MECHANIZED RICE TRANSPLANTING IN BANGLADESH

How to make it profitable

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Executive Summary

This documentation is in lended to summarize problems, prospects, investment and profitability of mechanical transplanting in Bangladesh.Transplanting is one of the labor intensive works in rice cultivation. Farmers faced labor shortage in peak time of transplanting and wage rate is high on that period. Sometimes, farmers were compelled to delay in transplanting which incurred yield loss. Mechanical rice transplanting is a new technology and gaining attention to the Bangladeshi farmers. Mechanically transplanted rice produced more grain yield than manually transplanted rice due to use of tender aged seedling. Rice transplanter is a sophisticated machine. It needs special knowledge to operate, repair and maintenance works. Farmers of Bangladesh are not aware of the benefit of using mechanical rice transplanter. Extensive demonstration works should be conducted elsewhere in the country to build-up the knowledge of mechanical rice transplanter. There is a lack of skilled operator and should be emphasized on the development of skilled operators. Practical hand-on training should be organized to develop a number of operators. They should be skilled especially in headland transplanting and maintaining straight line transplanting. The price of the transplanter is high, which is beyond the purchasing capacity of the ordinary farmers. Moreover, seedling should be raised in special type of trays. Development of entrepreneur might be the best solution to popularize this technology in the country. The proposed business model would be that the seedlings should be raised in the farmer's premises using their own seed and nursery will be managed by the farmers. The entrepreneur will provide training on to raise seedling in tray, nursery management and custom hire service of transplanter using the farmer's own seedlings. Government should provide sufficient assistance to the entrepreneur to procure transplanter and train them on operation, repair and maintenance of transplanter. It will generate rural employment opportunity in the country.

Acronyms and Abbreviations

ACI	Advanced Chemical Industries Limited
Aman	Paddy/Rice cultivated in rainy season (July to November)
Aus	Paddy/Rice cultivated in summer season (May to August)
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BCR	Benefit cost ratio
Boro	Paddy/Rice cultivated in winter season (January to May)
BP	Bed planting
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CT	Conventional tillage
DAE	Department of Agricultural Extension
DAS	Days after seeding
FMPHT	Farm Machinery and Postharvest Technology Division
GBK	Golden Barn Kingdom Pvt. Ltd
GoB	Government of Bangladesh
hp	Horse power
HT	Hand transplanting
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
MT	Mechanical transplanting
NGO	Non-government organization
NT	No-tillage
RDA	Rural Development Academy
rpm	Revolution per minute
ST	Strip tillage
Tk	Taka

TABLE OF CONTENTS

TABLE OF CONTENTS

Introduction

Bangladesh is facing serious challenge to feed and adequately nourish the millions of mouth. Yearly two million peoples are added in the country and land decreasing 80,000 ha annually. It is estimated that population will reach 215.4 million by 2050 (Kabir *et. al.,* 2016). The demand of clean rice grain by 2050 has been projected to reach 47.2 million ton at an anticipated per capita income growth rate of 2%. The farmers have to grow more food within the limited land resources to meet the growing demand. Rice, wheat, maize, jute and pulses are the major cereal crops grown in Bangladesh. Rice being the staple food of about 163.65 million people of Bangladesh and grown in about 11.35 million has in three distinct rice growing season- namely *boro* (Dec-April), *aus* (April-July) and *aman* (Aug-Nov) (Hussain *et. al.,* 2012). The yearly per-capita rice consumption is decreasing from 180 kg in 1977 (Ahmad and Hasan, 1983) to 148 kg in 2015 (Kabir *et. al.,* 2016). Rice provides about two-thirds of total calorie supply and about one-half of the total protein intakes of an average person in the country. About 75% of the total cropped area and over 80% of the total irrigated area is planted to rice. The cultivated land is decreasing at 0.40% but number of farms increasing at 2% per year. Average farm size is 0.5 ha and day by day decreasing but no sign of decreasing productivity. Average plots per farm are 3.2 indicating high degree of land fragmentation and average size of plots are 0.16 ha. Non-farm household number is increasing at 7% per year (Mandal, 2014).

Land area

Table 1 presents the land area coverage in agricultural and non-agricultural sector. Crop land includes land under cultivated, cultivable waste and currently fallow. Crop land area is decreasing 67% in 1976 to 60% in 2010. This indicated that crop land decreased more than five times as much during 2000 to 2010 compared to 1976 to 2000. In some *beel* and *haor* areas, single *boro* rice crops were grown after replenish water during winter season. Those lands are so soft and difficult to operate farm machines especially transplanter. The area under non-agricultural land increased to 24,00,867 ha (16.47%) in 2010 indicated that large area of agricultural land is converted to non-agricultural land, which is the challenge to increase crop production in limited land area.

Labor situation

Transplanting, weeding, harvesting and threshing are the four major labor intensive operations in rice cultivation. Manual paddy transplanting is the tedious, laborious and time consuming operations requiring about 123-150 man-hr ha^{-1}, which is roughly 19-22% of total labor requirement of rice production (Islam *et. al.,* 2015). 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. The agricultural labor force followed decreasing trend (48.3 % in 2002-03 and 45.1 % in 2013) whereas increased in non-agricultural sector (51.7% in 2002-03 and 54.9% in 2013) due to shifting low productivity to high productivity sector (BBS, 2015). The human stress and drudgery involved in transplanting operation is also very high.

Table 1 Area coverage under different land types

Land cover type	Year 1976		Year 2000		Year 2010	
	Area, ha	% of total	Area, ha	% of total	Area, ha	% of total
Agricultural land	**13,303,654**	**91.83**	**12,742,274**	**87.69**	**12,176,904**	**83.53**
Crop land	9,761,450	67.38	9,439,541	64.96	8,751,937	60.04
Forest	1,754,917	12.11	1,311,121	9.02	1,434,136	9.84
Mangrove forest	452,444	3.12	486,791	3.35	441,455	3.03
River	911,819	6.29	888,441	6.11	939,073	6.44
Lake	50,829	0.35	58,261	0.40	51,739	0.35
Beel&haor	239,977	1.66	251,774	1.73	250,727	1.72
Aquaculture	582	0.00	143,506	0.99	175,663	1.21
Tea estate	119,847	0.83	138,533	0.95	96,152	0.66
Salt pan	11,789	0.08	24,306	0.17	36,022	0.25
Non-agric. land	**1,183,605**	**8.17**	**1,788,307**	**12.31**	**2,400,867**	**16.47**
Rural settlement	885,637	6.11	1,458,031	10.03	1,766,123	12.12
Urban & industrial	26,799	0.18	47,495	0.33	87,616	0.60
Accreted land	271,169	1.87	282,781	1.95	547,128	3.75
Total	**14,487,259**	**100**	**14,530,581**	**100**	**14,577,771**	**100**

Source: Hasan *et. al.,* (2013)

Need of mechanical transplanter

Transplanting of rice crops is the most important agricultural operation. 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. It was reported that a delay in transplanting by one month reduces the yield by 25% and a delay of two months reduced the yield by 70% (Rao and Pradhan, 1973). Ergonomic studies suggest that the manual work for transplantation is taking toll on human body. The works related to musculoskeletal disorders (WMSDs) have also become a major problem in many countries. Musculoskeletal disorders are common among these workers especially lower and upper back disorders due to bending and squatting body posture in manual rice transplanting and uprooting activity (Hagberget. al., 1995). The mechanical rice transplanting has been considered the most promising option, as it saves labor, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Mechanically transplanted plot showed significantly higher grain yield (9-14%) than hand transplanted method due to use of infant seedling and better planting efficiency (Islam *et. al.,* 2015). 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 operation.

Mechanical rice transplanter

Development history of transplanter

Rice transplanters were first developed in Japan in 1960s, whereas the earliest attempt to mechanize rice transplanting dates back to late 19th century. In Japan, development and spread of rice transplanters progressed rapidly during 1970s and 1980s. Rice transplanter is a specialized transplanter fitted to transplant rice seedlings onto paddy field. A common rice transplanter comprises a seedling tray like a shed roof on which mat type rice nursery is set; a seedling tray shifter that shifts the seedling tray like a carriage of type writers; and plural pickup forks that pick up a seedling from mat type nursery on the seedling tray and put the seedling into the soil, as if the seedlings were taken between human fingers. Labor requirement in manual and mechanical transplanting ranged from 123-150 and 9.0-10.5 man-hr ha^{-1} which was 19-22 and 1.65-2.00% of total labor requirement in rice cultivation, respectively (Islam *et. al.*, 2015). Mechanical transplanting requires considerably less time and labor than manual transplanting. It increases the approximate area that a person can plant from 7000 to 10,000 m^2 in South Korea per day.

Classification of rice transplanter

Category

Transplanters can be classified based on two parameters:

- Type of nursery requirements
- Nature of prime mover

On the basis of nursery

- Washed seedling transplanter
- Mat-type seedling transplanter

Washed seedlings

- Use washed roots seedling on mat that has four to six leaves appearance about 20 to 30 cm long washed at time of transplanting.
- In some instance, overgrown roots are pruned to facilitate easier transplanting operation requiring about 175 people per hour per ha.

Mat-type

- The seedlings are raised on trays by spreading pre-germinated seeds on the soil of thickness 1.5-2.0 cm and allowed to grow 11-14 and 25-30 days in warmand cold environment, respectively.

On the basis of prime mover requirements

- Manual transplanter
- Self-propelled transplanter -Walking and riding
- Animal drawn transplanter
- Tractor mounted transplanter

Many years ago, BADC used manual rice transplanter in their farms in limited scale. This machine requires much pulling force. Animal and tractor mounted transplanter were not introduced in the country. Walking type transplanter is comparatively cheaper and handy machine. Basic characteristics of the ride on and walking type transplanter are given below.

Basic feature of ride on rice transplanter

The DAEDONG rice transplanter is imported by ACI motors limited, Bangladesh (Photo 1). Photo 2 shows the depth, seedling density and space setting. Table 2 shows the specification of the ride on rice transplanter. The present market price of the Korean made DAEDONG 6-row ride on type transplanter is Tk 14,00,000.

Photo 1 Riding type rice transplanter

a. Depth setting

b. Seedling density setting

c. Plant to plant space setting

Photo 2 Machine setting

Table 2. Specification of riding type rice transplanter

Country of origin			People's Republic of Korea
	Model		DAEDONG Rice Transplanter
	Type		Ride
	Overall length (mm)		3120
	Overall width (mm)		2140
	Overall height (mm)		1655
	Overall weight (kg)		620
Dimensions		Type	4-stroke, air-cooled OHV gasoline
	Displacement (CC)		437
	Maximum output kW/rpm		10.5/3600
	Fuel tank capacity (L)		15-20
	Starting method		Electric motor start mode
	Steering		Hydraulic power steering mode
Traveling section	Tires	Front	Anti-puncture tire
		Diameter, mm	650
		Rear	Solid rubber
		Diameter, mm	900
	Gearshift	Forward	2 speeds (Steeples variable speed)
		Reverse	1 speed
Transplanting section	Transplanting mechanism		Rotary type
	Number of rows		6
	Transplanting distance, cm Row to row		30
	Transplanting distance, cm (plant to plant)		14, 16, 19, 22
	Planting pitch control		Adjustable
	Planting depth control		Adjustable
	Planting depth, cm		0.8-4.4
	Number of spare seedling rack		6
	Transplanting speed, m/sec		0 to 1.36

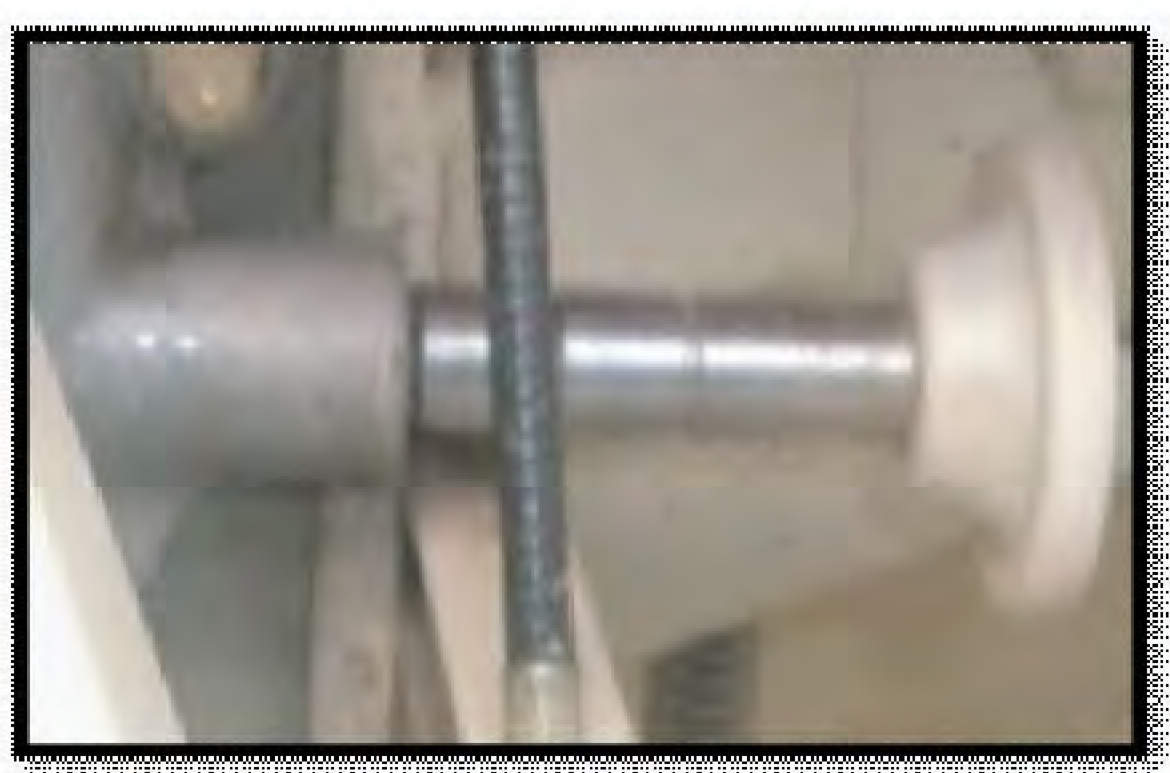
Basic features of walking type rice transplanter

Self-propelled four-row walking-type rice transplanter of different makes and models are imported by ACI motors limited, The Metal (Pvt.) limited and Corona tractors limited. Photo 3 shows the DP480 model 4 row walking type transplanter. It has a fixed row spacing of 30 cm and has provisions for adjustments of planting depth, number of seedlings per hill, hill spacing and planting speed (Photo 4). Table 3 presents the specification of the walking type rice transplanter. The present market price of the Korean made 4-row walking type transplanter is Tk 4,00,000.

Photo 3 Four-row walking type rice transplanter

a. Seedling density control lever

b. Depth control lever



c. Spacing control lever

Photo 4 Machine setting

Table 3. Specification of walking type rice transplanter

Country of origin	South Korea
Model	DP480
Engine power, hp	3
Engine revolution, rpm	2000
Total engine displacement, cc	150
Fuel	Petrol
Gear	2 forward, 1 reverse
Transplanting rows	4
Hill spacing, cm	13, 15, 17
Starting mechanism	Recoil starting

World situation of mechanical transplanting

Although rice is grown in areas other than Asia, rice transplanters are used mainly in the East, Southeast, and South Asia. However, rice transplanters are considerably expensive for almost all Asian small-hold farmers. The countries like Japan and Korea have shifted from conventional manual transplanting to machine transplanting because of labor scarcity in those countries.

Usages of transplanter and its status

Mechanical transplanting is an emerging technology in Bangladesh. Farmers are not habituated to use tender age seedling. The rice transplanter has already attracted the interest of many farmers, traders and manufacturers and some farmers are already using this technology. One manual labor transplants approximately 500 m^2 in one day whereas with self-propelled rice transplanter one can transplant 16,195 m^2 in a day (Wikipedia). Almost 300 walking type transplanters were procured by DAE, BRRI, BADC, GBK and IRRI under project assistance. Those machines are used for demonstration purpose. Syngenta also procured seven transplanters for commercial use. Rice transplanters were used in 1,400 experimental and exhibition plots in 2,041 ha land. Total numbers of farmers trained on the use of rice transplanter were 3,329 and among them 158 were expert and 3,171 were preliminary trained. It was also observed that rice transplanter used in 200 upazilas under 50 districts of Bangladesh (Anonymous, 2013).

Seedling raising

BRRI initiated to develop a suitable seedling raising technique for manual transplanter during 1993. Baqui (1994) conducted an experiment to raise seedling in tray with an admixture of the equal amount of clay loam, sandy loam and cowdung-dust at BRRI farm. The soil moisture content was maintained at 2.87, 12.95, 13.18 and 77.94% at the time of soil packing into the seedling trays. Friable soil was found more convenient to pack into the seedling trays compared to the other soil moisture. Clay soil mat collapsed in the transplanter during field test. The author recommended that lighter soil preparation i.e. an admixture of the equal amount of clay loam, sandy loam and cowdung were good for seedling raising in trays.

Islam (1999) conducted a three factorial experiment to raise seedling on tray at different soil composition to identify the optimum soil composition and moisture content of the seedling mat at which the shearing strength is minimum while the soil bearing and the volumetric indices are maximum and to identify the optimum age of the seedling for better performance. Silty clay loam was collected from BRRI farm and mixed with sand, cow dung and saw dust in different proportions by volume as S_1 = 90% silty clay loam soil + 10% cow dung, S_2= 80% silty clay loam soil + 10% sand + 10% cow dung, S_3= 70% silty clay loam soil + 20% sand + 10% cow dung, S_4= 70% silty clay loam soil + 10% sand + 10% saw dust + 10% cow dung. Three moisture levels of the seedling mat were considered in the range between 20 to 50 percent as M_1= Mat with saturation level moisture content (45- 50%), M_2= Mat with intermediate moisture content (30-35%) and M_3= Mat with friable range moisture content (20-25%). Four levels of seedling age were considered in the range of 10 to 20 days as A_1 = 10 days, A_2 = 13 days, A_3 = 16 days and A_4 = 19 days. The shearing strength was found the highest at friable range (8.25 N cm^{-2}) of moisture contents followed by intermediate (4.21 N cm^{-2}) and saturation (3.21 N cm^{-2}), respectively. The seedling mat with silty clay loam soil at a moisture content of 30-35% (db) produced the maximum value for soil bearing index (0.84), which was essential for better crop establishment. The age of greenhouse seedling should be 13-15 days for convenient use in the transplanter. The addition of saw dust to the silty clay loam soil decreased soil cohesion as well as soil bearing index and hence it was not recommended to raise seedling on that medium.

Hossen (2012a) conducted an experiment to raise seedling on tray using 14 treatments combing with different seed covering materials as well as dry and sprouted seed. The treatments were as follows: T_1= Dry seed+ soil+ rice husk, T_2= Dry seed+ soil+ sawdust, T_3= Dry seed+ soil+ soil, T_4= Dry seed+ (soil+cowdung) + rice husk, T_5= Dry seed+ (soil+cowdung) + sawdust, T_6= Dry seed+ (soil+cowdung) + soil, T_7= Sprouted+ soil + rice husk, T_8= Sprouted+ soil + sawdust, T_9 = Sprouted+ soil + soil, T_{10}= Sprouted + (soil+ cowdung) + rice husk, T_{11}= Sprouted + (soil+cowdung) + sawdust, T_{12}= Sprouted + (soil+cowdung) + soil, T_{13}= Frame+ sprouted+ soil and T_{14}= Frame+ dry seed+ soil + rice husk. The highest number of seedling per square centimeter was found in T_9 (4.25) followed by T_{13} and T_7, respectively. Seedling raised in T_9 combination found more suitable for machine transplanting. The author also recommended that paddy seed density in each tray should be more than 130 g for bold grain, 140 g for medium and slender grain and 120 g for extra-long and slender suitable for mechanical transplanter to avoid missing hill.

Hossen and Rahman (2014) conducted an experiment to identify the effect of growing media on quality seedling in terms of seedling strength and rolling quality of the seedling mat in *aman* and *boro* season during 2013-14. Seedlings were raised on plastic tray using sandy loam and clay loam soil mixed with decomposed cow-dung, mustard cake, rice straw organic fertilizer, rice bran, poultry litter and vermicompost at the rate of 0, 10, 20, 30 and 40%. Rice variety BRRI dhan28, BRRI dhan29 and BRRI dhan49 were used in the experiment. Rolling quality decreased and seedling height increased with the increase of mixing rate of organic fertilizer except rice bran and mustard cake for both types of soil whereas number of seedling per unit area decreased with the increase of organic fertilizer mixture after a certain limit for both types of soil irrespective of season. Aman season showed better performance on rolling quality of the seedling mat irrespective of soil type and organic fertilizer with the rate of mixture 0-30% except mustard cake. Around 10-30% cow-dung, rice straw organic fertilizer, vermicompost, 10% poultry liter and 20-30% rice bran with both types of soil was found suitable for seedling mat. Rolling quality of the seedling mat and seedling height varied among the organic fertilizers with both types of soil in the order of cow-dung>rice bran>vermicompost>poultry liter>rice straw organic fertilizer>mustard cake. Clay loam soil showed better performance on rolling quality of the seedling mat and seedling strength over sandy loam soil. Boro season produced more seedling strength because of stunted seedling for cold spell that produced more dry matter per unit length over *aman* season.

Mamun *et. al.*, (2013) conducted two experiments at Bangladesh Rice Research Institute, Bangladesh in *aman* season (September, 2012) and *boro* season (January, 2013) to find out suitable seedling raising materials for rice transplanter. Seedlings were raised on plastic trays using soil alone, 75% soil + 25% decomposed cow dung, 75% soil + 25% ash, 75% soil + 25% saw dust, 75% soil + 25% rice husk and 75% soil + 25% decomposed poultry manure. The sprouted and dry seed of BRRI dhan49 and BRRI dhan29 were sown in *aman* and *boro* season, respectively. The recommended seedling number (3 leaves per seedling) and suitable seedling height (12 cm) could be achieved from 12-day-old seedling in *aman* and 25-day-old seedling in *boro* for transplanting using rice transplanter. Both sprouted and dry seeds showed satisfactory performance with soil media alone. Greener leaves, longer shoot and root length, more seedling vigor and strength, and better nutrient composition as well as field performance was obtained from seedling grown on soil media containing 25% cow dung or rice husk or poultry manure mixture. Using rice transplanter, farmers could save US $ 5.0-9.0 per 33 decimal of land.

Kamruzzaman *et. al.* (2014) conducted a study to develop an effective technique for resisting adverse effect of cold weather on rice seedling growth in Rangpur district during Boro season 2011-12. Nine (9) treatments were taken under polythene shed as cover of various colors and thicknesses. The treatments were T_1= Put under 0.04 mm thick white polythene shed during day and night; T_2= Put under 0.04 mm thick white polythene shed during night only; T_3 = Put under 0.04 mm thick blue polythene shed during day and night; T_4 = Put under 0.04 mm thick blue polythene shed during night only; T_5 = Put under 0.04 mm thick black polythene shed during day and night; T_6= Put under 0.04 mm thick black polythene shed during night only; T_7 = Put under 0.08 mm thick black polythene shed during day and night; T_8= Put under 0.08 mm thick black polythene shed during night only and T_9= Control (traditional seedling raising without shed). The highest stem thickness was observed under 0.04 mm thick white polythene shed during night. The lowest number of plants was obtained in traditional seedling without shed. Plant quality in other treatments was found significantly better than traditional seedling without shed. Seedling raising in tray under polythene shed is very efficient and affordable technique during cold season of Bangladesh.

Transplanter operation

JICA, Japan provided two-row walking type power rice transplanter (AP 200) to BRRI to test the field performance. The field capacity of the transplanter was 0.09- 0.12 ha hr^{-1} and the percentage of missing hill was less than 2% (Islam and Islam, 2000). Islam *et. al.* (2001) conducted two experiments to observe the performance of Japanese power rice transplanter at BRRI, Gazipur in *aman* and *boro* seasons and it was compared with hand transplanting methods. The machine planting was found 20 times faster than the traditional method and obtained 17% more yield than the traditional method.

Hossen (2012b) tested the field performance of four-row walking type transplanter (DP480) using tender aged seedling (22-26 days) in aman season and compared with hand transplanting using BRRI dhan32 and BRRI dhan49. The yield of the machine and hand transplanting plot was 4.95 and 4.85 t ha^{-1}. During evaluation, average speed (m sec^{-1}), field capacity (deci hr^{-1}), fuel required (l hr^{-1}), transplanting width (cm), no. of plants per hill, number of hill m^{-2}, missing hill m^{-2}, floating hill m^{-2}, buried hill m^{-2} and damaged hill m^{-2} were found 0.8, 68.3, 0.88, 120, 3-6, 20, 1.8, 0.8, 0.5 and 1.1, respectively.

Islam *et. al.* (2013) evaluated the field performance of mechanical rice transplanter in unpuddled condition under minimum tillage practices in sandy loam soil during *aman* 2012 season. Tillage treatments were (i) conventional puddling (CT) in puddle condition and (ii) no tillage (NT) (iii) bed planting (BP) (iv) and strip tillage (ST) in unpuddled condition. Transplanting time was higher in unpuddled than puddle plot. Floating hill was also higher in unpuddled plot due to increase in soil hardness and unable to provide proper anchorage and gripping force to seedlings. Grain yield of unpuddled transplanting was similar to puddle transplanting. Mechanical transplanting overcomes the constraints of manual transplanting in unpuddled condition.

The 6-row ride-on transplanters were commercially operated in farmers' field Bogra, Natore and Joypurhat districts. By providing technical suggestion and machinery adjustment, the number of tray requirement per acre was drastically reduced from

133 to 88. Another 6-row ride-on transplanter (DUO66) was operated in 14 farmers' plot Nandigram, Bogra. Picker setting was adjusted to 2. Tray requirement per acre was also drastically reduced from 109 to 72. S3-680 model of 6-row mechanical transplanter was operated in Pathanpara, Joypurhat. Seedling density nob was set at 2. In 53% places, more than eight numbers of seedlings were dispensed in each hill. Number of seedling per hill should be reduced to 5-6. Seedling density should be adjusted depending on the seedling condition in tray. The area coverage of transplanting depended on plot size, shape, soil condition and the distance among the plots (Islam, 2014).

Ahmmed *et. al.* (2014) conducted the study at agricultural blocks of the Department of Agricultural Extension (DAE) at Kurigram sadar upazila to assess the feasibility of mechanized rice transplanter in paddy field to reduce the cost of cultivation. Field performance of a four-row rice transplanter was evaluated and its acceptability was analyzed. Transplanting by rice transplanter was 61 percent more profitable than that of the conventional method. The effective field capacity, theoretical field capacity, field efficiency and fuel consumption of the rice transplanter were 0.16 ha hr^{-1}, 0.19 ha hr^{-1}, 81.83% and 0.6 L hr^{-1}, respectively. Cost analysis and other suitability ensured the good prospect of the rice transplanter in future. Rice transplanter owner should make a target to achieve minimum area of 24.69 ha for a year to payback the investment for a custom hiring rate Tk 5,000 per ha.

Hossen *et. al.* (2014a) evaluated the field performance of mechanical rice transplanter in unpuddled field under minimum tillage in clay loam and loamy soil during 2012-13. Tillage options showed significant effects on fuel consumption of rice transplanter operations except in loamy soil. Mechanical transplanting saved 14-18% fuel in strip and zero tillage condition. Missing hills was observed the highest in bed and zero tillage (12-13%) followed by conventional tillage (10%) and strip tillage (8%) due to more floating plants. Strip tillage showed significantly higher grain yield (5.3 t ha^{-1}) followed by zero, conventional and bed tillage (5.0-5.1 t ha^{-1}).

Hossen *et. al.* (2014b) evaluated the performance of a mechanical rice transplanter under minimum tillage and inundation periods. The study was conducted both in farmers' field, Kushtia, Rangpur and BRRI research farm, Gazipur in clay loam, loam and sandy loam soil. The experiment was followed split plot design with three replications where strip tillage (ST), zero tillage (ZT) and conventional tillage (CT) as main plot and the inundation periods as sub-plots before transplanting were 12, 18 and 24 hrs. The 4 row walk-behind type rice transplanter (DP480) was used to transplant seedling. Tillage treatment did not affect the missing hills in clay loam and sandy loam soil. In loamy soil, lowest percentage of missing hills was observed in ST. ZT provided more missing hills because of more floating plants followed by CT. There were fewer missing hills with 24 hrs inundation with each tillage treatment. There was no inundation effect on weed infestation. ZT and ST showed significantly highest weed infestation compared to CT. It can be recommended that mechanical transplanting should be done after 18 hrs inundation for ST and 24 hrs inundation for ZT and CT to get more benefit of rice production.

Hossen *et. al.* (2014c) incorporated strip tillage system in ride on transplanter to make strip and seedling placement with the strip simultaneously in one pass operation with a view to minimize land preparation cost and ease of transplanting in unpuddled condition. Engine power available at a 3600 rpm was conveyed to the strip tillage rotary shaft with the arrangement of a belt-pulley, worm gearing, shaft-universal joint, involutes spline shaft and bevel gear resulting in a 450 rpm rotary blade speed. A leveroperated tensioning pulley was included into the belt drive to engage and disengage the power to the strip tillage shaft. The tine was designed to produce a 2 cm deep ×2 cm wide strip. The developed transplanter was tested in the soil bin and research field. In both condition, developed transplanter was found suitable to make strip and place seedling satisfactorily in unpuddled soil. Further test is needed to evaluate the modified rice transplanter.

Islam *et. al.,* (2015) conducted the experiment 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. T_1 = Hand transplanting (HT) and T_2 = 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. BRRI dhan28 was used to conduct the experiment in both the locations. Fuel consumption of 4-row walking type mechanical transplanter obtained 5.25 L ha^{-1}. The field capacity and field efficiency of rice transplanter obtained 0.11-0.12 ha hr^{-1} and 64-70%, respectively. Conventional seedbed preparation required 37-55 man-hr ha^{-1} whereas 71-77 man-hr ha^{-1} 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 ha^{-1} which was 19-22 and 1.65-2.00% of total labor requirement in rice cultivation, respectively. Number of seedling tray requirement ranged from 215-230 ha^{-1}. Missing hill obtained 1-2% 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 cost of growing mat type seedling for mechanical transplanter was 53% whereas the cost of raising traditional seedbed was 34% of the cost of manual transplanting. BCR of MT and HT was 1.18-1.19 and 1.03-1.06, respectively.

Yield comparison

Effect of tender age seedling on yield

A study was conducted in the farmers' field Kodma, Omorpur, Nandigram, Bogra during *aman* 2013 and Amin Nagar, Nandigram, Bograduring *boro* 2014 season. Self-propelled four-row walking type rice transplanter was used to transplant seedling. Missing/floating hill was observed insignificant in mechanically transplanted field. Tegra mechanical transplanting produced 14-23% higher grain yield in both the seasons. The total cost of production, gross return, gross margin and BCR were the highest in mechanical transplanting in two seasons. BCR was higher in mechanical than hand transplanting in both seasons due to higher grain and straw yield. Mechanically transplanted rice was profitable than hand transplanting in both seasons (Islam and Rahman, 2014).

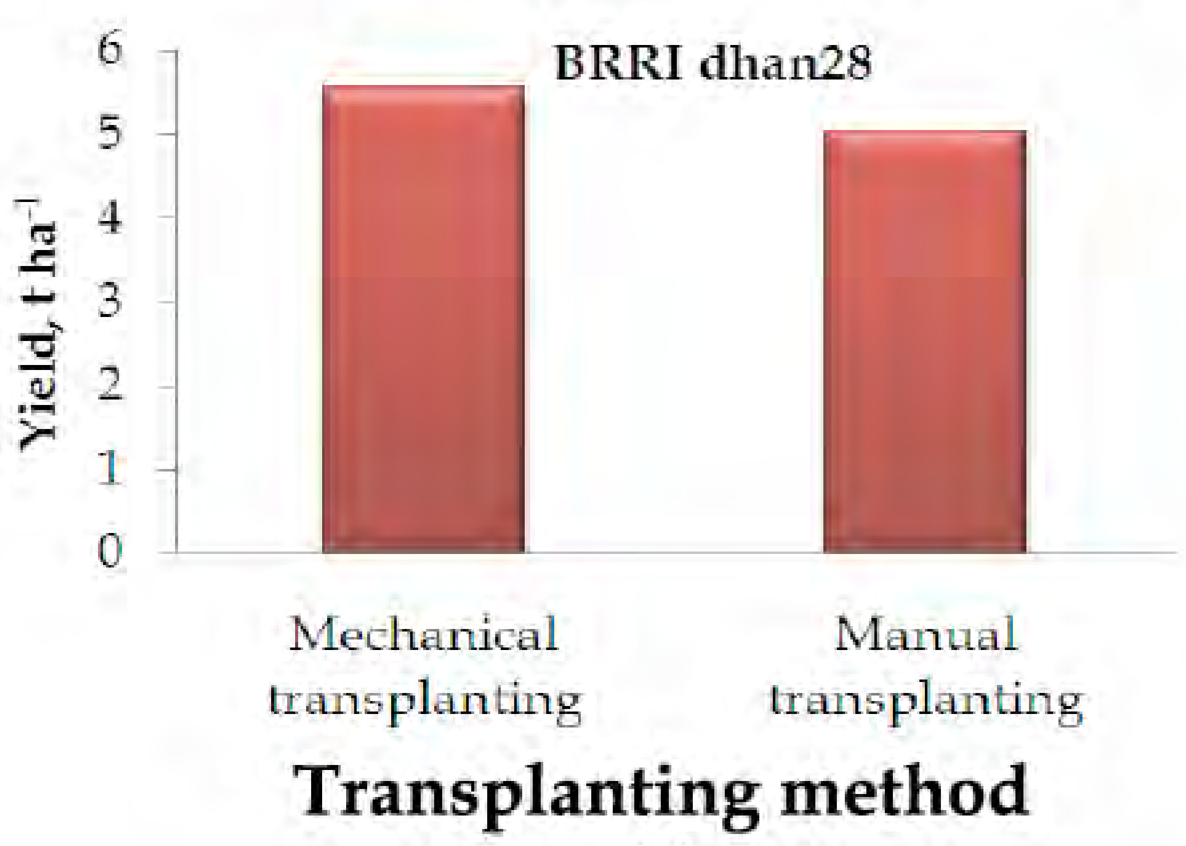
Table 4 shows the yield performance of mechanically transplanted rice over manually transplanted rice during *aman* season. Mechanically transplanted rice produced the highest yield than manually transplanted rice (Islam *et. al.,* 2015b).

Table 4. Grain yield of mechanically transplanted plot in Gopalganj district

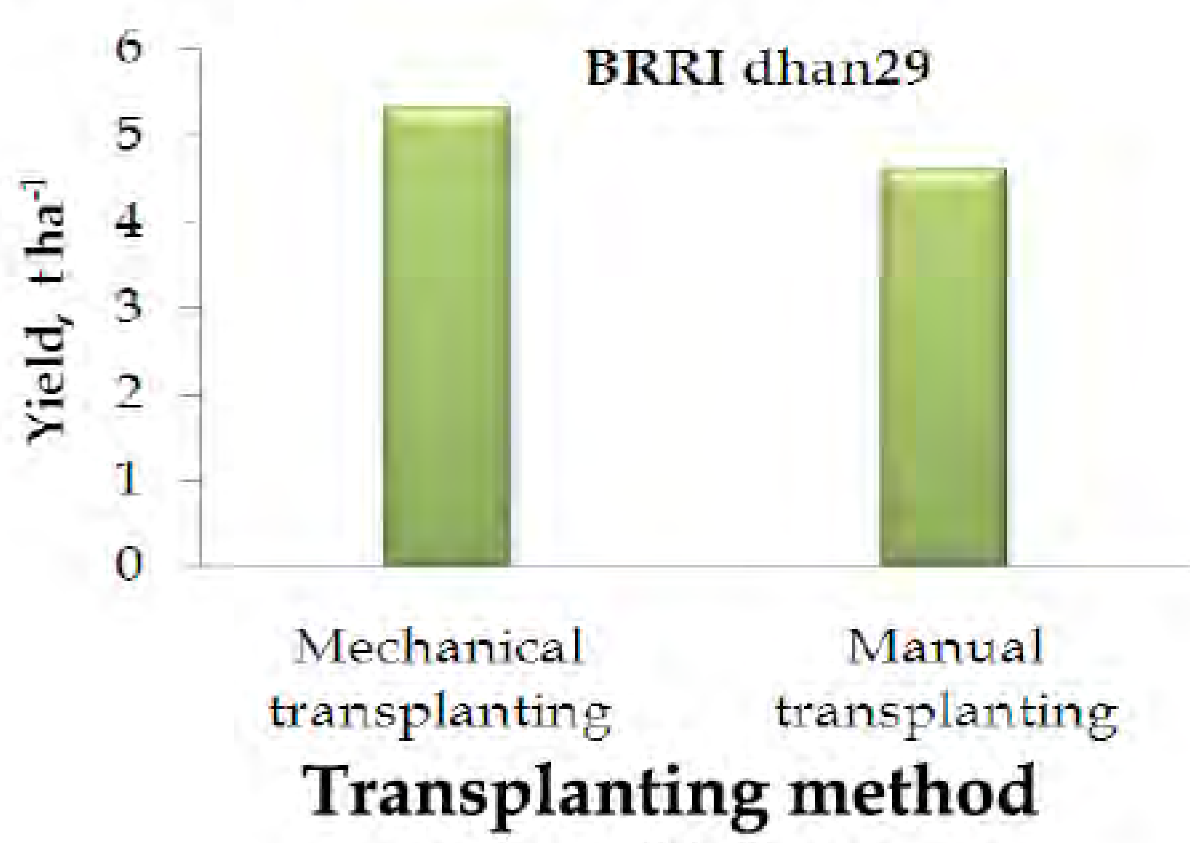
Treatment	Variety	Yield (t ha^{-1})
MT	BRRI dhan39	4.45 ± 0.15 (N= 2)
MT	BRRI dhan56	3.71 ± 0.27 (N= 5)
HT	BRRI dhan39	3.66 ± 0.18 (N= 3)

MT = Mechanical transplanting, HT= Hand transplanting

Grain yield of mechanically and manually transplanted field was compared in Rangpur district during *boro* 2015 season (Fig. 1a). Seedling age of BRRI dhan28 in mechanically and manually transplanted field was 28 and 46 days, respectively. Grain yield of mechanically transplanted field showed 10% higher than manually transplanted field (Islam *et. al.,* 2015a). Yield performance of mechanically and manually transplanted rice was compared in Nilphamari district during *boro* 2015 season (Fig. 1b). BRRI dhan29 was grown in the experiment. Mechanically transplanted rice yielded more (15%) than that of manually transplanted rice (Islam *et. al.,* 2016a).



(a)



(b)

Fig. 1 Comparative yield of mechanically and manually transplanted rice

Yield performance of mechanically and manually transplanted rice was compared in Gopalganj district during *aus* 2016 season (Fig. 1c). BRRI dhan48 was grown in the experiment. Tillering ability and effective tiller of mechanically transplanted rice was higher than manually transplanted rice. Grain yield of mechanically transplanted rice (3.93±0.14 t ha^{-1}) was 15% higher than manually transplanted rice (3.43±0.07t ha^{-1}) due to presence of highest filled grain in each panicle (Islam *et. al.*, 2016b).

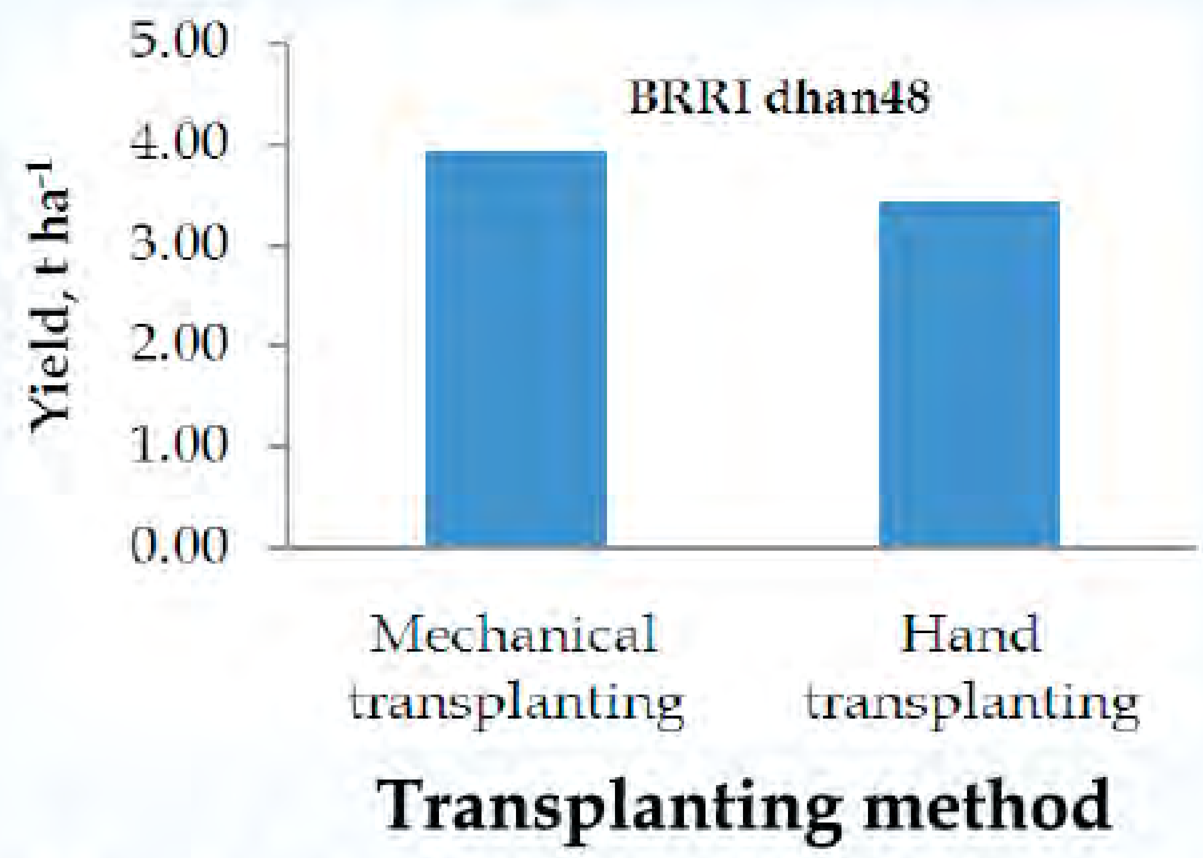
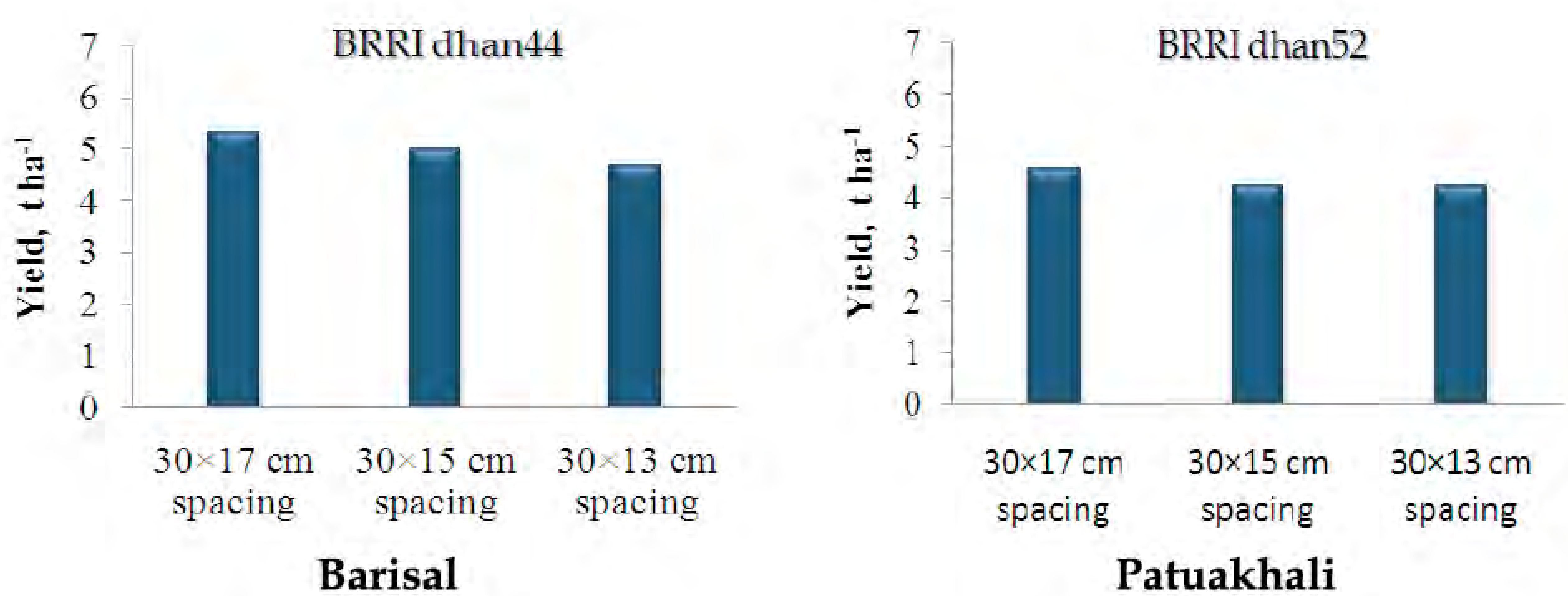
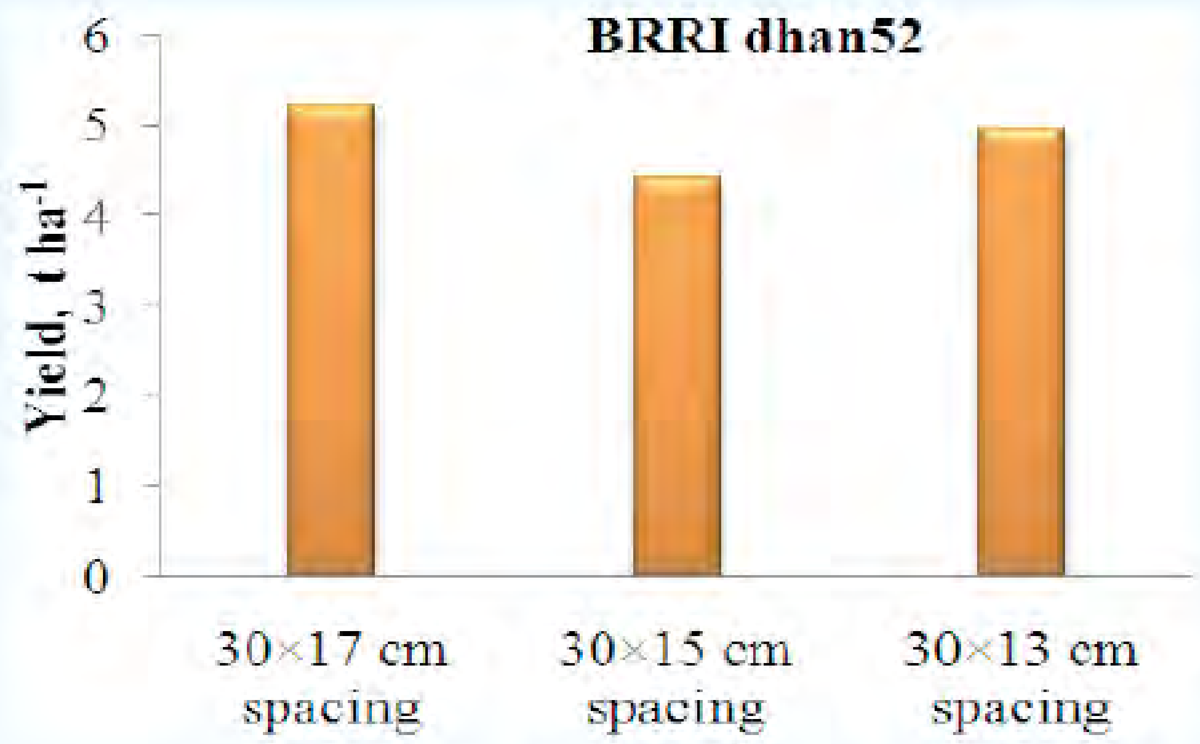


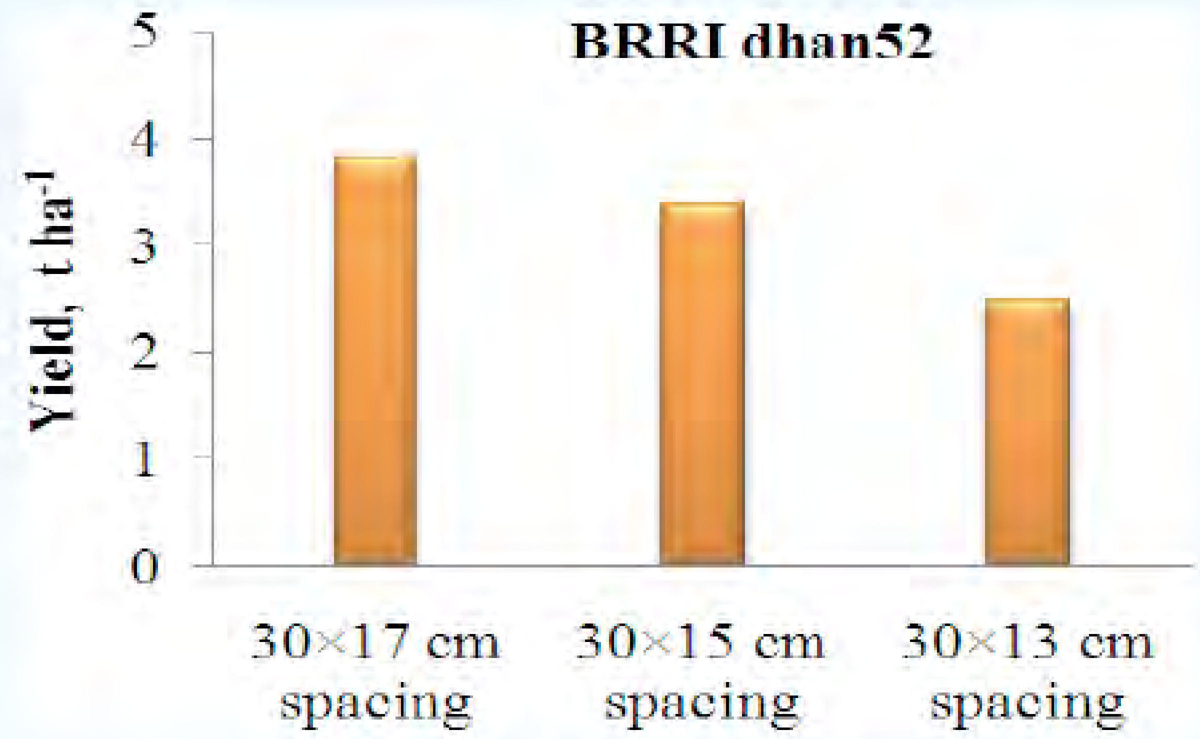
Fig. 1c Comparative yield of mechanically and manually transplanted rice

Effect of plant to plant spacing on yield

Field trial of transplanter was conducted in the farmer's plot Barisal, Patuakhali, Lalmonirhat and Nilphamari districts. BRRI dhan44 and BRRI dhan52 were grown in the trial plot. Figure 2 shows the yield performance of mechanically transplanted rice in different plant spacing (13, 15 and 17 cm). Rice seedling transplanted by mechanical transplanter in 17 cm space setting produced the highest grain than the close space setting (13 and 15 cm). Pests were attacked in closer spacing (13 cm) plot, which might be due to lack of good aeration and light interception (Islam *et. al.*, 2016a).







Lalmonirhat **Nilphamari**

Fig. 2 Rice yield in different plant to plant space settings

Table 5 shows that the yield performance between mechanically and manually transplanted rice at different plant to plant space settings in the farmer's field of Jhenaidah and Kushtia district. Similar yield was obtained in mechanically and manually transplanted rice fields. It was observed that farmers could harvest paddy 10-12 days earlier in the mechanically transplanted plots. Number of effective tiller was found more than that of manual transplanting due to younger aged seedlings and wider line spacing (Islam *et. al.,* 2016c).

Table 5. Comparative yield performance of rice transplanted by mechanical rice transplanter at different plant to plant spacing

Location	Variety	Treatment	Yield, t ha^{-1}
Gosaidanga, Shailkupa, Jhenaidah	BRRI dhan39	MT (Spacing 30 ×13 cm)	5.13
		MT (Spacing 30 ×15 cm)	5.03
		MT (Spacing 30 ×17 cm)	5.11
		HT (Spacing 20 x20 cm)	5.07
Baria, Kushtia Sadar, Kushtia	BRRI dhan62	MT (Spacing 30 ×13 cm)	5.61
		MT (Spacing 30 ×15 cm)	5.13
		MT (Spacing 30 ×17 cm)	5.22
		HT (Spacing 20 x20 cm)	5.29

MT= Mechanical transplanting, HT= Hand transplanting

Seedling raising

Seed germination

The seed germination and seed vigor should be more than 95 and 80%, respectively in mat type seedling raising to avoid missing hill. Seed germination depended on water availability and temperature. The germination percentage was calculated based on the following formula:

$$\text{Germination rate (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds on tray}} \times 100$$

Seed selection and treatment

Healthy seeds should be selected by specific gravity method. Dry seeds are emerged in water to remove unfilled grain and other impurities. After soaking, seed should be removed from water and spread it over the surface. Bavistin (a.i. Carbendazim) powder was mixed with water. Seed will be immersed in bavistin treated water to protect the seeds from the seed borne diseases.

Seed soaking and sprouting

Seeds were kept into soaking for 24 hr. Soaking time depends on ambient condition and water temperature. It is recommended to soak seed in 8-12 hr and not more than 24 hr. Excessive soaking time leads to decompose the seed. The seeds were kept for sprouting in bucket. After that, seeds were taken out from water and then kept in gunny bags to create warm environment for seed sprouting. It is generally taken minimum 24 hours for sprouting. Oven is generally used for sprouting in winter season and the temperature in the oven should be kept at 50-60°C.

Soil sieving

Collect dry soil free from debris, hard metal, roots and other foreign materials and then sieving for removing any kind of stone and debris from soil.

Seed rate

Seed rate is very much important to maintain proper growth of seedling. The seed rate should be optimized for different sizes of rice variety to get optimum number of seedling. Dry seed of 130g for bold grain, 140 g for medium and slender grain and 120 g for extra-long and slender variety is recommended to avoid missing hill during operation of mechanical transplanter (Hossen, 2012a). Higher seed rate influences on slender seedlings. Seedling growth appeared good in warm than cold environment.

Tray preparation

There are two methods of seedling preparation

I. Tray system

II. Plastic mat or long mat system

The plastic trays were used to raise mat-type seedlings. Dry soil was filled in tray and sprouted seeds were spread uniformly over the tray. In each tray, dry seed of 130-140g was used (Photo 5). Trays should be covered with straw to protect the seeds from the birds.

a. Sprouted seed

b. Filling tray with dry soil

c. Seeding

d. Uniform distribution of seed

Photo 5 (a-d) Seedling raising on tray

e. Seed bed

f. Watering

Photo 5 (e-f) Seedling raising on long mat

Nursery management

Prior to transplanting, seedlings need to be raised in a nursery. Seedling nurseries usually use 5-10% of the total farming area. Appropriate nursing systems must have the availability of sunlight, land, labor, irrigationand drainage system. Watering will be done twice a day by rose cane until complete emergence of seedlings. The mat seedlings are ready to transplant when attained 3-4 leaves and 10-12 cm height (Photo 6).

a. Watering

b. Seedling in tray

Photo 6 Seedling raising

Tray preparation time

Time required to prepare 200 trays were given in Table 6. Five activities were done to prepare tray. Highest time (32%) would be required in soil sieving.

Table 6 Time requirement for preparation of 200 trays

Sl no.	Activity	Time, hr
1	Soil sieving	5.50
2	To fill one third of the tray with soil	3.20
3	To spread the seed in tray	3.20
4	To cover the tray with soil	2.30
5	Watering by sprayer	3.20
	Total	**17.4**

Seedling age

- Seedlings will be ready for transplanting in 12-15 days after seeding (DAS) in *aman* and *aus* season and 25-30 days in *boro* season
- In *boro* season, BRRI dhan28 and BRRI dhan29 required 25 and 30 days, respectively for proper mat formation due to cold

Mechanical transplanting

Land preparation

Proper land preparation and leveling greatly influence the field performance of the transplanter. Therefore, inundate the field with water to get the land well soaked for a few days and let the biomass decompose. Inundate the plot with 5-6 cm of water and operate tractor/power tiller rotavator for puddling. The water should be in excess to prevent soil sticking on implement or on wheels. Complete the puddling operation by using rotavator. Level the plot with ladder in such a way that there should not be any depression patch and the water should stand uniformly. Transplanting operation should be done after one day of land preparation for proper soil sedimentation.

Operation of rice transplanter

The following steps are essential to start and operate transplanter

- Adjust the gear in neutral condition and disengage the main clutch
- Adjust the chock valve before starting the engine
- Pullthe rope to start transplanter
- Ensure that the main gear turns on in move position
- Press down the lift control lever to uplift the main body
- Ensure that density control lever is adjusted in middle position
- Depth control remains in the middle
- Engage the main clutch to move forward
- Press the right hand clutch to right turn and left hand clutch to left turn
- Press the stop button to stop the engine

Land condition

- Fields should be well puddled and leveled
- Drain the excessive water in the fields and allow mud to settle for 1-2 days after the final puddling
- The subsurface soil layers need to be hard enough to support the transplanting machine
- Soil should be sufficiently wet so that it would not stick to and interfere with planting parts or wheels of the transplanter
- Water height should be maintained at 1-2 cm

Transplanting

- Before starting the transplanter, seedling mat was rolled and fed to the
- mechanical transplanter
- Fix the adjustments such as hill spacing, number of plant per hill and planting depth are based on the machine operator's manual
- In mechanical transplanter, line to line distance is fixed at 30 cm and plant to plant spacing can be varied
- Load the seedling mats on the machine and transplant the seedlings at the selected machine setting (Photo 7-9)

Photo 7 Mat type seedling

Photo 8 Seedling carrying

Manual

Mechanical

Photo 9 Rice transplanting

Awareness development

Promotion of mechanical transplanting

Role of research station

Farm Machinery and Postharvest Technology Division of BRRI conducting large scale demonstration of mechanical transplanting in the farmers' field. The division has considered this issue as a top priority and prepared action plan to disseminate the technology. As a continuation of the program, extensive training on seedling raising technique, operation, repair and maintenance of transplanter are being conducted in the farmers' field. Researchers are also trying to find out the suitable business model on the commercially use of mechanical rice transplanter.

Role of extension agent

Government extension agent DAE is playing a vital role for faster adoption of this technology and has taken initiative to disseminate the mechanical rice transplanting in the farmers' field.

Role of NGOs/private organizations

Agriculture based NGOs/private organizations may provide credit facility with practical training to the entrepreneur to purchase transplanter and support them to provide custom hire service. Some NGOs and private organizations are also involved in the dissemination activities of mechanical transplanter.

Government assistance and initiative

Mechanical transplanter is imported from South Korea and China. The GoB has taken early preparedness to minimize peak agricultural labor shortage in coming days and given emphasis to introduce rice transplanter. GoB provided full assistance to the public organization to procure and supply transplanter for large scale demonstration in the farmer's field. GoB has also taken special care in *haor* areas and supplied 100 transplanters to the farmers' group for proper use of the transplanter. Farmers are using this technology in their fields.

Adaptive trial

Adaptive trial and field demonstration of seedling raising technique and mechanical rice transplanting were conducted by BRRI, DAE, BAU, GBK, BRAC, IRRI, BADC and private organization in the farmers' field to create awareness among the farmers to use transplanter. Introductory sessions were arranged to familiarize the machine performance, operation technique, unit price, repair and maintenance of the machine. Farmers commented on the use of traditional seedling in mechanical transplanter. Farmers were informed that traditional seedling could not be used in mechanical transplanter. Seedling should be raised in either tray or mat in special way to suit the mechanical transplanter. The farmers should know the seedling raising technique before using mechanical transplanter (Photo 10).

Photo 10 Field trials of rice transplanter

Field day

Field day is another way to create awareness and faster dissemination of the technology. Several field days were organized by BRRI, DAE, BRAC, IRRI, GBK and private company in farmers' field to share the experience on the benefit of using mechanical transplanter. Most of the farmers saw the operation of transplanter in the first time. They became surprised to see the performance of the transplanter and encouraged them to mechanized transplanting. Crop cut program also organized to show the yield benefit of mechanically transplanted rice (Photo 11).

Photo 11 Field day program

Motivational tour

Motivational tour is one of the most efficient ways to convince the target people. BRRI organized motivational tour on the performance of rice transplanter for the Sub-Assistance Agricultural Officers (SAAO) and farmers from different upazilas. The memories from such event last longer (Photo 12).

Photo 12 Motivational tour

Training on operation, repair and maintenance

Twenty-one-day long training

DAE under "Farm Mechanization Project" organized 35 twenty-one-day long residential training program on the operation, repair and maintenance of farm machinery especially mechanical transplanter and combine harvester under the financial support from Farm mechanization project. From 2010, DAE trained 942 operators came from different districts. Corona Tractors Limited, Dhaka provided the training facilities. Resource speakers from BRRI and other organizations delivered class lecture and practical hand-on training to the participants. After gaining knowledge from the training, one participant named Md. Nizamuddin in association with Mr. Golam Mostafa, mechanic, DAE trained the local farmers on mat type seedling raising and formed transplanting village. The operator got transplanter support from The Deputy Director, DAE, Jhenaidah and transplanted 13 ha land in *aman* 2015, *boro* 2016 and *aman* 2016 season. The Metal (Pvt) Limited also provided plastic trays and technical support to the operators (Sheikh and Biswas, 2016). This could be a good example on the impact of long-term practical training.

Five-day long training

GoB has given priorities on farm mechanization activity in the *haor* areas and provided farm machinery support especially transplanter and harvester to the farmers to protect the crop from flush flood. DAE distributed 100 transplanters to the farmers group in *haor* areas. During 2014-15, DAE and BRRI jointly organized 14 five-day long residential training program on the seedling raising technique, operation, repair and maintenance of transplanter to the farmers of *haor* area. The Corona Tractors Limited, Dhaka provided the training facilities. After training, one farmer in Kuliarchar upazila under Kishorganj district has taken initiative to raise seedling on trays and polythene. The farmer offered rental charge of Tk 5000-7500 per ha for mechanized transplanting by using their transplanter and seedlings (Sheikh and Biswas, 2016).

Three-day long training

Three-day long residential training on the operation and maintenance of promising farm machinery were conducted in FMPHT division, BRRI, Gazipur. A total of 120 farmers from different upazilas under western districts of Kushtia, Chuadanga, Jhenaidah, Meherpur; northern districts of Rangpur, Lalmonirhat, Kurigram, Nilphamari and coastal districts of Barisal, Jhalokathi, Barguna and Patuakhali attended the training session. The participants were selected based on the practical knowledge on the operation of power tiller. Class lecture and practical session were arranged for the participants. Step by step procedure to raise seedling in tray was shown practically to the participants. Each participant prepared seedling in tray. Knowledge was also given to the participants on the operation and maintenance of mechanical rice transplanter. At the end of the training, review session was arranged to get feedback from the participants about the training and certificate was given to the participants (Photo 13).

Photo 13 Three day-long training program

Day long training

FMPHT division of BRRI has been conducting one-day long training program on **"Seedling raising technique and operation and maintenance of transplanter"** extensively in different locations in the farmers' field with the assistance of DAE personnel since 2009. More than 7,000 farmers were trained on seedling raising technique and operation and maintenance of the transplanter (Photo 14).

Photo 14 Day-long training program

Advantage and constraint of mechanical transplanting

Several researchers studied the performance of rice transplanter in the present land tenure system and socio-economic condition of the farmers. The following advantages and constraints were identified during operation of transplanter in the farmers' field.

Advantages

- Ensure timeliness in operation
- Less transplanting shock
- Early vigor of seedling
- Better tillering
- Uniform maturity of crop that facilitate timely harvest
- Grain yield is higher than hand transplanting due to use of infant seedling
- Less time is required than hand transplanting
- Low labor requirement
- Reduce the burden of peak time labor requirement
- Easy to operate in the field
- Require less energy
- Reduce the drudgery of the labor
- Avoid continuous bending of posture
- No skin disease in hand
- Sometimes crops mature earlier than traditional system
- Facilitate to increase cropping intensity
- Less incidence of 'bakanae' disease due to less root injury
- Reduces health risks of farm laborers
- Generates employment and alternate sources of income for rural youth through custom hire services of mechanical transplanting

Problem faced by farmers

- Skilled operator is needed to operate the machine properly
- Transplanting machine is expensive, which is beyond the purchasing capacity of the ordinary farmers
- Seedling tray is not available in the local market
- Needs lot of seedling tray in each field
- Infant seedlings might be inundated due to heavy rain in *aman* and *aus* season
- Needs special attention to operate the machine in headland
- Special care should be taken to raise seedlings in nursery
- In water logged field, water wave displaced the seedling due to movement of transplanter
- Seedling mortality is high in cold season

Precautions to use transplanter

- Lands should be well prepared and leveled
- Water height should be maintained at 1-2 cm
- Water height should be maintained uniformly to avoid floating hill and seedling submergence
- Transplanter should be operated in the field after 24hr of land preparation for settlement of soil particle
- Operate the machine in lengthwise to reduce the headland turning
- Operator should calibrate the machine interms of soil condition, soil type, seedling height, seedling density, seedling spacing and number of seedling dispensed in each stroke
- Operator should operate the machine slowly and carefully to ensure the proper placement of seedling
- Operators should know the technique to operate the machine in the headland
- In case of heavy rain, drainage system should be available

Constraints

- Farmers are not aware about the benefit of using tender age seedling in mechanical transplanter. They are habituated to use old age seedlings
- Lack of knowledge on the use of rice transplanter
- Lack of skilled operator to operate the transplanter
- Initial cost of transplanter is very high
- Very limited use approximately 10-15 days in one location
- Lack of farm road to access the transplanter in the field
- Unable to operate the transplanter with full efficiency due to fragmented and irregular shape of land
- Unable to operate in very soft soil having no plough pan
- Unable to anchor the seedlings in very hard soil
- Unable to operate in the pocket area having irregular shape of land
- Irregular shaped land having pocket area needs extra labor to transplant seedling manually as machine cannot move in that area
- Land is not well leveled and it creates water log in the undulated land

Case study

Syngenta, a joint venture company of Syngenta AG Switzerland and BCIC, Bangladesh came forward to start business on mechanized transplanting in the name of Tegra.Tegra packages consist of providing healthy seedlings, mechanical transplanting, herbicide application and advisory support on agronomic service. Tegra business started as a pilot project in Bogra and Natore district during 2012. Mechanical transplanting is a crucial part to success of Tegra business. BRRI provided 6-row ride on type transplanter and technical support under public private partnership approach to promote this technology in the farmers' field on commercial basis. This case study was undertaken to evaluate the Tegra commercial transplanting during 2013-14.

Fuel consumption

Fuel consumption depends on the plot size, shape, transplanting area, movement from one field to another, plot to plot distance and distance from machinery shed to transplanting field. Fuel consumption of 4-row walk behind mechanical transplanter required 4.5 L ha^{-1} whereas, in ride-on type required 18 L ha^{-1}. Monitoring officer should maintain the fuel stock depending on the next day area coverage of transplanting, number of plot to be transplanted and traveling distance from machinery shed to transplanting field.

Seedling tray requirement

Seedling tray requirements during transplanting were categorized as tray required in mechanical transplanting, gap filling and pocket area filling. It was estimated that almost 92% trays were required in mechanical transplanting (Fig. 3). The most important thing to be considered that 6% tray was required in pocket area filling by manual labor due to irregular shape of the plot. This type of plot could not be avoided due to present land tenure system.

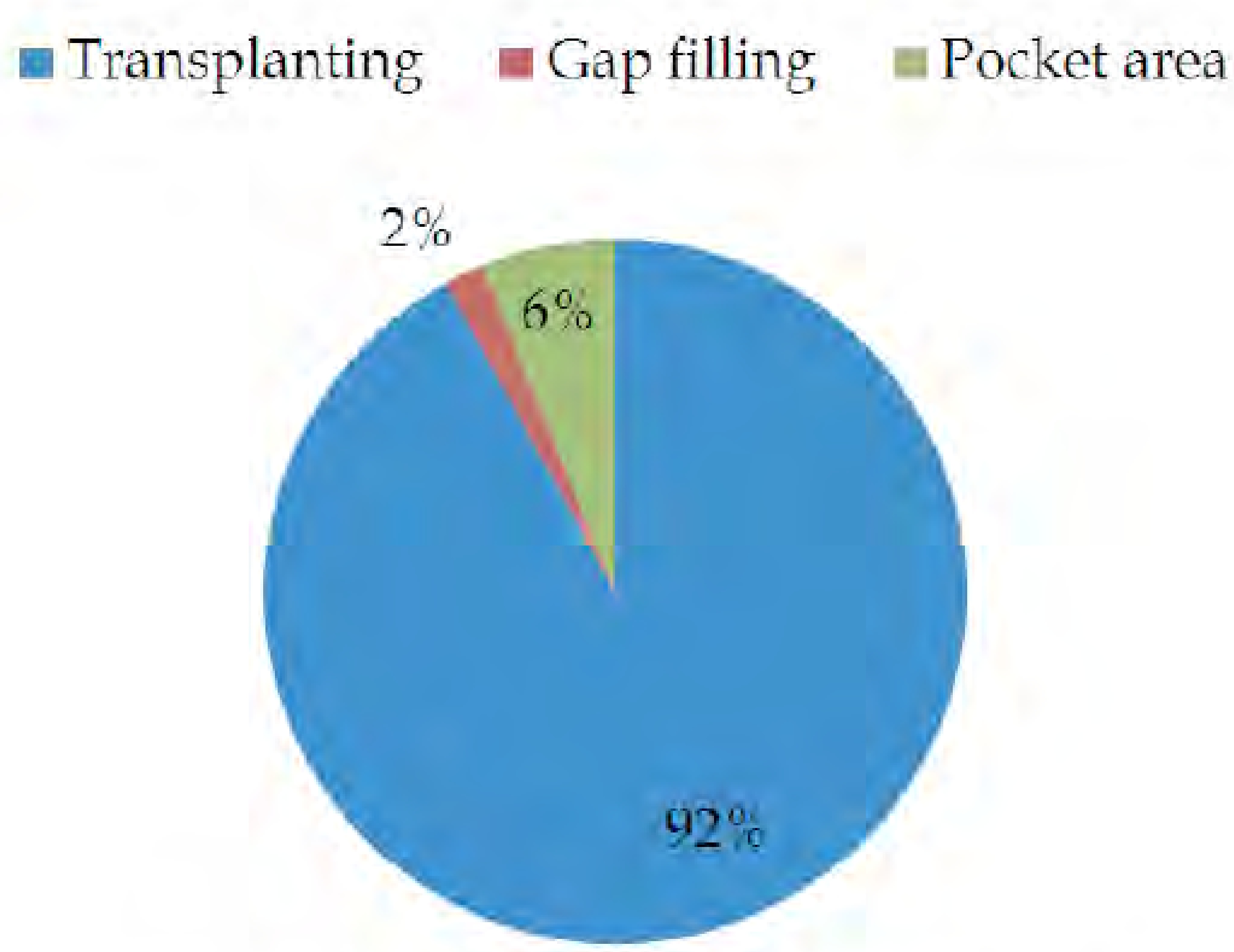


Fig. 3 Seedling tray requirement

Time distribution

Transplanting activity can be categorized as operating, movement, cleaning and idle time. It was estimated that 52% times spent as plot to plot movement and idle time (Fig. 4). Scattered plots increased the movement time. Headland turning took more time in smaller sizes of land. Lost time increased due to movement of the machine from one plot to another. Idle times categorized as avoidable and unavoidable. Avoidable idle time included that the plots are not ready, shortage of seedling, excess water height. Careful management can improve the situation. Unavoidable idle time included heavy rainfall and machine breakdown. Entrepreneur should focus on the reduction of idle and movement time to increase the field capacity of the mechanical transplanter.

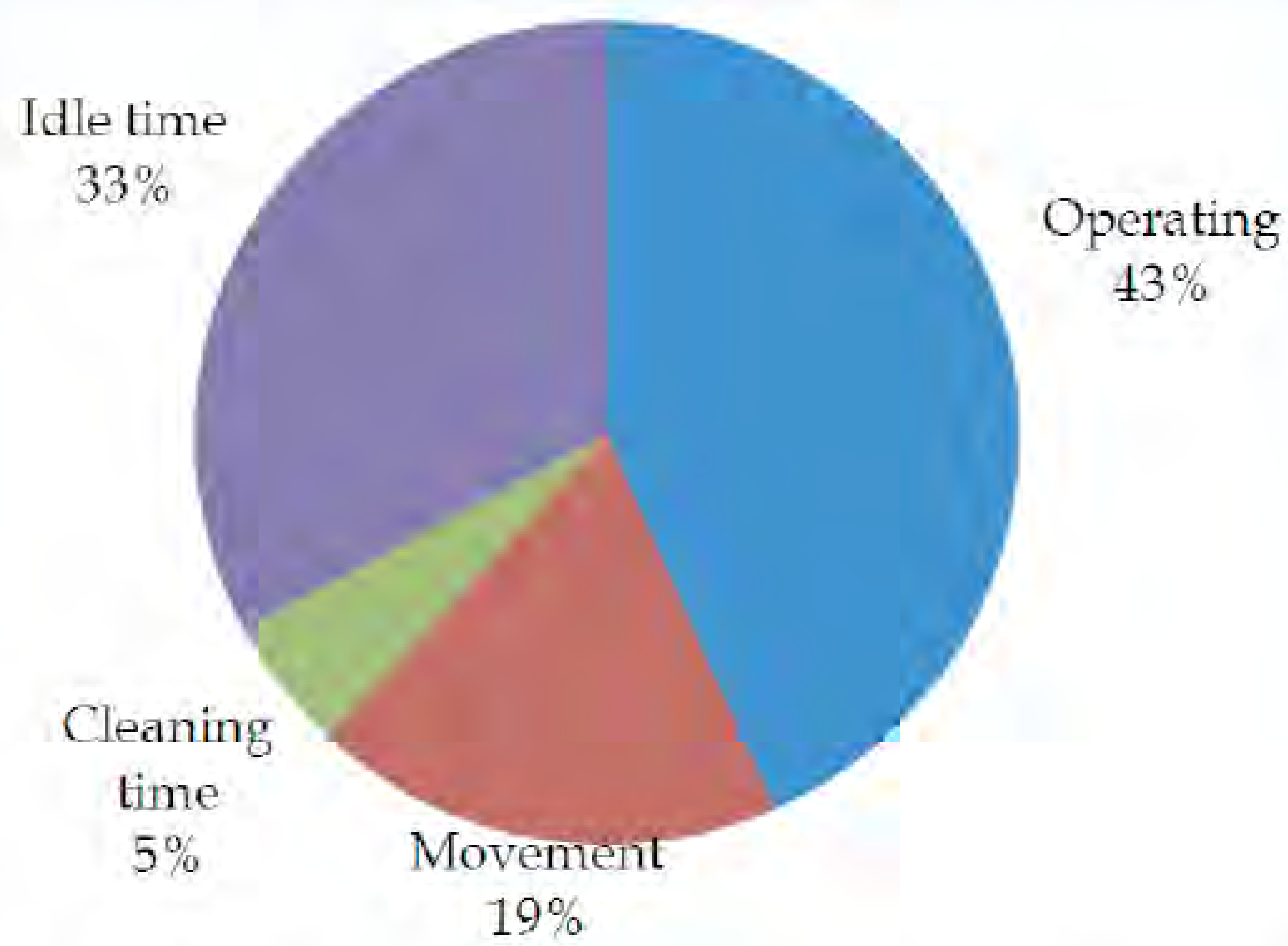


Fig. 4 Time distribution in different activities

Travelling distance

Crop field should be nearer to machinery shed to reduce travelling distance and increase the effective operationaltime. Wear and tear might occur in the rubber wheel if traveling on the concrete road. It is advisable to operate machine within one kilometer radius.

Labor requirement

In addition to operating the machine, operator should keep the record of tray requirement in each plot and close contact with the monitoring officer. One skilled labor is needed to load and unload the tray in the machine. Depending on the distance of plot from road, one to two laborers are needed to continuous supply of tray.

Land geometry

Plot shape

Plot shape is very much important to increase the field capacity and seedling tray requirement. It was estimated that 70% plots were uniform, 25% were irregular and 5% were mostly irregular (Photo 15). Irregular and mostly irregular plots should be avoided to increase effective field capacity of the transplanter.

Photo 15 Irregular plot

Plot size

Plot size also affects the effective field capacity of the transplanter. Ride on type machine required large plot for successful operation of the machine. A survey reveals that 15% of the transplanting plots are under 400 m^2 and 14% are under 440-520 m^2. These plots should be avoided to transplant seedling by ride on type transplanter. The size of plot should be more than 800 m^2 for ride on type transplanter. Length of plot was also another indicator to decrease the turning time as well as increase the field capacity.

Plot to plot movement of machine

Most of the plots were scattered and increased the loss time due to shifting the machine from one plot to another. Plot shape was not uniform (zigzag). Land was not leveled uniformly. Obstacles were also found in the plot, which hindered the machine movement (Photo 16). In Natore area, some lands were under mango tree plantation as it appeared profitable than rice cultivation. Some lands are smaller in size and headland turning took more time.

Photo 16 Obstacle in land

Varietal characteristics

Seedling characteristic varied with rice variety. It also attractsto the farmers. BRRI dhan49 was more attractive due to dark green color, optimum seedling height with strong erect stem and good vigor seedling. Whereas, BINA dhan7 possessed the excessive seedling height (>16 cm), light green color, slender stem and prone to tilting. In case of BINA dhan7, farmers were unhappy due to number of seedling dispensed per hill was low (Photo 17). They requested to transplant more seedlings in each hill, which influenced the seedling tray requirement.

Photo 17a Seedling of BRRI dhan49

Photo 17b Seedling of BINA dhan7

Depth of seedling placement

Seedling height is another important criterion to transplant seedling by mechanical transplanter. Seedling height having smaller height (<10 cm) may bury into the soil during transplanting. In cold season, seedling takes long time to attain sufficient height. Floating hill increased if seedlings are placed in shallow depth and water wave displaces the seedlings. Depth of seedling placement depended on water height and depth of puddled land. It was observed that water height ranged from 2-4 cm and depth of puddled field ranges from 9-15 cm (Photo 18). In case of soaked condition of land, wheel movement displaced the soil during turning (Photo 19). Water level should be maintained at 1-2 cm height for proper movement of the transplanter. Drainage system should be developed to drain rain water.

Photo 18 Water stagnation before transplanting

Photo 19 Turning effect

Spacing adjustment

Seedling tray requirement in each plot depended on space setting. It is recommended that plant spacing should be set at 16-17 cm. In practical situation, most of the places plant to plant spacing was higher than 16 cm. This might be due to skidding of the transplanter. Water height and puddled depth may also influence the actual plant spacing. In this situation, plant spacing should be set at 14 cm. If plant to plant spacing was set at 19 cm, in practical situation, most of the places plant to plant spacing was obtained lower than 19 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.

Seedling density adjustment

Seedling tray requirement in each plot largely depended on the seedling dispensed per stroke. More number of seedling dispensed per hill increased the tray requirement. Seedling density setting depended on seedling density in tray. Poor metering of seedlings increased the number of seedling per hill as well as increased the tray requirement. In a study, seedling density was set at 3, and some missing hills were observed. Again, seedling density was set at 4, it reduced the missing hill drastically however, increased tray requirement. Care should be taken to synchronize seedling density in tray and seedling density setting in machine to minimize missing hill.

Tray savings

During the study period, area coverage under mechanical transplanting was 10.65 ha and 621 trays i.e. 25% trays were saved after providing technical support (Fig. 5). It was possible to synchronize the seedling density in tray, plant height, seedling density setting, plant spacing setting, water height and depth of puddled field.

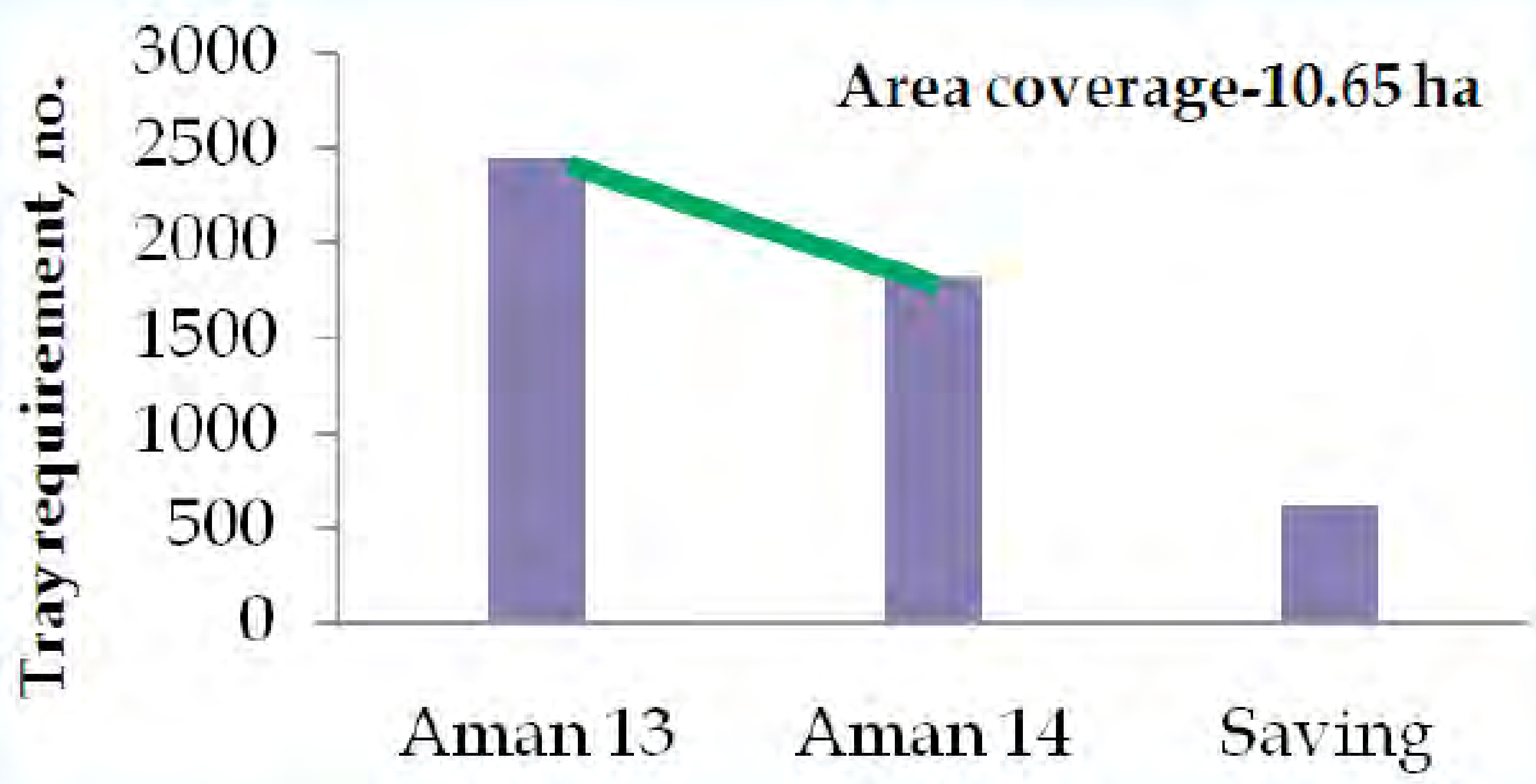


Fig 5 Tray savings

Special care for the entrepreneur

- Machine should be checked before operation in the field
- Machine should be operated by skilled operator
- Avoid small and irregular shape plot
- Plots should be clustered to reduce plot to plot movement time
- Plots should be nearer to nursery plot to reduce transportation cost
- Log book on daily use of trays should be strictly maintained
- Standby mechanic is needed to overcome sudden breakdown of machinery
- Target on area coverage in each day should be fixed for the operator
- Machine should be cleaned and maintenance works will be done after daily operation

Investment and profitability of mechanical transplanting

The country faces acute labor shortage during transplanting time. The farmers are finding the way to solve this issue. Agricultural labor force is shifting gradually to non-agricultural sector. Mechanical mean of transplanting is the best way to solve the problem. Government and private sector has taken initiatives to mitigate the labor shortage during peak period and introduced mechanical transplanter in Bangladesh. The performance of the machine was tested extensively elsewhere in the country. It has been proved that mechanical transplanting increased yield, improved labor efficiency, ensured timeliness in operation and faster in transplanting (Islam *et. al.,* 2015). Lack of awareness about the benefit of mechanical transplanting and ignorance in the raising of mat type seedling are the major constraints in faster adoption of mechanical transplanter. Moreover, transplanter is a sophisticated and costly machine. It is not economically viable for small and medium farmers due to scant resources. Moreover, limited days of use hindered the successful adoption of machine. There is a need to find out the way to make the investment profitable. The objective of this investigation is to estimate the amount of financial assistance to the entrepreneur/ farmers in order to purchase mechanical rice transplanter according to the various financial conditions and to suggest the best financial schemes and operational strategy for farmers.

An economic analysis following standard method was used to estimate the rental charge and payback period of the mechanical transplanter. Four-row walking type transplanter is considered to estimate the profitability of the mechanical transplanting. As the machine price is high and limited annul use, therefore government assistance and interest rate was varied to reduce the payback period.

Economic analysis The cost of operating the transplanter was computed using the following equation involving the fixed and variable cost items.

$$AC = FC + VC \qquad (1)$$

Where,

AC = annual operating cost, Tk yr^{-1}

FC = annual fixed cost, Tk yr^{-1}

VC= variable or operation cost, Tk yr^{-1}

Fixed cost It is independent of machine use and calculated on the basis of capital consumption method (CC). A capital recovery factor (CRF) was used to combine the total depreciation and interest changes into a series of equal annual payments at compound interest. The capital recovery factor can be interpreted as the amount of equal (or uniform) payments to be received for n years such that the total present value of all these equal payments is equivalent to a payment of one taka at present, if interest rate is i. This payment is used to estimate the capital consumption for farm machinery (Hunt, 1995).

$$CC = (P-S)\ CRF + S \times i \qquad (2)$$

$$CRF = \frac{i\,(i+1)^n}{(1+i)^n - 1} \qquad (3)$$

Where,

CC = capital consumption

P = purchase price of the transplanter, Tk

S = salvage value, Tk

CRF = capital recovery factor

i = interest on investment, %

n = life of machine, yr

Variable cost (VC) These costs are associated with the use of transplanter and calculated on the basis of the following equation (Hunt, 1995).

$$VC = \frac{A}{C}[(R \,\&\, M) \times P + L] \quad (4)$$

Where,

A = annual area coverage, ha

C = effective field capacity of the transplanter, ha hr^{-1}

R &M = repair and maintenance cost, %

L = labor cost, Tk hr^{-1}

Break-even analysis The break-even point (BEP) is that point at which neither profit is made nor loss incurred. The total costs of the farm enterprise would be the same as the gross income. It is important to continuously investigate the cost of operation of the farm machine. The farm's fixed costs have to be covered by the income: the higher the fixed costs, the longer it will take for the business to reach break-even and make a profit. Therefore, it is important to keep fixed costs down to a minimum level. The following formula was used to estimate the BEP of the machine.

$$BEP = \frac{FC}{CR-VC} \quad (5)$$

Where,

BEP = break-even point, ha yr^{-1}

FC = fixed cost, Tk yr^{-1}

VC = variable cost, Tk ha^{-1}

CR =custom hire rate, Tk ha^{-1}

Payback Period The payback period is the length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions. Payback period measures the time required for total cash outflows to equal total cash inflows, that is, the time required to break even.

$$\text{Payback Period, yr} = \frac{\text{Investment, Tk}}{\text{Profit, Tk yr}^{-1}} \quad (6)$$

Assumption Islam *et. al.,* (2016a) reported that cost of manual transplanting is Tk 7,510 per ha. They also report that operation cost of transplanter is Tk 3,324 per ha. From these values, fixed and operation cost of the transplanter is considered Tk 4,000 and 3,500 per ha, respectively. The maximum rental charge of the transplanter may be offered Tk 4,000 per ha to maintain the equal cost of mechanical and manual transplanting and beyond that transplanting cost would be higher than the manual. Islam *et. al.,* (2016b) reported that a four-row walking type transplanter can transplant annually maximum 45 ha land in three rice seasons due to multiple land holdings, inaccessibility to the field as other crops are existed there, small and fragmented land.

The purchase price of the transplanter	= Tk 4,00,000
Salvage value	= 10% of the purchase price
Interest on investment	= 12, 8, 4%
Repair and maintenance	= 5%
Life of the transplanter	= 6 yr

Boundary limit Payback period is considered maximum 3 years to make the business viable. The rental charge of the transplanter is considered Tk 4,000 per ha. Beyond that the cost of mechanical transplanting is higher than the manual transplanting. Farmers will get benefit if rental charge is less than Tk 4,000 per ha. Annual area coverage of each walking type transplanter should be within 45 ha due to present land tenure system.

Procedure As the machine price is higher and limited annual use, different levels of government assistance and interest rate with respect to annual area coverage is considered to draw curves. Payback period can be predicted from those curves.

Fixed cost of the transplanter

Fixed cost was calculated based on the purchase price, depreciation, salvage value, interest on investment, repair and maintenance of the transplanter. Machine value depreciated over time whether use it or not. The annual depreciated value to the transplanter was calculated as Tk 1,12,300, 1,01,000 and 90,200 for the interest rate of 12, 8 and 4%, respectively. Figure 6 shows the fixed cost of the machine with respect to government assistance at different annual use and interest on investment. These graphs will be helpful to the entrepreneur to make a decision for fixing the rental charge of the transplanter.

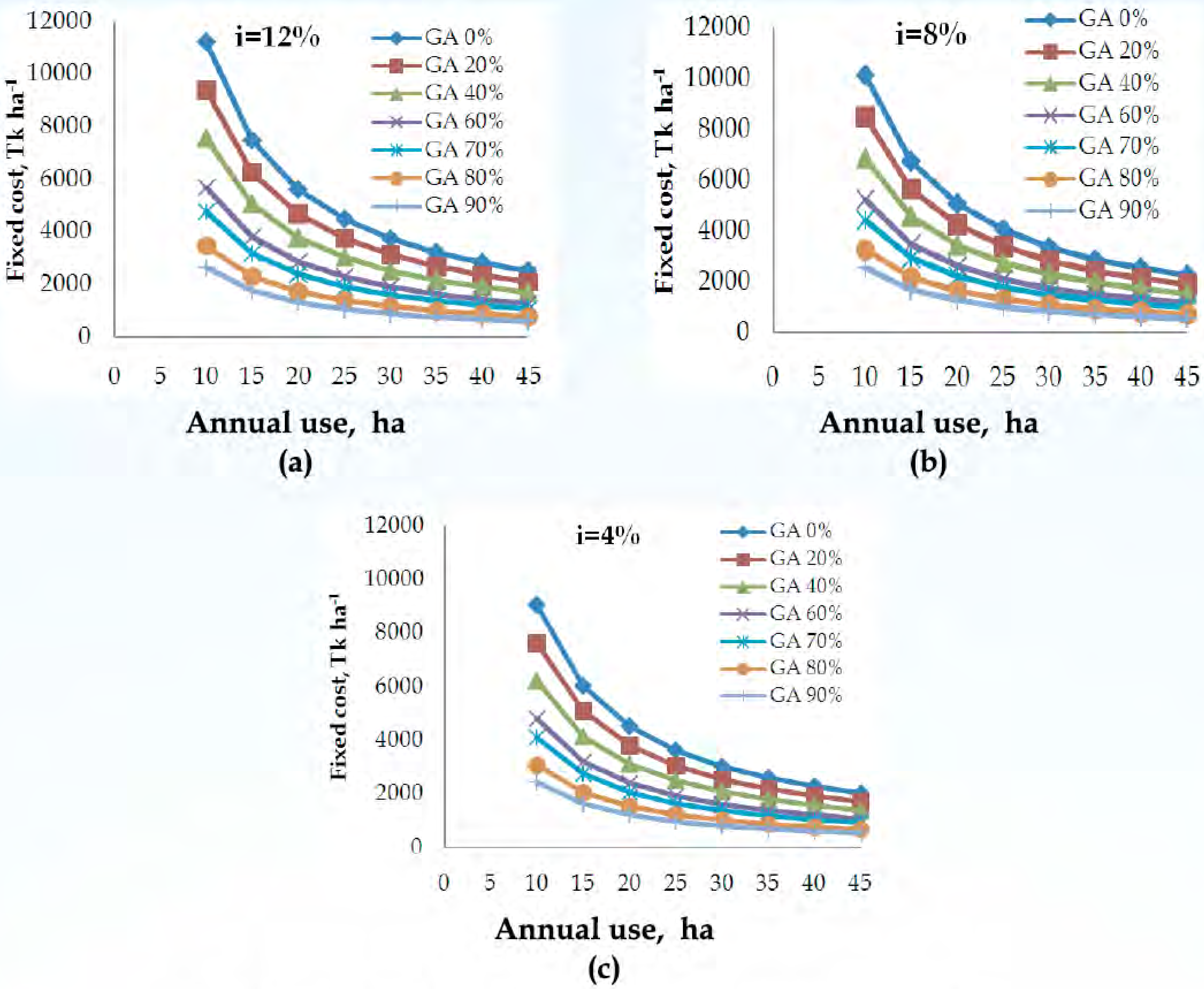


Fig. 6 Fixed cost with respect to government assistance at different annual use and interest rates

Payback period

The payback period was calculated based on the values from Figure 6. Different rental charges and interest rates were imposed to draw the graphs (Fig. 7-13). Payback period largely depended on the annual use of the machine and decreases with the increase in area coverage of transplanting.

With no assistance

Figure 7 shows the payback period for the four-row walking transplanter if purchased outright without receiving any incentive. Profitability started after 26.5 ha of annual use when rental charge offered Tk 4,000 ha (Fig. 7a1). Business will not be viable in any form if entrepreneurs purchase the transplanter without any government assistance for the annual area coverage of less than 45 ha. Payback period would be 15 years for the annual area coverage of 35 ha, which is not economically viable (Fig. 7b1). Payback period will be reduced to 5.1 if rental charge offered Tk 4,250 ha for the annual area coverage of 45 ha and the cost of mechanical transplanting will be higher than the manual. If rental charge offered Tk 3,750 per ha, the payback period would be 7.1

for the annual area coverage of 45 ha. Payback period will be reduced to 5.1 if 4% interest on investment is provided for same annual area coverage. If rental charge offered Tk 3,500 per ha, the payback period would be 8.9 for the annual area coverage of 45 ha. Payback period will be reduced to 6.0 if 4% interest on investment is provided for same annual area coverage (Fig. 7b3).

Business will not be viable if the entrepreneur purchases the machine outright without assistance and offered rental charge of less than Tk 4,000 per ha. It is indeed impossible to transplant 45 ha of land by four-row walking type transplanter due to multiple land holdings, small and irregular shape of plots. The payback period never reduced to three years by reducing interest on investment at any rate. This approach is not feasible due to higher rental charge and higher annual coverage. **Therefore, in no way, the transplanting business would be profitable if purchased at full price although soft loan may be provided.**

With 20% assistance

Figure 8 is drawn for the 20% incentives to purchase transplanter. Profitability started after 23.5 ha of annual use for the rental charge of Tk 4,000 ha (Fig. 8a1). Business will not be viable at 20% assistance to procure transplanter for the annual area coverage of 40 ha. Payback period would be 3.8 at 4% interest on investment for the same annual area coverage (Fig. 8b3). It is not needed to provide soft loan for the rest of the money if area coverage is expected to be more than 40 ha. The payback period would be 6.9 years if area coverage is considered 35 ha and reduced to 5.0 at 4% interest on investment. Payback period is reduced to 3.3 years for the rental charge of Tk 4,250 ha when annual area coverage is expected to 45 ha which is not feasible due to higher rental charge and higher annual coverage. Business can be viable if the rental charge offered Tk 3,750 per ha for the annual area coverage of 45 ha. Payback period will be reduced to 3.5 if interest on investment is 4% for the same annual use. Business will not be viable for the rental charge of Tk 3,750 and Tk 3,500 per ha for the annual area coverage of less than 40 and 45 ha, respectively which is not possible due to present land tenure system. On the other hand, the payback period will never reach to three years with the reduction of interest rate for the annual area coverage of less than 40 ha.

Therefore, the transplanting business would not be profitable if 20% assistance is provided to the organization or farmers to procure transplanter and rest of the 80% is invested with loan at reduced interest rate.

With 40% assistance

Rental charge ranged from Tk 3,500-4,250 ha is used to draw graph where 40% assistance is provided to procure transplanter (Fig. 9). Profitability started after 19 ha of annual use when rental charge offered Tk 4,000 ha (Fig. 9a1).The payback period would be 3.7 years and reduced to 3.1 if 4% interest on investment is applied for the area coverage of 35 ha (Fig. 9b3). Business will not be viable for the annual area coverage ofless than 35 ha. It is not needed to provide soft loan for the rest of the money if area coverage is expected to be more than 40 ha. Business will be viable for the rental charge offered Tk 3,750 per ha for the annual area coverage of 40 ha (Fig. 9a1). If area coverage is expected to be 35 ha, 4% soft loan may be provided for the rest of the money to make the business viable. Business will not be viable below the annual area coverage of 35 ha for the same rental charge.

Business will be less viable for the rental charge of Tk 3,500 per ha for the annual area coverage of 35 ha. The payback period never reached to three years although interest rate is reduced to 4% for the same annual use (Fig. 9b3). Rental charge ranged from Tk 3,500-3,750 per ha never incurred profit if annual area coverage is less than 30ha.

Annual area coverage of 35 ha may not be possible at the initial stage of mechanization. Therefore, transplanting business will not be viable if 40% incentive is provided to the organization or farmers to procure transplanter and rest of the 60% is invested with loan at reduced interest rate.

With 60% assistance

Profitability started after 14.5 ha of annual use for the rental charge of Tk 4,000 ha (Fig. 10). The payback period would be 2.5 years for the annual area coverage of 30 ha (Fig. 10a1). The payback period would be reduced to three years if 4% interest rate is applied (Fig. 10b3). However, area coverage is also reduced to 25 ha. It is not needed to provide soft loan for the rest of the money if area coverage is expected to be more than 25 ha.

Rental charge of Tk 3,750 per ha influenced the business viability for the area coverage of 30 ha and no need to provide soft loan for the rest of the money. If area coverage is expected to be 25 ha soft loan may be provided for the rest of the money to reduce the payback period. Business will not be viable below the annual area coverage of 25 ha for the same rental charge (Fig. 10a1).

Business will be viable for the rental charge of Tk 3,500 per ha with the annual area coverage below 30 ha. If area coverage is expected to be 25 ha soft loan may be provided for the rest of the money to reduce the payback period. Business will not be viable below the annual area coverage of 25 ha for the same rental charge.

At the initial stage of mechanized transplanting, it may not be possible to cover 30 ha land. Therefore, it would have the little possibility to make the transplanting business profitable if 60% cash incentive is provided to the organization or farmers to procure transplanter and the rest of the 40% is invested with loan at reduced interest rate.

With 70% assistance

Figure 11 shows the return and payback period at different government assistances and interest rates. Profitability started after 12 ha of annual use when rental charge offered Tk 4,000 ha (Fig. 11a1). The payback period would be 2.3 years for the annual area coverage of 25 ha. Business will be viable if less than 4% interest on investment is provided for the area coverage of 20 ha (Fig. 11b3). It is not needed to provide soft loan for the rest of the money if area coverage is expected to be more than 25 ha.

Rental charge of Tk 3,750 per ha influenced the business viability for the area coverage of 25 ha and no need to provide soft loan for the rest of the money. If area coverage is expected to be less than 25 ha soft loan may be provided for the rest of the money to reduce the payback period. Business will not be viable below the annual area coverage of 20 ha for the same rental charge (Fig. 11b). Business will not be viable for the rental charge of Tk 3,500 per ha with the annual area coverage of 25 ha.

It is possible to cover 20 ha of land under mechanized transplanting in three rice seasons. Therefore, transplanting business would be profitable with 70% cash incentive and 30% loan at reduced interest rate to procure transplanter.

With 80% assistance
Figure 12 shows that profitability started after 11 ha of transplanting at the rental charge of Tk 4,000 per ha. The payback period would be 1.9 years if rental charge offered Tk 4,000 ha for the annual area coverage of 20 ha (Fig. 12a1). It is not needed to provide soft loan for the rest of the money if area coverage is expected to be more than 20 ha (Fig. 12b). If interest rate is reduced, the payback period is also reduced to three years, however, area coverage is also reduced to 15 ha. At this stage, transplanting business would be profitable. Owner can also offer rental charge less than Tk 4,000 ha to reduce the production cost.

Rental charge of Tk 3,750 per ha may be offered for the annual area coverage of 20 ha. In that situation, no need to provide soft loan for the rest of the money. If area coverage is expected to be 15 ha soft loan may be provided for the rest of the money to reduce the payback period.

Rental charge of Tk 3,500 per ha may be offered for the annual area coverage of 20 ha. In that situation, no need to provide soft loan for the rest of the money. If area coverage is expected to be 15 ha soft loan may be provided for the rest of the money to reduce the payback period. Farmers will get benefit by reducing transplanting cost of Tk 500 per ha for the rental charge of Tk 3,500 per ha. Business will be less viable if area coverage is 15 ha and rental charge is Tk 3,500 per ha. Business will not be viable below the annual area coverage of 15 ha for the rental charge of Tk 3,500-4,000 per ha.

There is a little impact on soft loan for the rest of the money and discourage to provide the soft loan at this stage. Therefore, it is possible to make the transplanting business profitable if 80% incentive is provided to the organization or farmers to procure transplanter.

With 90% assistance
Profitability started after 7.5 ha of annual use when rental charge offered Tk 4,000 ha (Fig. 13). The payback period would be 3.7 year for the annual area coverage of 10 ha at an interest rate of 12% (Fig. 13a1). Owner can offer rental charge less than Tk 4,000 ha as well as production cost will be reduced. Business will be less viable for the rental charge of Tk 4,000 per ha for the annual area coverage of less than 10 ha. Soft loan has minor impact on the reduction of payback period for the rental charge of Tk 4,000.

Business will be viable for the rental charge of Tk 3,750 and Tk 3,500 per ha with the annual area coverage of 15 ha. Therefore, it is possible to make the transplanting business profitable if 90% cash incentiveis provided and invested 10% price with own expenses.

Benefit of farmers

Farmers will be benefitted from the custom hiring of transplanter forthe rental charge is less than Tk 4,000 per ha. In case of charge offered Tk 3,500 per ha, customer would get the benefit of Tk 500 per ha as compared to the manual transplanting of paddy. It seems monetary benefit is small however mechanical transplanting ensure the timeliness and faster operation, reduce drudgery of the farmers, and yield benefit due to use of tender aged seedling.

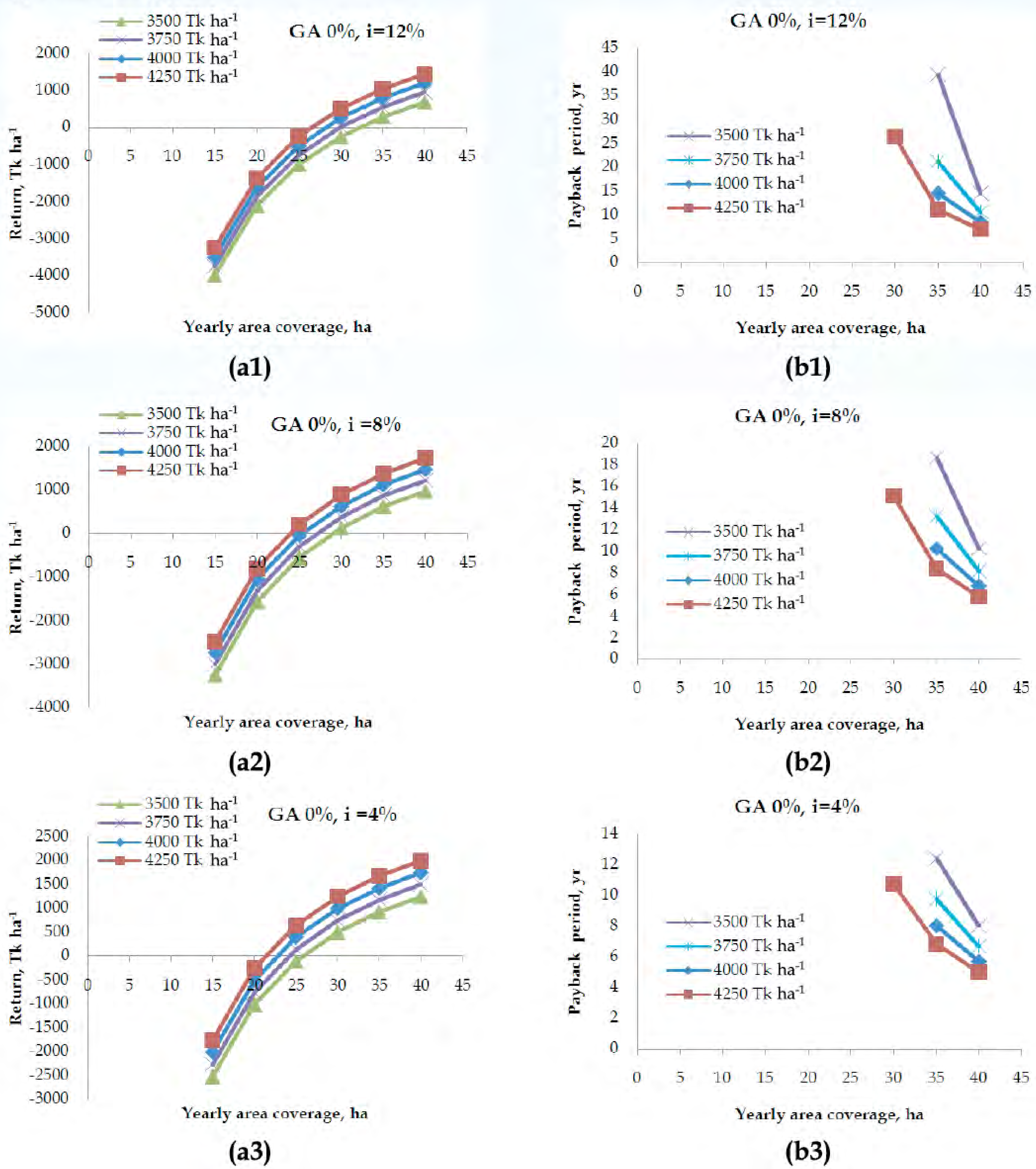


Fig.7. Return and payback period of transplanter with no assistance at different interest rates

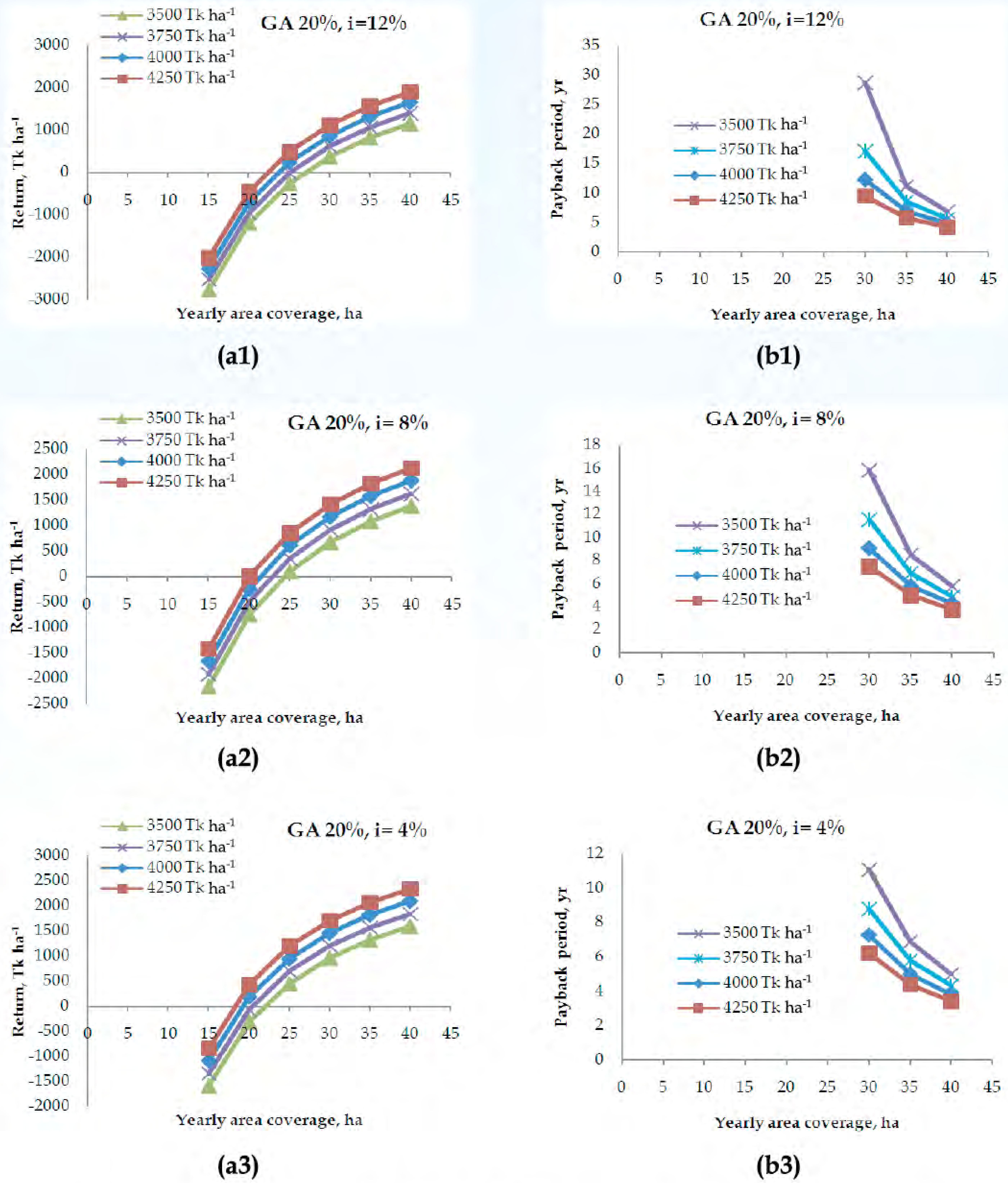


Fig. 8. Return and payback period of transplanter with 20% assistance at different interest rates

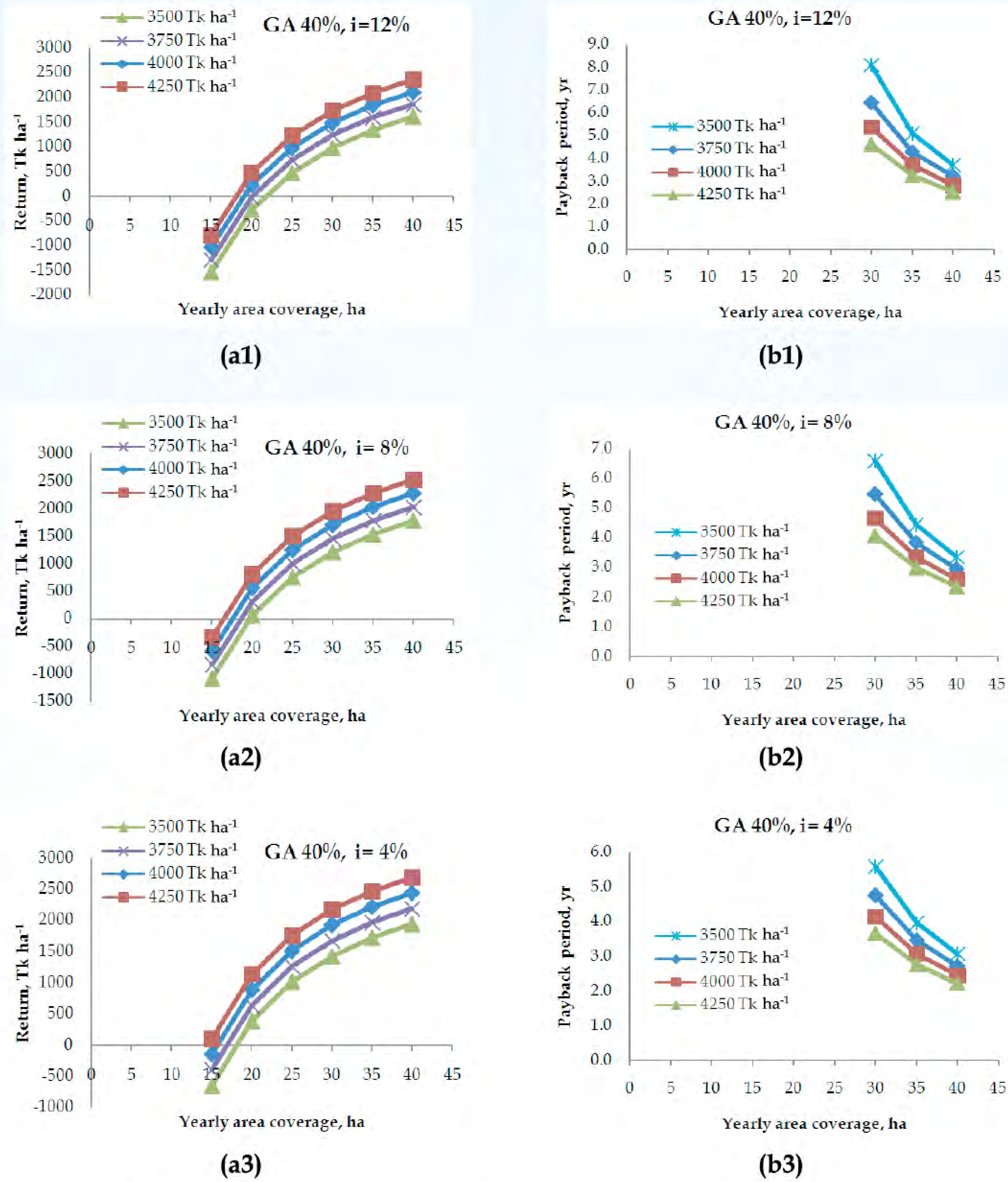
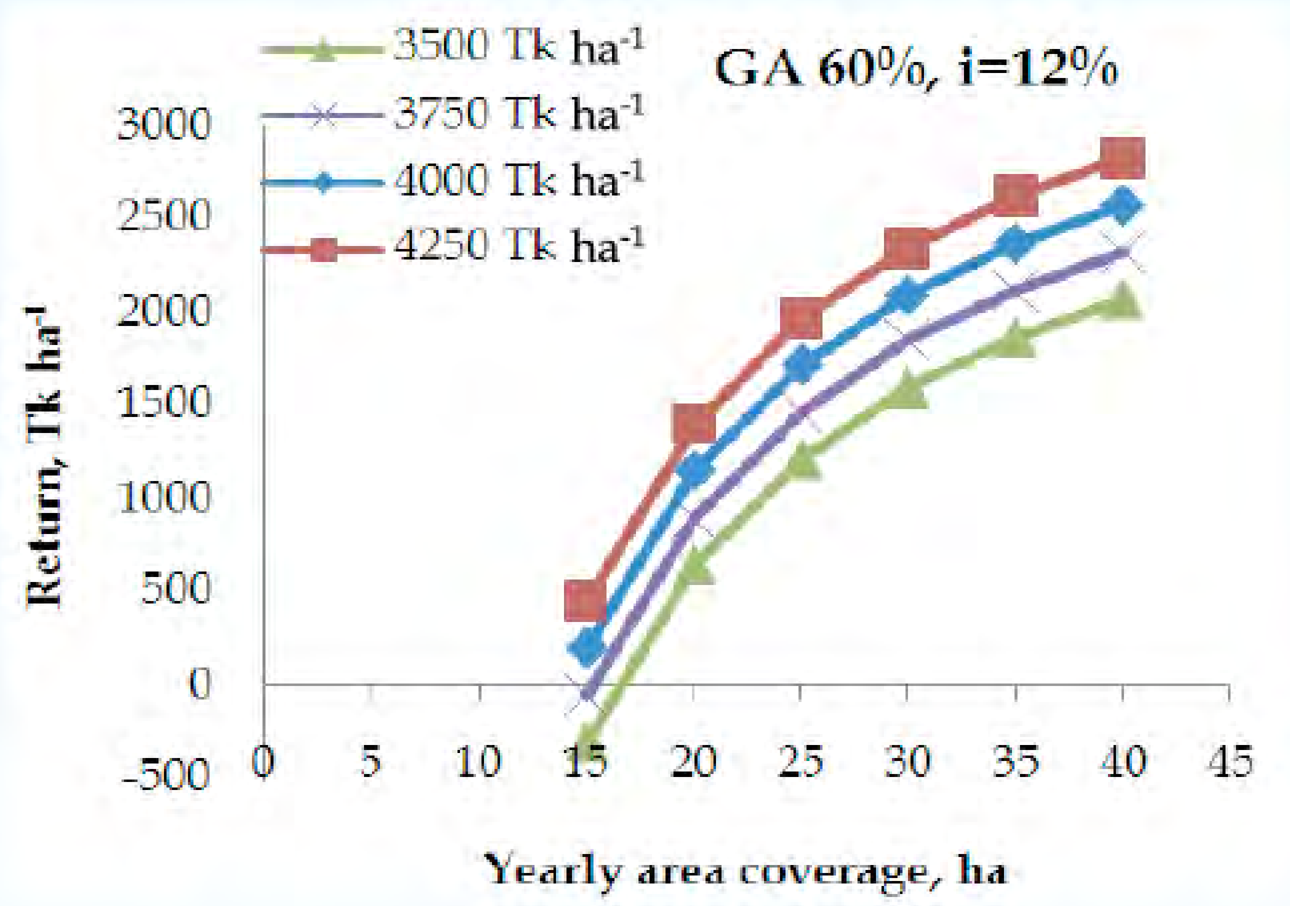
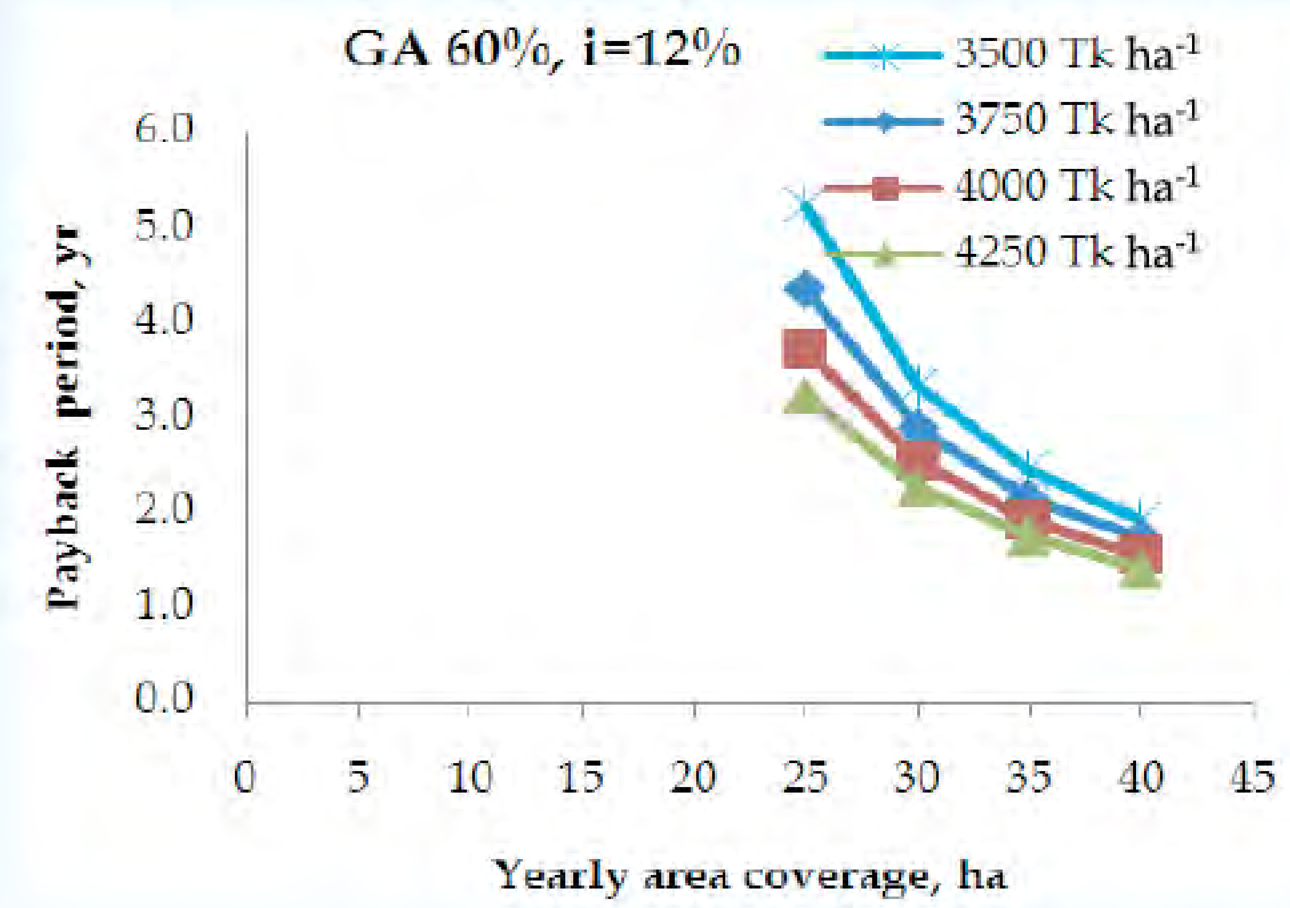


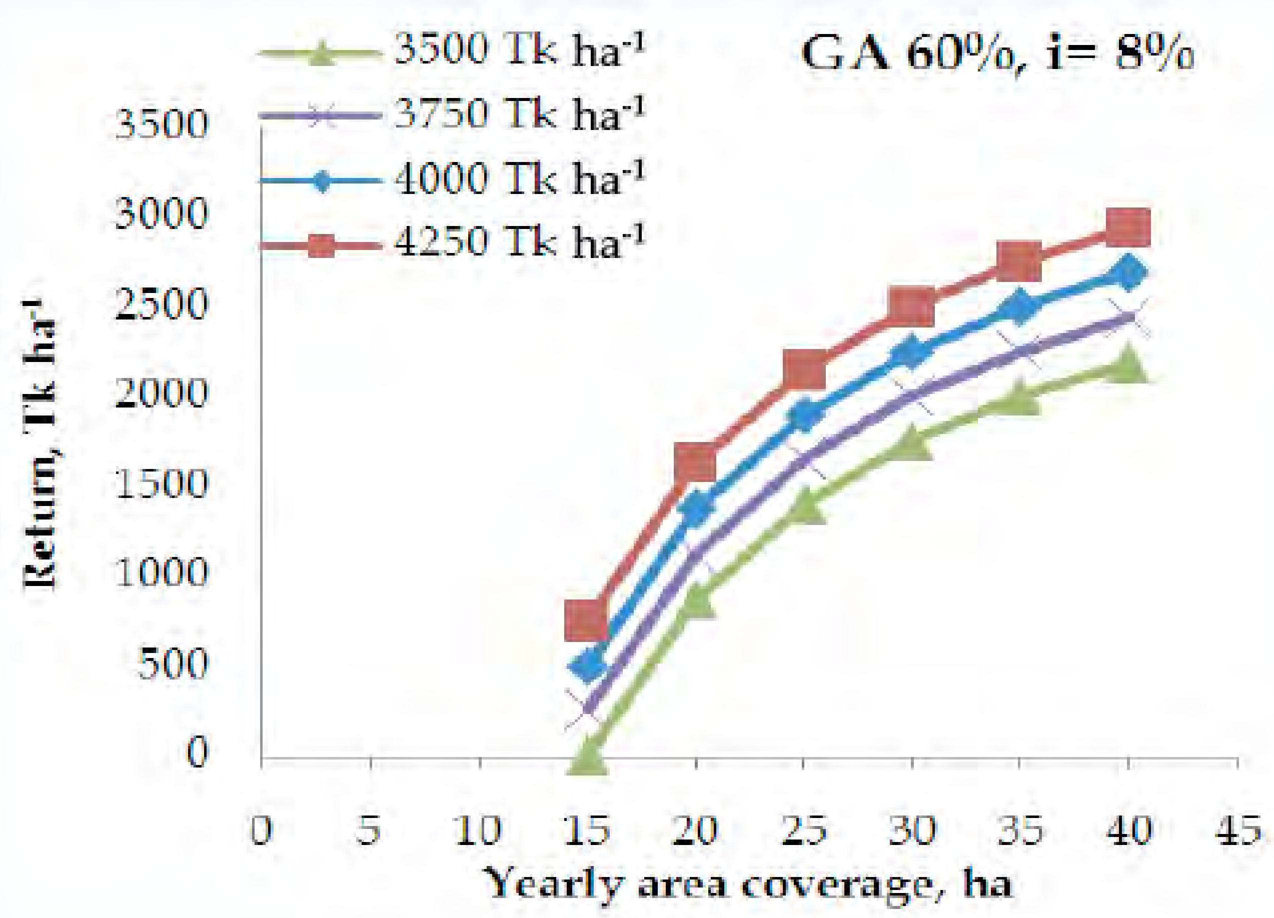
Fig.9. Return and payback period of transplanter with 40% assistance at different interest rates



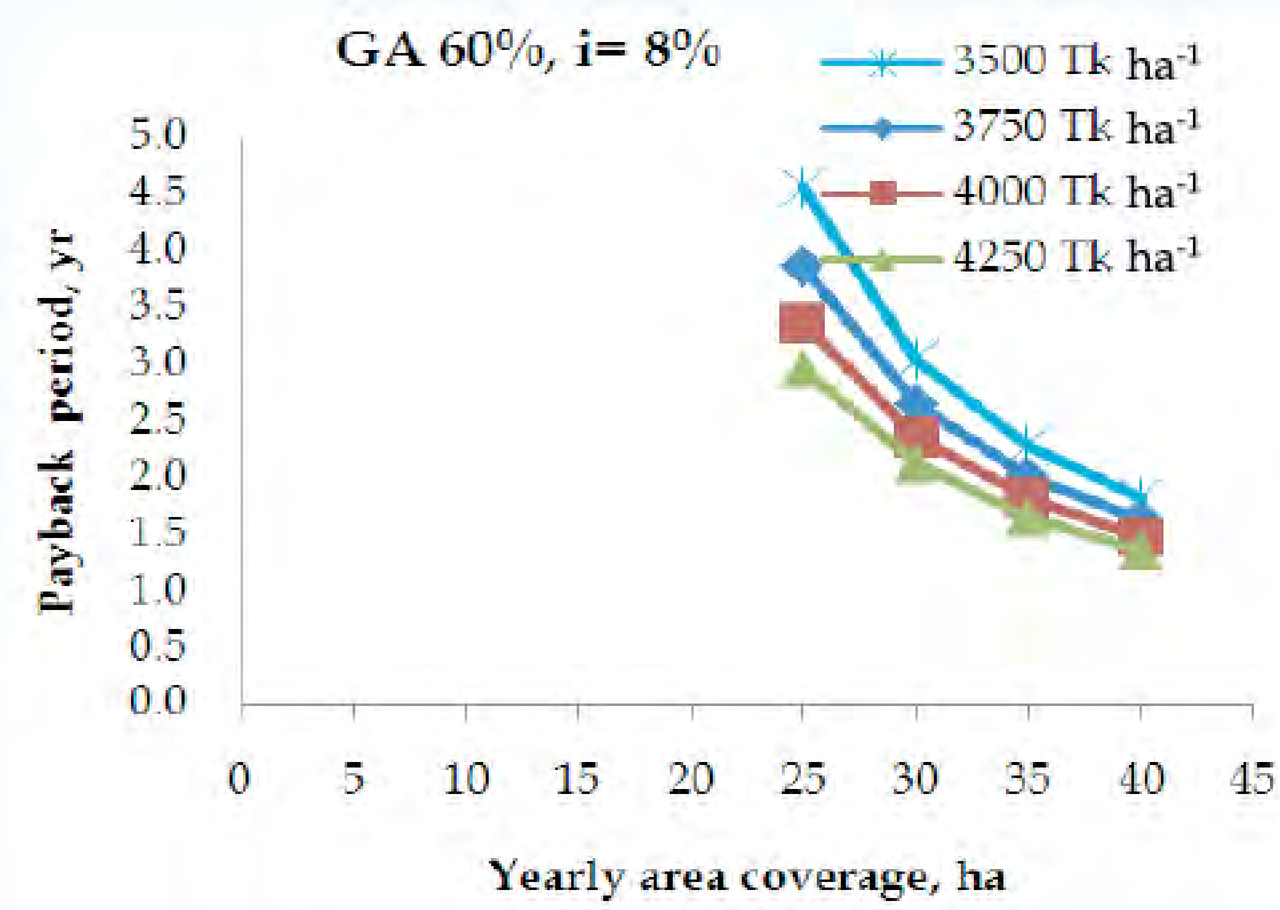
(a1)



(b1)



(a2)



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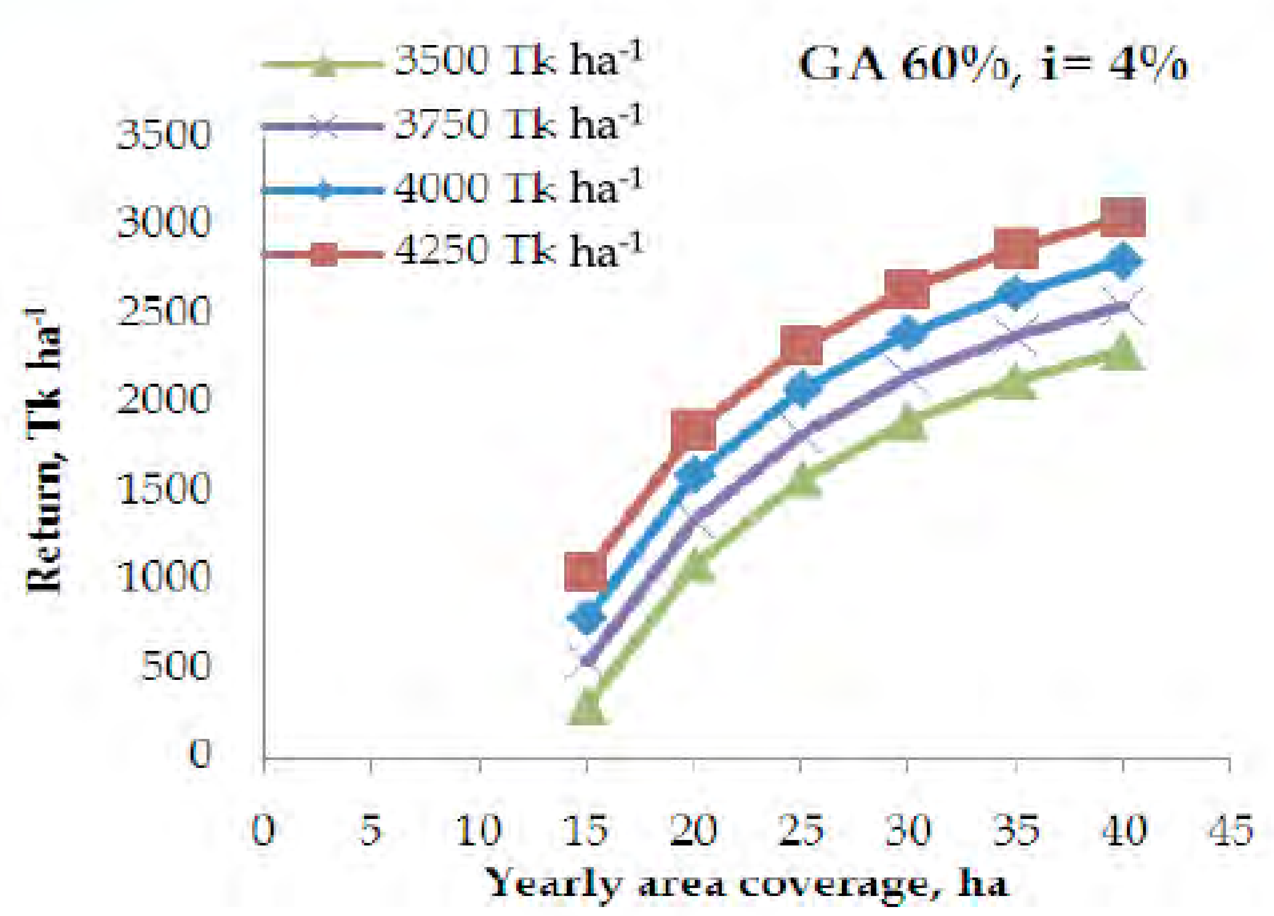
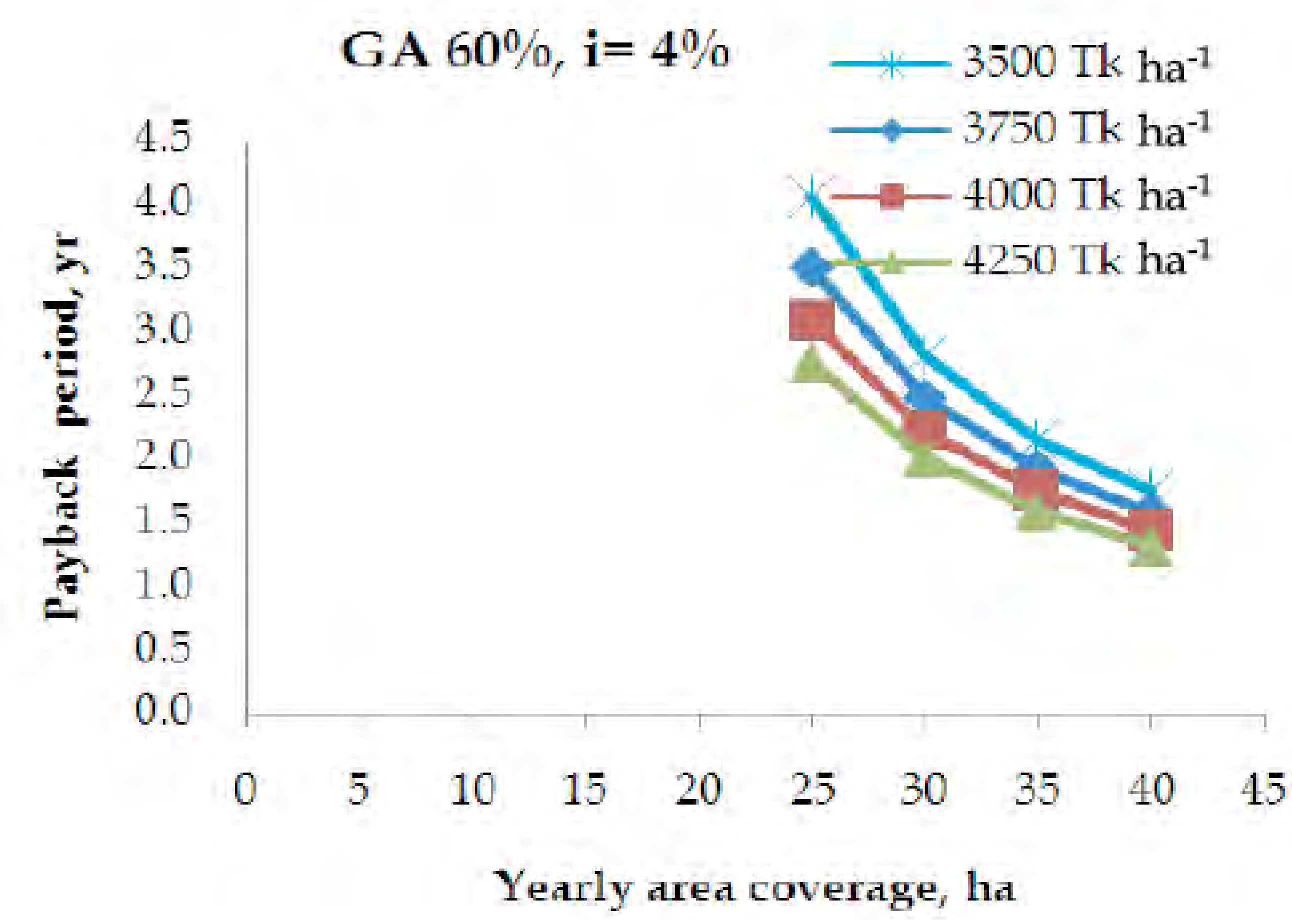


(a3)



(b3)

Fig.10. Return and payback period of transplanter with 60% assistance at different interest rates

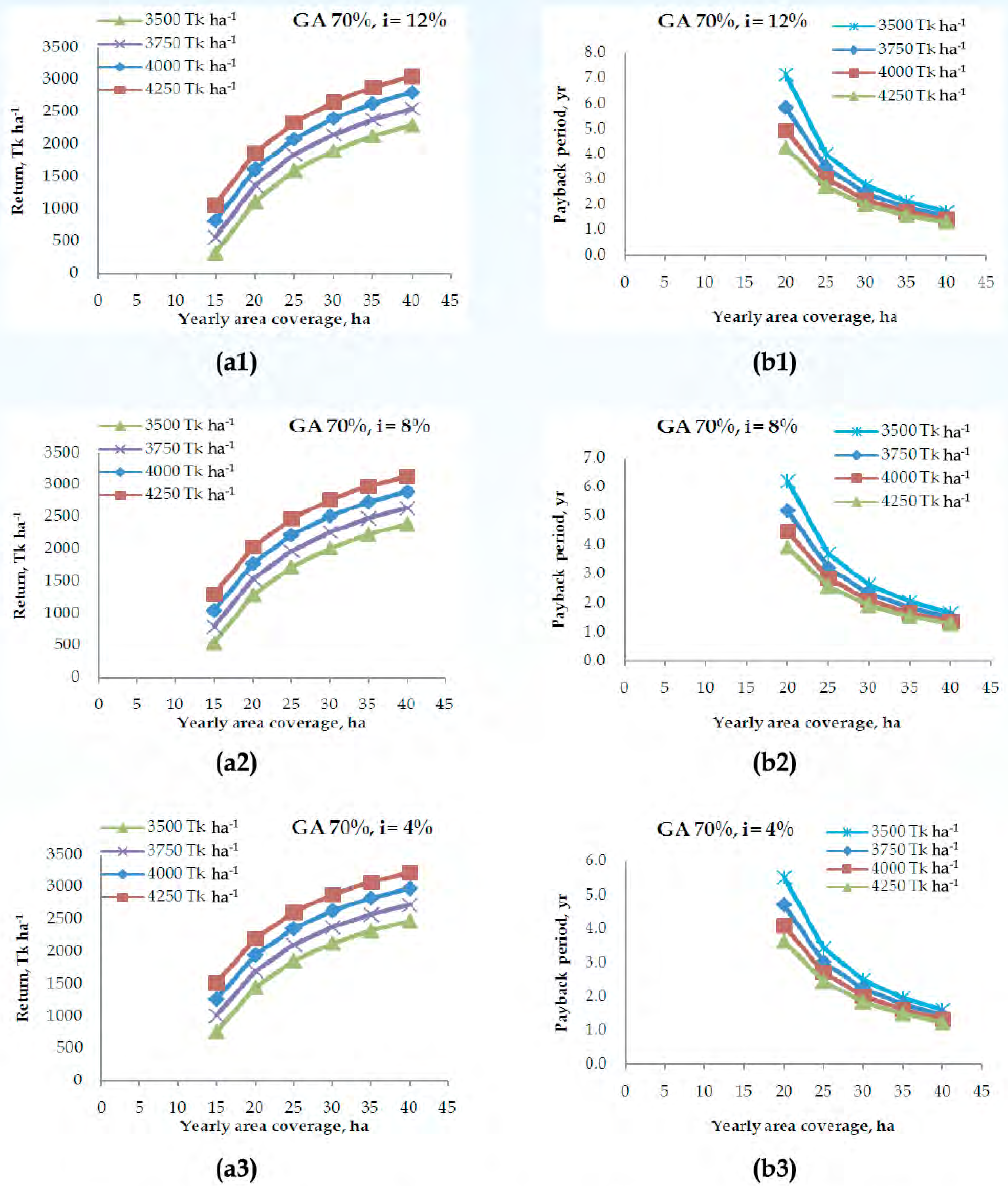


Fig. 11. Return and payback period of transplanter with 70% assistance at different interest rates

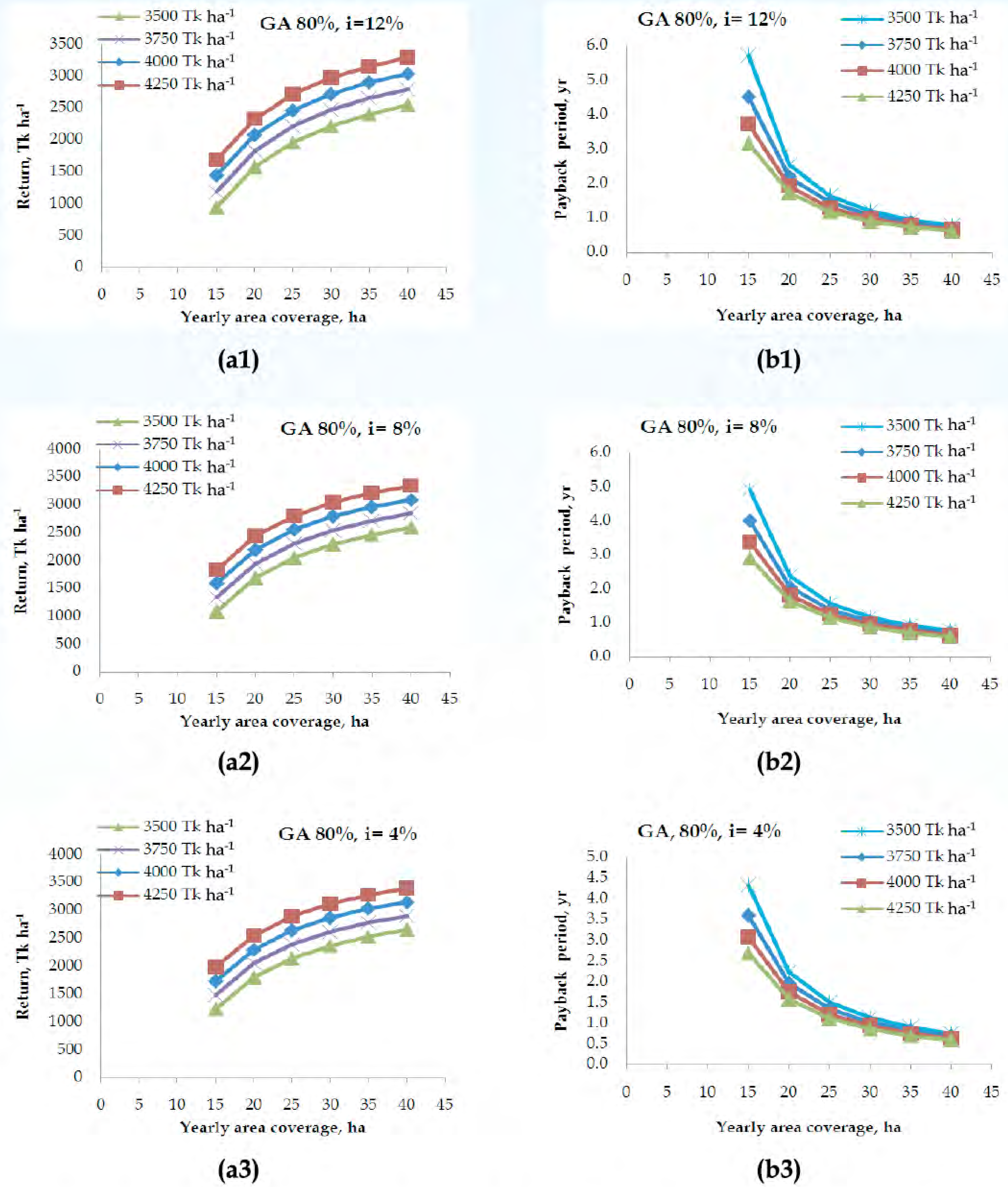


Fig.12. Return and payback period of transplanter with 80% assistance at different interest rates

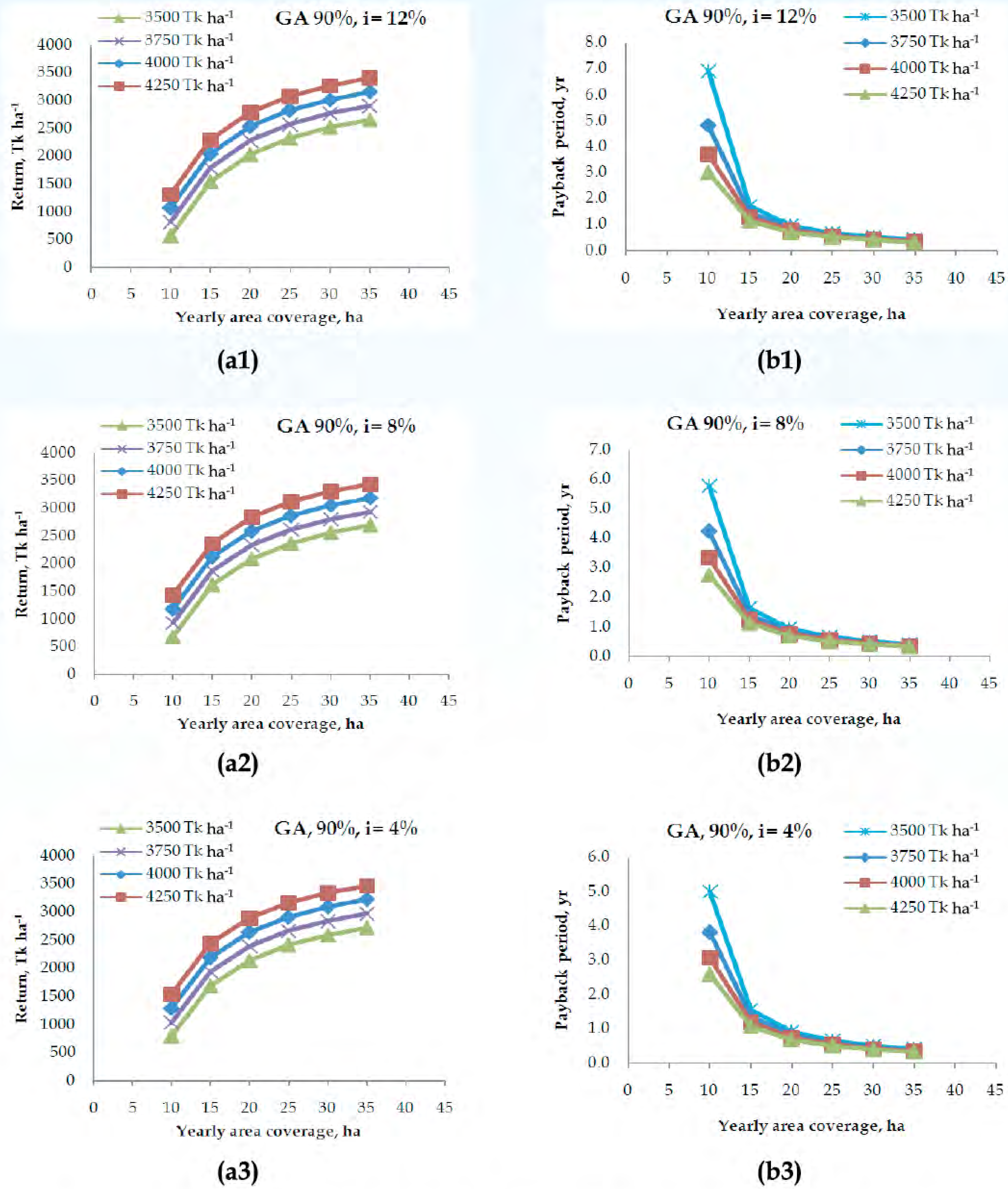


Fig.13. Return and payback period of transplanter with 90% assistance at different interest rates

Experience in South Korea

In 1981, Korean government provided 50% subsidy, 40% loan, leaving farmers' own expense at ten percent (with an eight percent annual interest rate) to the organizations since 1986 to procure agricultural machinery with an aim to minimize the burden of the farmers. The repayment of existing loans of small farmers was extended to seven years with a three-year grace period and interest rates were lowered to 3%. The repayment period of the money, with which a farm household borrowed to purchase farm machines, was also extended to seven years with a five-year grace period (AMK, 2000). Bangladesh can follow the experience of Korean mechanization as an initial stage of mechanization and socio-economic condition of the farmers.

Price comparison in South Korea and Bangladesh

Table 7 shows that the purchase price of the transplanter in Bangladesh is higher than that in Korea whereas labor price is the cheapest (12 times lower) in Bangladesh compared to Korea. On the other hand, cost of manual transplanting is 7.5 times higher in Korea than in Bangladesh. In Bangladesh, farmers have to sell 18 tons of paddy to buy a transplanter whereas, in Korea, farmers can buy the same transplanter by selling 2.5 tons of paddy. Therefore, mechanized transplanting is costly operation in Bangladesh indicating the urgency of government support to make the transplanting venture viable.

Table 7. Comparative price list of mechanical rice transplanter, labor and paddy in Korea and Bangladesh

Country	Price of 4-row walking transplanter, $\$ unit^{-1}$	Labor price, $\$ day^{-1}$	Manual transplanting cost, $\$ ha^{-1}$	Price of paddy, $\$ t^{-1}$	Price of rice, $\$ t^{-1}$	Paddy exchange to procure transplanter, $t\ unit^{-1}$
[1]South Korea	3,000	60	700	1200	2000	2.5
[2]Bangladesh	5,000	5	94	275	440	18

[1]Dr Kim, personal communication, [2]Islam *et. al.* (2016), 1$ = 80 Tk

Approach

At the initial stage, the government should provide one unit of transplanter to all upazilas under DAE for large scale demonstration, set up adaptive trial and provide training to build up mass awareness about the benefit of the mechanized rice transplanting. The government may provide one unit of transplanter to some of the promising farmers' groups and most vulnerable areas with full assistance of training on the operation, repair and maintenance of the transplanter. Farmers' group will fix the rental charge of the transplanter to meet up the repair, maintenance and management cost of the machine.

Second stage- If annual area coverage is expected to be 10 ha, 90% incentive may be provided to the farmers' group/entrepreneur to procure transplanter. Farmers' group/entrepreneur will invest 10% own expense.

Third stage- If annual area coverage is assumed to be 15 ha, 80% incentive and 10% with loan facility may be provided to the farmers' group entrepreneur to procure transplanter. Farmers' group/entrepreneur will invest 10% own expense.

Fourth stage - If area coverage is assumed to be 20 ha, 70% incentive and 20% with soft loan (below 8%) may be provided to the farmers' group/entrepreneur to procure transplanter. Farmers' group/entrepreneur will invest 10% own expense.

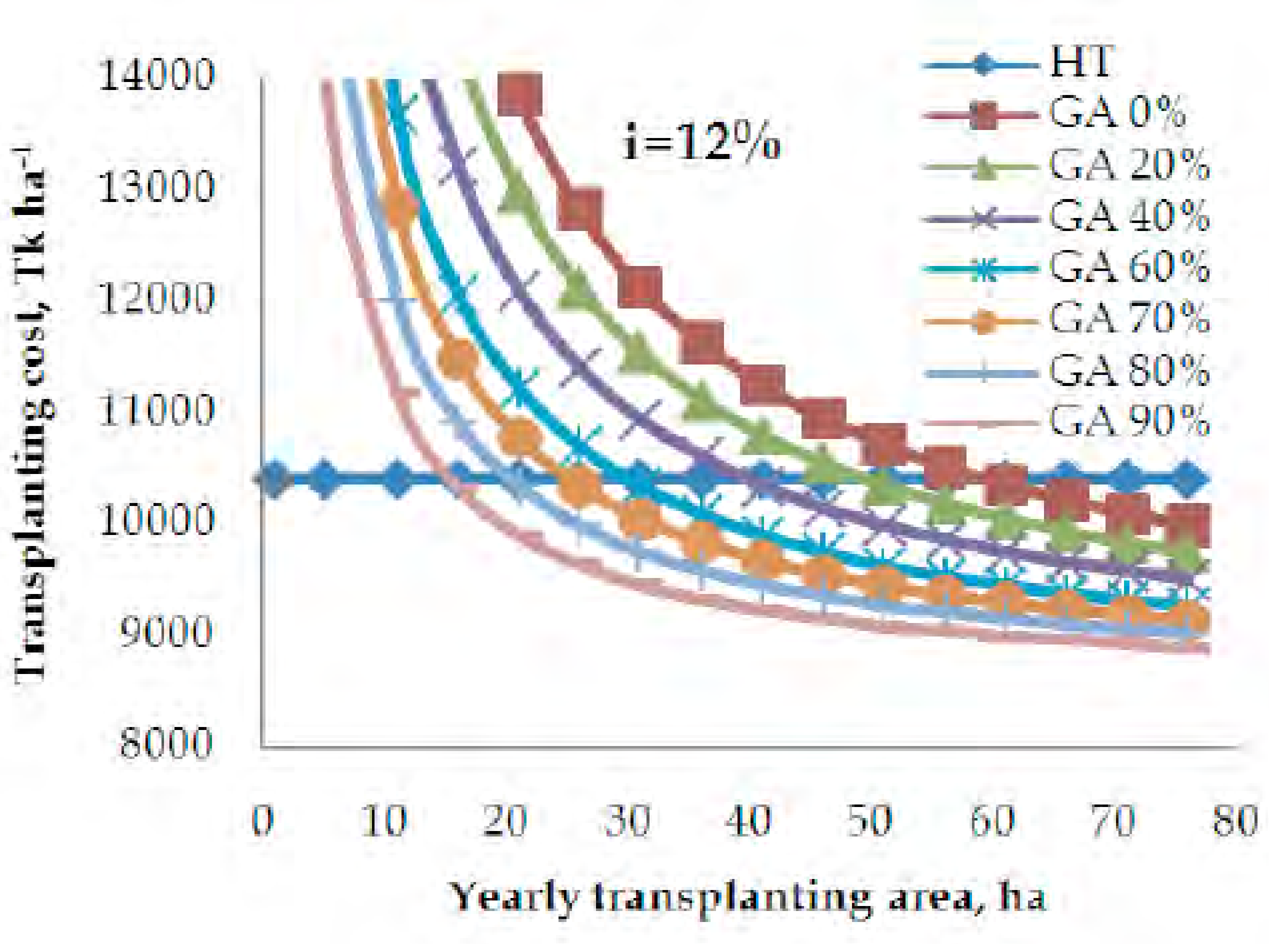
Fifth stage - If area coverage is assumed to be 25 ha, 60% incentive and 30% with soft loan (below 4%) and 10% own expense may be provided to the farmers' group entrepreneur to procure transplanter.

Sixth stage - If area coverage is assumed to be 35 ha, 40% incentive, 50% with soft loan (below 4%) and 10% own expense may be provided to the farmers' group entrepreneur to procure transplanter.

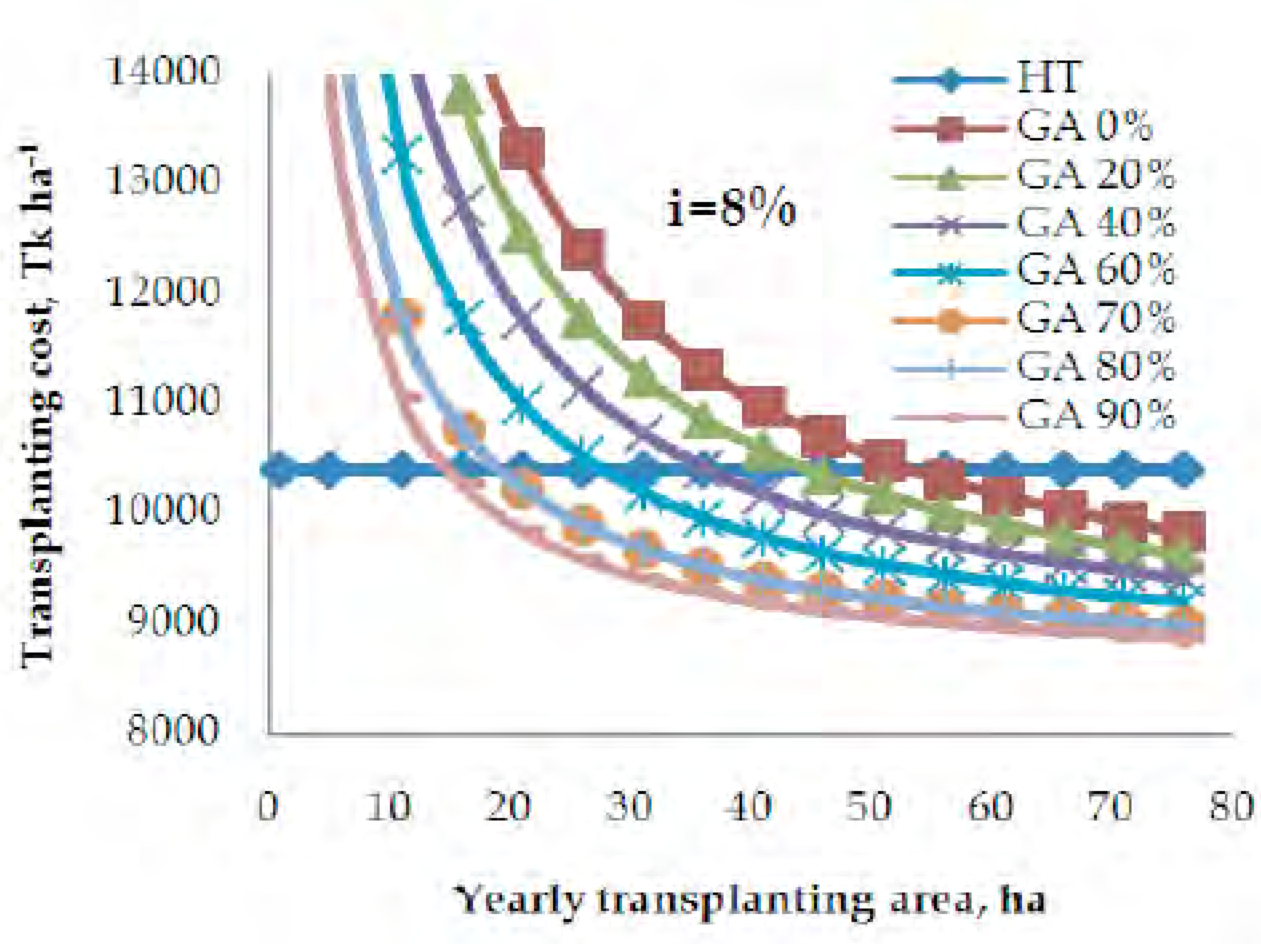
Seventh stage- If yearly area coverage is assumed to be 40 ha, 20% incentive, 70% with soft loan (below 4%) and 10% own expense may be provided to the farmers' group and entrepreneur to procure transplanter.

Break-even area

Break-even is a financial analysis tool to understand the profitability of business and take necessary actions to recover the cost of operation. Break-even point exactly determines the point at which the cost of service (Fixed and variable) and revenue is same i.e. profit is zero. This break-even point helps the entrepreneur/farmer to fix the area coverage of the transplanting service. Islam *et. al.* (2016) reported that from seedling raising to transplanting, the cost of manual and mechanical transplanting was obtained Tk 10,409 and Tk 8,512 per ha. These values are used to draw graph to find out break-even area at different government assistance and interest rates (Fig. 14). Farmers will get benefit after annual mechanical transplanting of 14-16, 17-20, 21-26, 25-30, 32-40, 40-50 and 47-60 ha land for 0, 20, 40, 60, 70, 80 and 90% government assistance, respectively at 4-12% interest on investment to procure transplanter.



(a)



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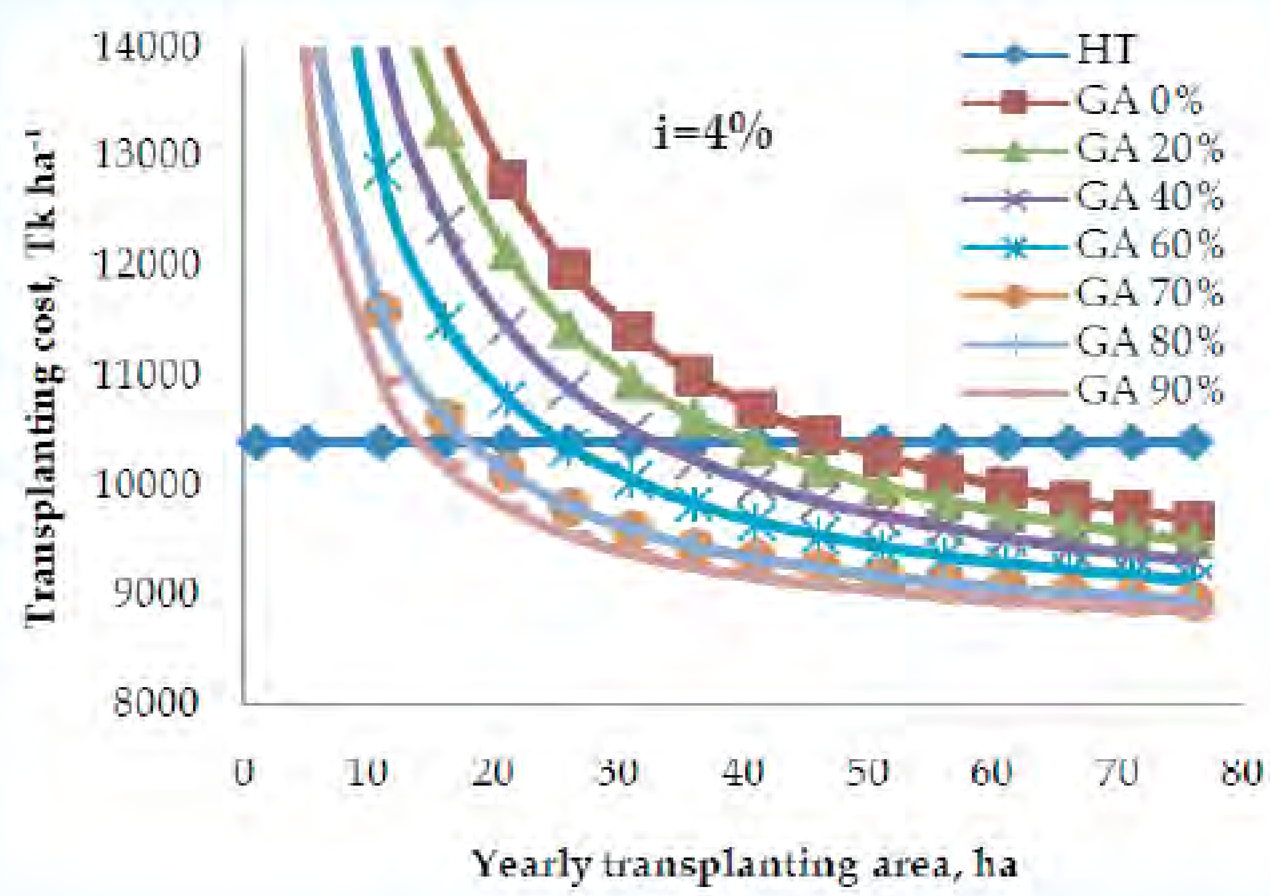

(c)

Fig. 14. Cost of mechanical transplanting with respect to hand transplanting at different government assistances

Transplanter demand prediction

Kabir *et. al.* (2016) mentioned that land area decreased 0.40% annually. Area coverage under *aman* rice cultivation during 2014-15 is 55,30,000 ha (BBS, 2015) in which 30% area is assumed to have inaccessibility of machine and direct seeded rice cultivation. According to the road map, the government has fixed the target of mechanized transplanting 20% in 2021, 40% in 2031 and 80% in 2041 (MOA, 2016). The annual area coverage of four-row walking type and six/eight-row riding type transplanter was considered as 45 and 80 ha yr^{-1} (Islam and Rahman, 2014). It is expected that area under mechanical transplanting of 95% in 2021, 90% in 2031 and 75% in 2041 will be covered by four-row walking type transplanter and the rest will be covered by six/eight-row mechanical rice transplanter. Figure 15 was drawn considering the above condition and field capacity of the four-row walking type and six/eight-row riding type transplanter. The predicted demand of the four-row mechanical transplanter would be 15,420, 27,165 and 39,091 in 2021, 2031 and 2041. The predicted demand of the six/eight-row mechanical transplanter would be 812, 3,018 and 13,030 in 2021, 2031 and 2041, respectivly

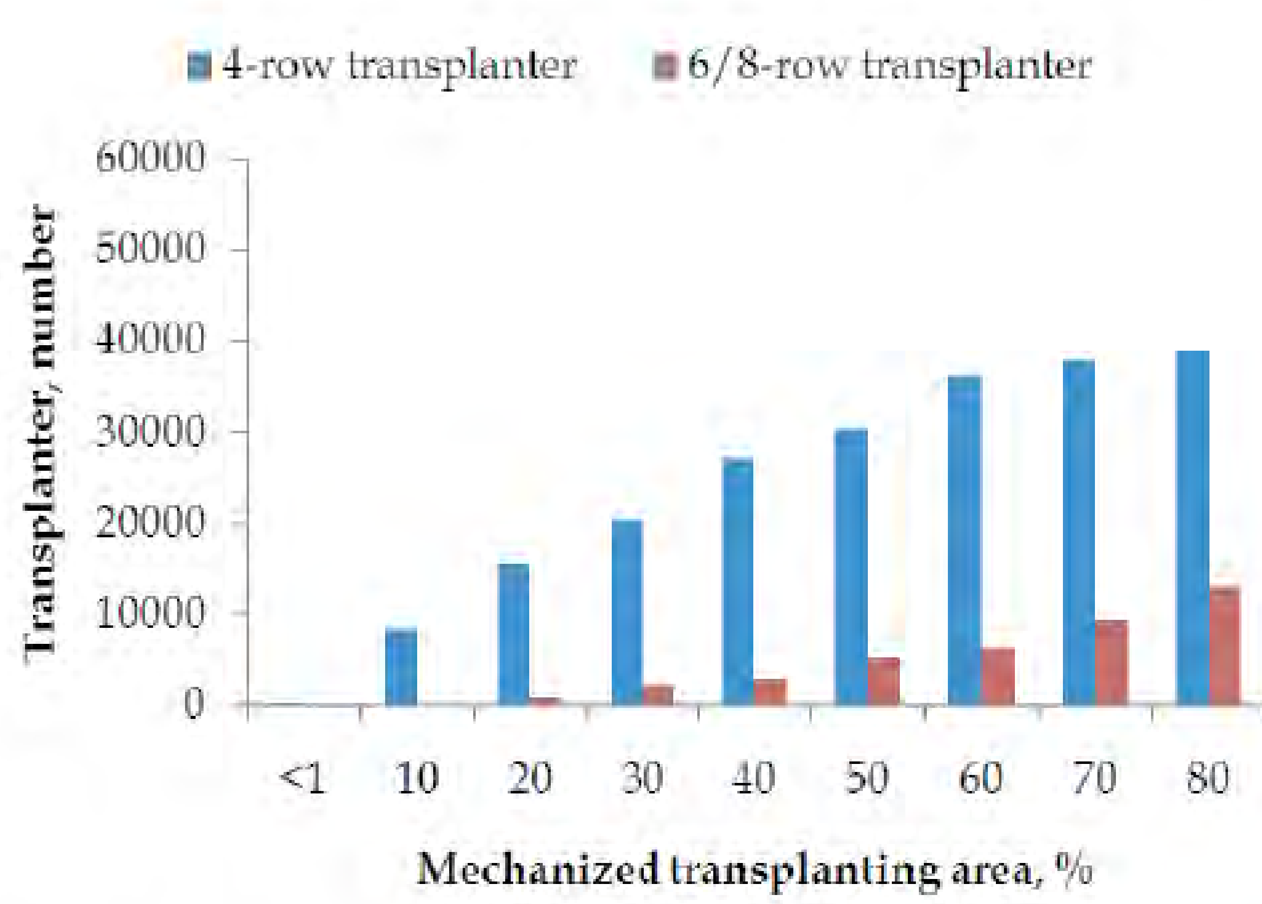

Fig. 15 Demand prediction of mechanical rice transplanter

Trouble shooting of the transplanter

Problem and probable solution

Problem	Solution
Spark plug	Clean and change the filter
Air cleaner	Clean by passing forced air and change the filter
Carburetor	Wash by petrol and adjust
Engine transmission belt	Change when distorted
Radiator	Clean the fin and change the distilled water
Accelerator	Cable change and adjustment
One touch lever	Change the fuse
Steering system	Check the gear box, nuts of turning shaft and adjust the nut
Hydraulic system	Check oil level
Griper clutch	Fuse, cable change and adjust
Picker	Check spacing lever, planting arm, needle shaft
Battery	Change acid, charging
Automatic switch	Change with new one
Engine fuel filter	Change after 1000 hrs of operation
Hydraulic oil filter	Change after 1000 hrs of operation
Brake pedal	Check the adjustment

Maintenance of the transplanter

Engine oil	Every day checking. First change after 30 hrs, then 200 hrs of operation
Transmission oil	Every day checking. First change after 50 hrs, then 200 hrs of operation
Rear axle oil	Every day checking. First change after 50 hrs, then 200 hrs of operation
Hydraulic oil	Every day checking. First change after 50 hrs, then 200 hrs of operation
Grease	Every day checking. Picker arm, gear box, chain cover roller and different greasing point
Picker	Regular checking of wear and alignment

Business model

Custom hire service

Custom hiring is meant to operate the farm machine for a certain period by paying only the service charge without owning the machine. Custom hiring facilitates the rapid expansion of mechanized cultivation. Hire services enabling farmers to get more time to carry out additional farm and non-farm works. The objective of the custom hire service is to foster farm mechanization by making easy access of farm machinery to the small and medium holder farmers. Transplanter is an expensive machine and requires advanced operating skill due to sophisticated and complex mechanism. Custom hire service is an appropriate way to keep the operating cost of transplanter at a reasonable level and helped in wide spread adoption of the mechanized transplanting. It will also create a business venture for the rural unemployed youths. Cash incentives should be provided to encourage entrepreneurs to set up infrastructure of custom hiring services of mechanized transplanting. Institutional credit should be made available to set up custom hiring service center. In Bangladesh, mechanized transplanting is now in rudimentary stage and very few organizations have taken initiatives to expand transplanting business by piloting different business model. Up to now, none of the models is proven business viable due to several constraints. Some of the business models are described below.

Syngenta model

During *boro* 2014 and *aman* 2014 seasons, transplanting operation was done in 43 ha area in 375 plots and 205 farmers were benefitted from the transplanting business. Syngenta charged Tk 15,000 per ha of land to be transplanted with an assurance to provide seed, seedlings, seedling carrying to the field, mechanical transplanting, gap filling and advisory support for successful crop production. Farmers themselves prepared their land at their own cost. In order to supply tray, the company prepared tray centrally using special media in different days according to the transplanting schedule. The trays were transferred to the nursery field by truck, which was very far from the tray preparation shed. Syngenta took lease of the big sized land for nursery. The workers of the nursery were taken proper care to raise seedling. Again the trays were transferred to the farmers' field using trucks and unloaded nearer to the field. The labor carried the trays to field using head and shoulder. The company could not get benefit as it incurred huge cost in tray preparation, tray carrying to the nursery, nursery management, seedlings carrying to the farmer's field, high wage for skilled operator and labor, transplanter rental charge, cost of fuel, repair and maintenance and stopped the mechanical transplanting business in 2015.

GBK model

Golden Barn Kingdom Pvt. Ltd (GBK) is an agroinput based multinational company and promoting mechanized agriculture in the country to reduce the transplanting cost, time and entrepreneurship development of the rural people. GBK started to cover BADC seed farms under mechanized transplanting in 2011. GBK worked with DAE, RDA and BRAC's Agriculture and Food Security Program to evaluate the field performance of mechanical rice transplanter in Tangail, Bogra and Rajshahi districts in 2012-2013. The company also continued their business activities in Dhaka, Mymensingh, Kushtia and Chuadanga districts. Seedlings were raised centrally in Ashulia, Dhaka with their own management and carried by truck to the farmers' field. Seedlings were transplanted using mechanical transplanter through taking promotional service charge of Tk 12,350 per ha. They have got positive response from the farmers and obtained encouraging yield benefit from the field trials. High rate of cost escalation was observed in nursery management and seedling transportation from nursery to the farmers' field. The company incurred huge monetary loss in commercial transplanting and stopped their business activities in 2015 (Rashid, 2016).

ACI model

ACI motors started commercial use of mechanical transplanter in the name of "Farm Service" with an aim to provide transplanting support to the farmers in participatory way at low cost with minimum investment. Initially, the company started piloting the model in one location taking 7 ha lands in Rangpur district during *boro* 2016. The company supplied the sufficient trays to each farmer depending on the land area to be mechanically transplanted. Farmers got hand-on training to prepare trays and nursery management. Farmers used their own seeds and soil to prepare tray. Nursery, plant protection, irrigation management and land preparation were done by the farmers with their own management and cost. The company transplanted the seedling using their transplanter by taking promotional rental charge of Tk 2,250 per ha. Crops were cared by the farmers and the company provided advisory service with no cost. The company continued the transplanting business in *aman* 2016 season. Several field constraints were identified during transplanting:

- Difficult to move transplanter from one field to another due to lack of farm road
- Some fields were not ready before the day of transplanting
- Excess water in the land hindered the movement of transplanting
- Transplanting schedule could not be maintained properly due to delay in land preparation
- Unable to operate transplanter in irregular shape of plot
- Seedling attained over height due to disruption of schedule
- Farmers were unsatisfied due to gap filling after mechanical transplanting

Proposed model of mechanical transplanting

Management cost of raising seedling in nursery bed is very high compared to traditional method. In order to cut down the nursery management cost, farmers themselves should raise seedling in their own premises using their own quality seed. Nursery management will be done by farmers as they are doing in traditional seed bed. At this stage, machinery contractor/company will not get profit in the transplanting business due to high management personnel cost.

Local service provider/entrepreneur may be best way to provide custom hire service of mechanical transplanting using the farmer's own trays. Sufficient cash incentive should be provided to the local service provider/entrepreneur to procure transplanter and set up infrastructure of custom hiring service.

Trading of mechanical transplanter

Three lead companies namely ACI motors limited, Dhaka; The Metal (Pvt.) Ltd, Dhaka and Corona tractors limited, Dhaka imported the rice transplanter of different makes and model from China and Korea (Table 8). Among them, ACI motors limited supplied most of the transplanter to the government institution. The local level market was not yet developed. The company imported the machine whenever they got tender from the authority. Till now, the company has sold 239 transplanters to different institutions. The Metal (Pvt) Ltd, Dhaka has sold 14 transplanters only.

Table 8 Transplanter sold by ACI motors limited

Year	Organization	Quantity	Type
2010	DAE	25	WT
		06	WT
2011	BRRI	04	RT
	BADC	10	WT
	BARI	01	WT
2012	IRRI	02	WT
2013	RDA	05	WT
	IRRI	02	WT
2014	IAPP	52	WT
	IRRI	02	WT
2015	DAE	25	WT
	DAE	100	WT
Others (Farmers)		05	WT
Total		**239**	

WT= Walking type, RT = Riding type

Customer service

Operation and maintenance training to the owners

The company should provide basic operation and maintenance training to the customer and his operators to ensure proper maintenance and better performance of the machine.

After sale service

The company should provide after sale service immediately after getting the complaint from the customer because of transplanting time is very limited.

Availability of spare parts

The company should maintain sufficient stock of different parts to provide instant support.

Conclusions and Recommendations

Conclusions

Mechanically transplanted rice produced more grain yield than manually transplanted rice due to use of tender aged seedling. Mechanical transplanter is sophisticated and costly machine. However, special care should be taken to raise seedling suitable for mechanical transplanter. Extensive field demonstration, field day, sharing workshop, seminar and training program should be conducted in different seasons throughout the country to create awareness about the benefit of mechanical transplanting. Development of local service provider is the key factor to provide transplanting service to the farmers. Transplanting business venture will be profitable if the government provides more than 60% incentive with less than 4% soft loan for the rest of the money to procure transplanter. Cost of mechanized transplanting will be reduced compared to hand transplanting if the government provides more than 70% incentives and soft loan with less than 4% to procure transplanter.

Recommendations

- Cash incentive and soft loan is mandatory to procure transplanter
- Raise fund to promote the instantaneous supply of transplanter
- Financial lending institute should provide soft loan to procure transplanter
- Support the entrepreneur for easy access to purchase, operation and maintenance of transplanter
- Extensive field demonstration will help to generate farmers' perceive in mechanized transplanting
- Encourage NGOs and private companies to set up field trial of mechanized transplanting
- BRRI and DAE should work together in coordinated way for faster adoption of the technology
- Public and private sector should organize extensive training for using rice transplanter in crop cultivation
- The farmers need to be educated regarding its proper use since mechanized transplanter requires mat - type nursery
- Entrepreneurship development is imperative for wider scale adoption of transplanter
- The importing companies of the rice transplanter must provide training on operation, repair and maintenance of seedlings raising on trays and after sales service at least few years

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