.3 Effect of transplanting methods on gross return and net return

Figure 4.10a and 4.10b showed the total production cost, gross and net return. The gross return was calculated based on the then market price of paddy and straw. In Rangpur site, the gross returns obtained Taka 1,03,038 and 93,418 per hactre for mechanical and Hand transplanting method where as in Jhenaidah site, the gross return obtained Tk 88,875 and 77,610 per ha for mechanical and Hand transplanting method. The net return showed Tk 16700 and 5343 per hectare for mechanical and Hand transplanting method in Rangpur site. The net return obtained Tk 13,742 and 2,301 per hactre for mechanical and Hand transplanting method in Jhenaidah site. From these results it could be concluded that Tk 11,357 and 11,441 per hectare should be saved for mechanical transplanting method over the Hand transplanting method in Rangpur and Jhenaidah site. The details data of the experiment are given in (Appendix 4a and 4b).

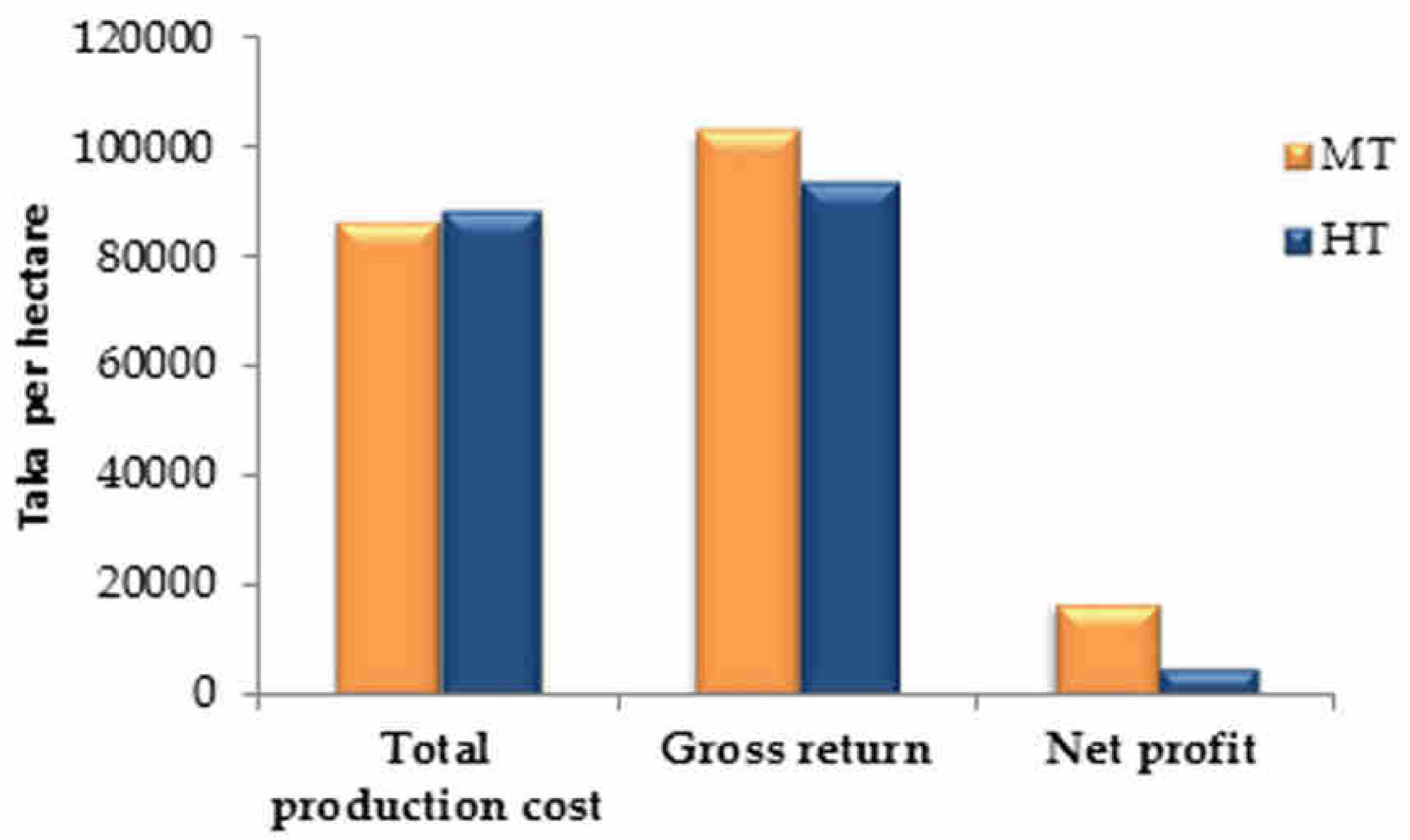


Fig. 4.10a: Effect of transplanting method on production cost, gross return and net profit at Rangpur

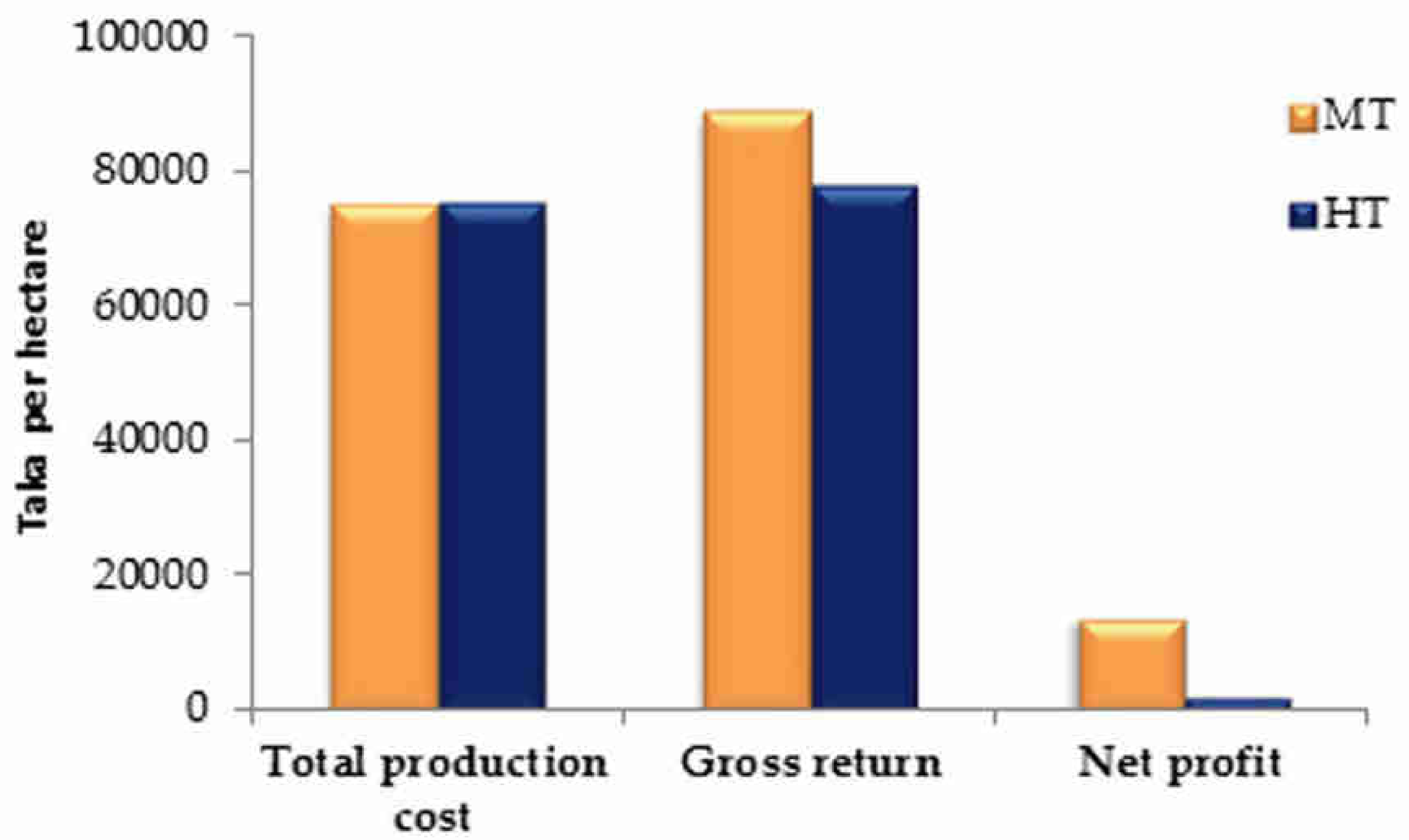


Fig. 4.10b: Effect of transplanting method on production cost, gross return and net profit at Jhenaidah

4.15.4 Effect of transplanting method on benefit cost ratio (BCR)

The BCR for different transplanting method is shown in the Fig. 4.11a and 4.11b.The lowest BCR was obtained in the Hand transplanting method and it was due to higher labor cost, higher seed rate and higher planting cost for labor crisis. The BCR obtained 1.19 and 1.18 for MT whereas, 1.06 and 1.03 for Hand transplanting method in Rangpur and Jhenaidah sites, respectively. BCR of MT showed 13-15% higher than HT due to lower input cost and higher grain yield (Appendix 4a and 4b).

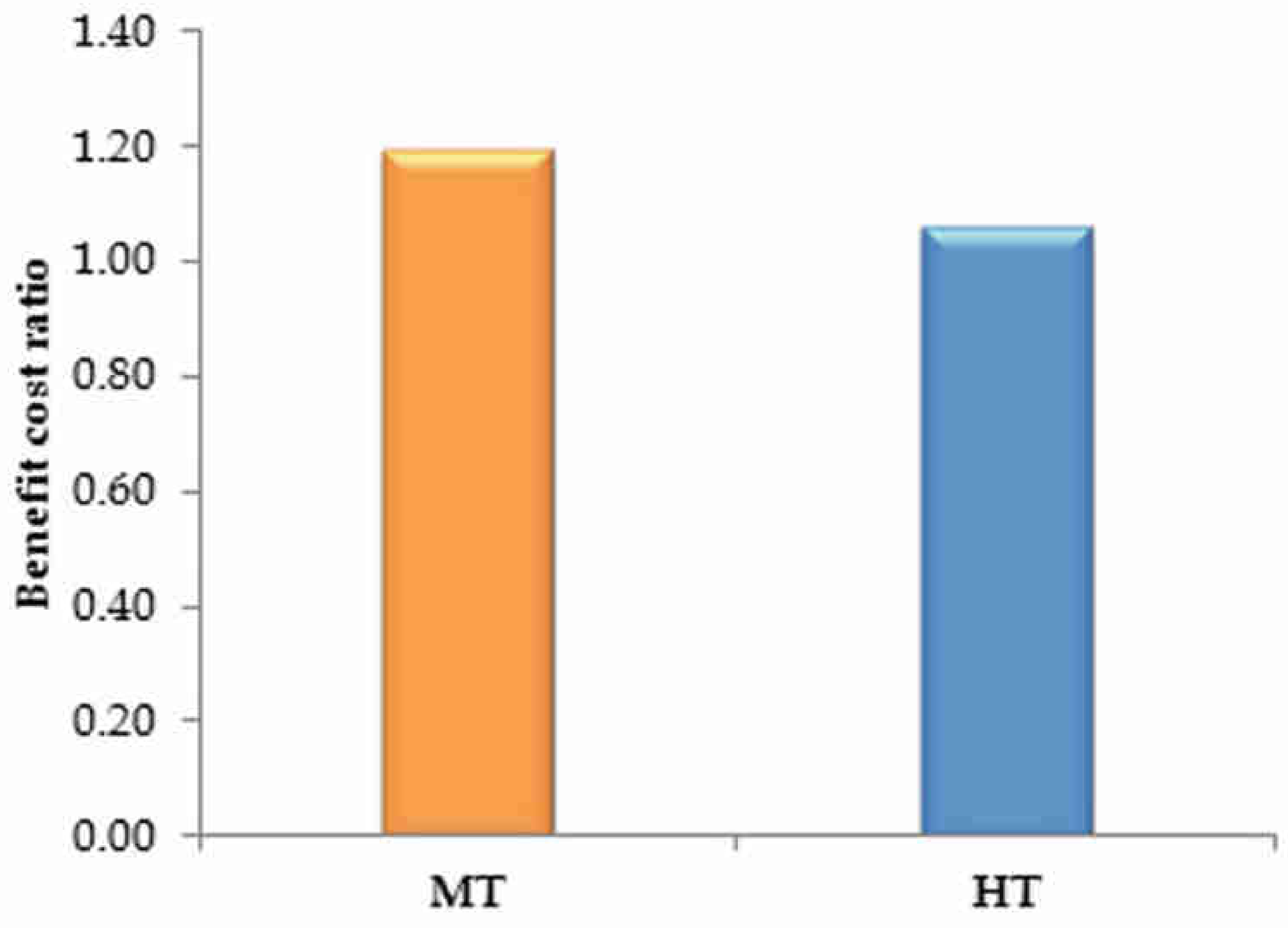


Fig. 4.11a: Effect of transplanting method on benefit cost ratio (BCR) at Rangpur

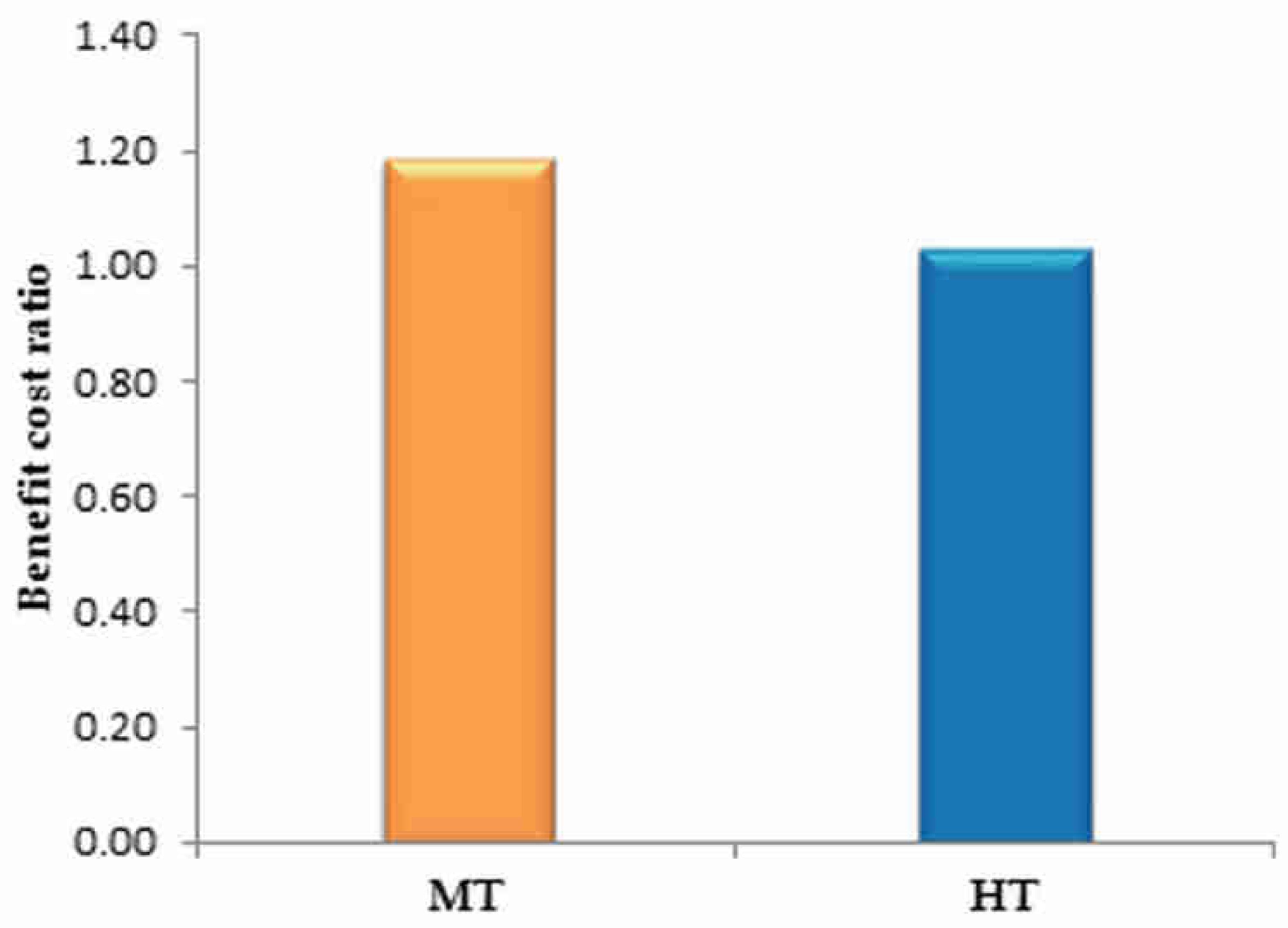


Fig. 4.11b: Effect of transplanting method on benefit cost ratio (BCR) at Jhenaidah

4.15.5 Rental charge

Rental charge was calculated based on fixed cost of transplanter machine. Machine value depreciated over time. Fixed cost was calculated based on purchase price, depreciation, salvage value, interest on investment repair and maintenance of the transplanter. The annual fixed cost of the transplanter was calculated as Tk 97,470. Rental charge largely depended on the annual use of the machine. Rental charge decreased with the increase in area coverage of transplanting (Fig. 4.12). Minimum rental charge of the machine may be offered Taka 268 for 50 days of annual use.

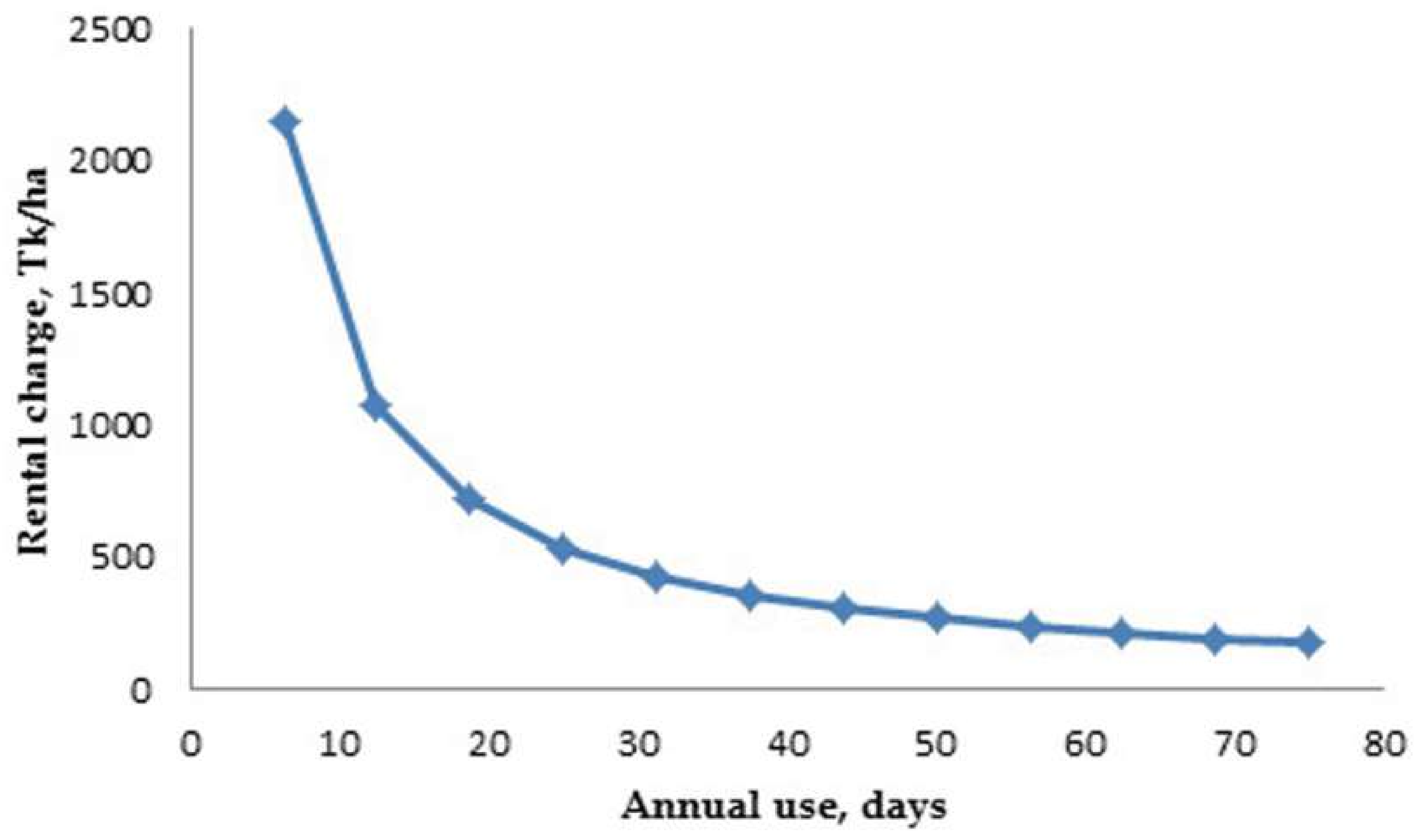


Fig. 4.12: Rental charge of the transplanter

Conclusion

Mechanical transplanting increase grain yield, reduce the production costs and improve labor efficiency. It can be concluded that mechanical transplanting method is economic than the Hand transplanting method.

Recommendation

- The results should be validated in different agro-ecological zone during cold and warm season.
- Extensive dissemination program of mechanical transplanting should be undertaken to create awareness among the farmers.
- Skilled operator should be developed for proper operation, repair and maintenance of the transplanter.

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Appendix 1a: Field trial of 4-row walking type mechanical rice transplanter at Mithapukur, Rangpur

Plot No.	Name of the farmers	Treatment	Date of seeding	Date of transplanting	Date of machine operation	Crop duration (Seeding to 30/04/15), days	Field duration (Transplanting to 30/04/15), days
01	Md. Harun	HT	29/11/14	10/01/15	-	151	110
02		MT	06/12/14	09/01/15	09/01/15	144	111
03	Md. Touhidul	HT	29/11/14	10/01/15	-	151	110
04		MT	06/12/14	09/01/15	09/01/15	144	111
05	Md. Shafiul	HT	29/11/14	10/01/15	-	151	110
06	Alam	MT	06/12/14	09/01/15	09/01/15	144	111
07	Md. Lal Mia	HT	29/11/14	10/01/15	-	151	110
08		MT	06/12/14	09/01/15	09/01/15	144	111
09	Md. Meradul	HT	29/11/14	10/01/15	-	151	110
10		MT	06/12/14	09/01/15	09/01/15	144	111
11	Md. Azadul	HT	29/11/14	10/01/15	-	151	110
12	Md. MonoerHossain	MT	06/12/14	09/01/15	09/01/15	144	111

Appendix 1b: Field trial of 4-row walking type mechanical rice transplanter at Sailakupa, Jhenaidah

Plot No.	Name of the farmer	Treatment	Date of seeding	Date of transplanting	Date of machine operation	Crop duration (Seeding to 30/04/15), days	Field duration (Transplanting to 30/04/15),days
01	Md.	HT	15/12/14	01/02/15		136	88
02	Nawsher Ali	MT	02/01/15	30/01/15	30/01/15	119	90
03	Md.	HT	15/12/14	31/01/15		136	89
04	Shahidul Islam	MT	02/01/15	30/01/15	30/01/15	119	90
05	Md.	HT	15/12/14	30/01/15		136	90
06	Mithul Mondol	MT	02/01/15	30/01/15	30/01/15	119	90
07	Md. Ikbal	HT	15/12/14	30/01/15		136	90
08	Mondol	MT	02/01/15	30/01/15	30/01/15	119	90
09	Md.	HT	15/12/14	31/01/15		136	89
10	Santu Rahman	MT	02/01/15	30/01/15	30/01/15	119	90
11	Md.	HT	15/12/14	31/01/15		136	89
12	Khairul Islam	MT	02/01/15	30/01/15	30/01/15	119	90

HT - Hand transplanting, MT - Mechanical transplanting

Appendix 2: Specification of DP-480 4-row mechanical rice transplanter

Itemized List			Specification
Model			DP480
Size	LXWXH	mm	2385x1530x870
	Weight	Kg	160
Engine	Engine Type		NA37
	Piston displacement	cc	148
	Gross Power	Ps/rpm	3/1800
Drive train	Tire	Front	612
		Transmission Type	
	Transmission Stage		3
	Speed	Ahead(km/h)	4.2
Working Efficiency		Min/10a	25~35

Appendix 3a: Unit price of fertilizer, herbicide and pesticide (Price year 2015)

Sl no.	Insecticide/herbicide	Unit	Tk unit^{-1}	Sl no.	Fertilizer	Unit	Tk unit^{-1}
1	Trooper	kg	900	4	Urea	kg	17
2	Nativo	kg	800	5	TSP	kg	22
3	Virtako	kg	15000	6	MP	kg	15
				7	Gypsum	kg	16
				8	Zinc	kg	150

Appendix 3b: Price list seed, grain and by-product (Price year 2015)

Sl no.	Crops	Seed rate, kg ha^{-1}	Price, Tk kg^{-1}		Tk bigha^{-1}
			Seed	Grain	Straw
1	Paddy	35	35	16.25	

Appendix 3c: Wage rate, water charge, fuel price (Price year 2015)

Sl no.	Activity	Unit	Tk unit^{-1}	Sl no.	Activity	Unit	Tk unit^{-1}
1	Land preparation	man-hr	50		**Machine rent**		
2	Seeding	man-hr	50	9	Transplanter	hr	263
3	Leveling	man-hr	50	10	Diesel	l	69
4	Transplanting	man-hr	50	11	Water	ha	10500
5	Weeding	man-hr	50	12	Land rent	ha/season	20000
6	Harvesting	man-hr	50	13	Interest rate	%	12
7	Threshing	man-hr	50				
8	Winnowing	man-hr	50				

Appendix 4a: Effect on transplanting method on gross return, net return and benefit cost ratio (BCR) at Rangpur

Treatment	Input cost, Tk/ha	Return from grain, Tk/ha	Return from straw, Tk/ha	Gross return, Tk/ha	Net return, Tk/ha	Benefit Cost Ratio (BCR)
	A	B	C=A+B	D	E	F
MT	86338	90513	12525	103038	16700	1.19
HT	88075	82063	11355	93418	5343	1.06

Appendix 4b: Effect on transplanting method on gross return, net return and benefit cost ratio (BCR) at Jhenaidah

Treatment	Input cost, Tk/ha	Return from grain, Tk/ha	Return from straw, Tk/ha	Gross return, Tk/ha	Net return, Tk/ha	Benefit Cost Ratio (BCR)
	A	B	C=A+B	D	E	F
MT	75133	78750	10125	88875	13742	1.18
HT	75309	68775	8835	77610	2301	1.03