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Small Farm Mechanization in Rice for Doubling the Income of Small and Marginal Farmers in Gajapati district, Odisha: A Case Study

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A B S T R A C T

In Odisha, the small and marginal holdings constitute around 90% of the total number of holdings, which is supposed to further increase in the future because of the ever-increasing population. These small and marginal farmers are generally unable to afford large scale mechanization. They generally afford for small farm tools and implements that are either manually operated or operated by animal power. These small implements need improvement for qualitative and quantitative output apart from the reduction in drudgery and cost involvement. A good number of improved bullock drawn and manually operated farm implements have been developed for different field operations. There is huge scope for small farm mechanization mostly in the tribal-dominated hilly terrain based districts like Gajapati. It also has a tremendous impact on the socio-economic status of the small and marginal farmers. In Odisha and particularly in the district Gajapati, rice is the major crop in *Kharif* and is dominated by 92% small and marginal landholdings. Therefore, the use of efficient farm implements for rice-based farming systems and the evaluation of its benefits in farmers' field is essential before large scale demonstration. This study revealed that using improved machineries the small and marginal farmers of the district are gaining 4.5% higher yield, 60%saving in the cost of cultivation and 1.75 higher net return in rice cultivation which implies that small farm mechanization is the key for doubling the farmers' income.

Introduction

Today, the average per capita operational landholding size in the country is estimated as 1.16 ha and about 86% of the landholdings belong to small and marginal farmers owning less than 2 ha land on an average (Prasad *et al*, 2014). Farm mechanization is the process of using agricultural machinery in agricultural farms to accomplish the unit operations in agriculture in less time. In current times, powered machinery has replaced many jobs formerly carried out by manual labor or by working animals such as bullocks, oxen, and horses. However, small and marginal farmers find it difficult to invest in costly farm machineries and mostly depend on the hiring of farm implements to carryout agricultural operations. In rainfed hilly terrain areas, the operational window for various agricultural operations like; land preparation, sowing, and inter-culture is narrow. Failing to complete the agricultural operations within this limited window often leads to compromise in crop production and productivity. In addition to it, labor scarcity at peak agricultural operations is a serious problem faced by farmers.

The agrarian scenario of the state of Odisha and the country has gone through huge changes after independence and during the green revolution in particular. It has been remarkably outstanding because the country has become self-sufficient in food grain production even having more than 1.3 billion population today. The agricultural production and productivity in the state have certainly reached the pinnacle of success, getting the National level Krushi Karman awards for four years in a row. Nevertheless, there remain a lot of issues that need to be addressed sooner or later to this flow of success further. Since the availability of cultivable land is almost saturated and climate change is now a global concern; hence, it has become much challenging to increase crop production with the rising trend of population and also to strengthen the agrarian economy in the coming future.

The per capita land holding is getting squeezed due to the rise in population thus; the number of small and marginal farmers goes on increasing year after year. As of today, the marginal and smallholdings constituted 74.74% and 18.23% of the total holdings commanding 44.53% and 30.40 % of total operated area where the scope for mechanization has certainly raised few doubts considering the socio-economic status of these categories of farmers (Odisha Agriculture Policy-2013).

Gajapati district is one of the tribal-dominated districts of Odisha. It was listed in the Prime Minister's 100 poorest districts of India in 2006 and one of the 31 Most Extremist Affected Districts (MEAD) of the country. It is also enlisted as one of the aspirational districts of the country in 2018 by NitiAayog, Govt. of India. It is one of the 19 districts in Odisha, which received assistance from the Backward Regions Grant Fund Programme (BRGF). It is also a minority concentrated district. As per census 2011, the tribal population of the district is 54%. The district has 73% marginal and 19% small farmers (Census, 2011). It has seven blocks, 149-gram panchayats (GPs), and 1499 revenue villages. Crop fields are small and fragmented and mostly terrace based cultivation takes place in these blocks. Thus, the use of a tractor or power tiller operated farm equipment is very difficult in these areas and almost all the agricultural unit operations are carried out using bullock drawn or manually operated equipments (Singh *et al*, 2017). The district has 166207draught animals used in agriculture. The bullocks are mostly of Motu breed having lower body weight. The average body weight varies from 200-300 kg per bullock. Bullocks are engaged in various operations like ploughing, puddling, leveling, sowing behind the plough, intercultural and harvesting operations, as well as transportation of produce. Rice is the major crop of the district and is cultivated in 32000 ha area in *Kharif*. Although farmers are getting low returns from rice cultivation, still they go for rice cultivation for meeting their family food requirements. As such, rice is the ecologically suitable crop in these local agro-climatic conditions during *Kharif*. Hence, the popularization of farm mechanization can benefit small and marginal landholdings in several ways like the reduction in cost of cultivation, saving of time, reduction of drudgeries of agricultural workers, and ultimately increase the net return form rice cultivation (Benos *et al.*, 2020). Therefore, Krishi Vigyan Kendra (KVK), Gajapati in collaboration with All India Coordinated Research Project (AICRP) on Utilization of Animal Energy (UAE) and Ergonomics and Safety in Agriculture (ESA),College of Agricultural Engineering & Technology (CAET), Odisha University of Agriculture & Technology (OUAT) is initiated to popularize efficient farm implements for small and marginal farmers of the district through on-farm testing (OFT), frontline demonstration (FLD) and capacity building programs with target to doulble the income of small farms.

Materials and Methods

Study area

This study has been carried out in the district Gajapati. The district is situated in the North-Eastern ghat agro-climatic zone. It lies between 83°50' to 84°30'E longitude and 18°50' to 19°40'N latitude (Fig. 1). It has seven blocks, out of which 5 blocks are having undulated topography. The district has a 3850 km^2geographical area. The climate of the district is sub-tropical and sub-humid having an average annual rainfall of 1400 mm and the average temperature varies from 8 to 40℃ during winter and summer, respectively. Major crops of the district are rice, maize, ragi, green gram, blackgram, arhar and vegetables etc. Rice is the dominant crop during *Kharif*.

Constraints to small farm mechanization

There is neitheran absolute approach for transferring farm mechanization technologies, nor there is any strategy that exists to promote the adoption of agricultural machines. Variability of the field conditions and the needs of the farmers limit the creation of a standard approach for the dissemination of farm mechanization. To suggest appropriate strategies for small farm mechanization technologies, the problems associated with mechanizing small farms were prioritized. First of all, the lack of adequate information on the availability of efficient machineries at farmers' level is still a challenge even after having a rather good network of digital communication in Gajapati.

Information is the key to making any decisions. Many farmers are unaware of the availability of suitable machinery, tools, or implements that could be the solution to different tedious works. Secondly, small farm size is a big issue for large scale mechanization because this is against the principle of economic farm size.

The mechanization of small, discontinuous patches of land may prove to be inefficient for operations like land preparation and harvesting etc. The third constraint identified as the resistance of farmers to accept the change or the modern technology. Although many farmers are very much open to new ideas and technology, still some farmers believe in the "wait-and-watch" principle. The fourth issue is farmers are unable to utilize the available machinery due to lack of sufficient training on operational skills even after getting machineries in free of cost through different schemes. Many times it is also observed that extension staff engaged for farm mechanization in various institutions does not have in-depth knowledge on the subject.

In addition to these, the lack of proper coordination between research and extension functionaries is also creating barriers for the dissemination of technology from lab to field. Above all, the poor economic status of the small and marginal farmers deprives the theme of purchasing an efficient farm machinery of high initial cost (Fernando *et al.*, 2005).

Strategies adopted to overcome the constrains

KVK, Gajapati has taken strategic interventions to popularise small farm mechanization in the district in collaboration with AICRP on UAE and ESA, OUAT, Bhubaneswar. More than 100 number of training programs have been organized in the district and more than 20 number of efficient farm machineries have been demonstrated for small farm mechanization in rice-based cropping systems in the collaboration.

Specialized initiatives also have been taken up for popularising gender-friendly farm machineries among farm women. A set of machinery for rice cultivation has been provided to different self-help groups (SHGs) through watershed mission with initiatives of KVK, Gajapati. During the on going COVID-19 situation, online trainings, webinars have also been arranged for the farmers for the popularization of small farm mechanization with the support of NGOs and line department officials.

Details of farm machineries used for package demonstration in rice

A set of efficient machinery mostly recommended by the College of Agricultural Engineering and Technology (CAET), OUAT, Bhubaneswar has been selected for the package demonstration in rice.

A trial has been made to cover all the major unit operations starting from field preparation to harvesting of rice through efficient manually operated or bullock drawn farm machineries. In this study transplanted rice has been considered for package demonstration. The details of farm machines undertaken for the package demonstration program are given in Table 1.

Use of OUAT mouldboard plough

It is an animal-drawn small size mouldboard plough used for primary tillage operation. The OUAT mouldboard plough is made up of mild steel with a replaceable share and has a working width of 100 mm with a field capacity of 0.016 ha/h, and field efficiency of 75% (Fig. 2). This plough leaves no uncut land after tillage operation due to the trapezoidal cross-section of the furrow, unlike the *desi* plough, where due to triangular furrow some portion is left uncut beneath the surface. This plough accounts for better inversion and pulverization apart from a higher depth of cut (UAE, 2020).

Use of OUAT puddler

The OUAT puddler is used for secondary tillage operation under the wetland rice cultivation system to facilitate transplanting (Fig. 3). This puddler is made of mild steel and has got a frame with a set of blades for puddling, one seat for the operator, and a pair of transport wheels. The output of this puddler is 0.087 ha/h with a higher puddling index of 65% as compared to conventional puddling by *desi* wooden plough because of higher width of operation by three gangs of mild steel blades (UAE, 2019). The operator sits on the seat of the puddler during puddling; thus it reduces the time, cost, and drudgery involved in the conventional puddling method by wooden *desi* plough.

Use of three-row manual transplanter

The tree row manual rice transplanter consists of floats made of marine plywood, seedling tray that accepts the mat type nursery, a tray indexing mechanism, and fingers for planting seedlings (Fig. 4). When the operator pulls the machine and operates the handle, the three fingers gather two or three seedlings and place them in the puddled soil in three rows.

The row to row distance is maintained at 220 mm. By using this machine a farmer can transplant 0.018 ha in an hour. Its cost is Rs. 9000/-.

Use of a mandva weeder

The weeder consists of only one rotor, float, frame and handle. The rotor is cylindrical in shape, having serrated strips welded on the shaft along its length (Fig. 5). The float, rotor, and handle are joined to the frame. The float controls the working depth and does not allow rotor assembly to sink in the soil. The Mandva weeder is operated by push-pull mode. The weeder is used to remove weeds between rows of paddy crops efficiently. The average field capacity of Mandva weeder is 0.014 ha/h and the cost is Rs. 1080/- in Odisha.

Use of battery operated sprayer

This sprayer consists of a pump and an air chamber permanently installed in a 16 liters tank (Fig. 6). It has a dual-mode of operation. The pump is either operated by battery or by the arm of the operator using the handle and spray with the other. It has a spray lance fitted with a nozzle and has two straps for mounting the sprayer at the back of the operator.

Uniform pressure can be maintained by keeping the pump in continuous operation. It is used for spraying insecticides and pesticides on any crop, small trees, and shrubs. The average field capacity of the battery sprayer is 0.15 ha/h and the cost is Rs. 4000/- in Odisha.

Use of improved sickle

It consists of a blade and handle. Tang of the blade is bent in 'Z' shape and inserted in a wooden handle (Fig. 7). The tang is secured firmly in the handle by a metal ring. The ‘Z’ shape of tang protects the farmer’s hand rubbing against the soil. The blade is made from mild steel flat section or leaf spring steel and forged to shape. The cutting edge is beveled and sharp. It is available in the market as an improved sickle manufactured by Falcon Company and its market cost around Rs. 110/- per sickle. Its field capacity is 0.012 ha/h.

Use of pedal operated paddy thresher

It consists of a wire-loop type threshing cylinder, power transmission system, mild steel sheet body, and foot pedal. The threshing cylinder consists of wire-loops of ‘U’ shape embedded in wooden or metallic strips joined to two discs (Fig. 8). A shaft carries the threshing cylinder and is connected to the transmission system. The transmission system consists of meshed gears or sprocket-chain mechanism.

The larger gear or sprocket is connected to the foot pedal/bar with links. The foot pedal/bar is always in a raised position. On pressing the pedal the threshing cylinder starts rotating. For continuous rotation of the cylinder, the pedal is lowered and raised repeatedly. For operation, the paddy bundle is held in hands and the ear head portion of the crop is placed on the rotating cylinder. The wire-loops hit the ear heads and grain get detached from the rest of the crop. The capacity of the machine is 250 kg/h. The present cost of the thresher is 6225/- rupees.

Use of manual hand winnower

It is used to clean cereal grains (Fig. 9). It is available with a hand-operated/pedal operated and motor operated model. One person has to rotate the handle of the winnower while another person has to drop the un-cleaned grains in front of the winnower by a certain height by using kulah. The capacity of the machine is 45kg/h. The present cost of the thresher is 4250/- rupees.

Treatment Details

The experiment was conducted in the farmers' field considering 15 farmers. The experiment has been continued for three years. Data collected during the demonstration has been analysed statistically. The experimental details are as follows:

T_1: Farmers' Practice (FP)
T_2: Package demonstration (PD)
Number of replications: 15

Cost economic indices

Economic performance indicators undertaken in the study are calculated mathematically using the equations (i), (ii) and (iii).

$$\text{Gross Income}\left(\frac{Rs}{ha}\right) = \frac{\text{Yield}\left(\frac{t}{ha}\right)}{\text{Selling price}\left(\frac{Rs}{t}\right)} \quad \text{(i)}$$

$$\text{Net Income}\left(\frac{Rs}{ha}\right) = \text{Gross Income}\left(\frac{Rs}{ha}\right) - \text{Cost of cultivation}\left(\frac{Rs}{ha}\right) \quad \text{(ii)}$$

$$\text{Benefits to Cost (B:C) Ratio} = \frac{\text{Gross Income}\left(\frac{Rs}{ha}\right)}{\text{Cost of cultivation}\left(\frac{Rs}{ha}\right)} \quad \text{(iii)}$$

Results and Discussion

The study has been carried out at 15 number of farmers field and the performance of the machinery has been recorded at the time of operation. Different agronomic parameters like plant height, number of tillers, number of grains per panicle and grain yield have been recorded and compared with the existing farmers practice. The cost of operation of individual unit operations has been calculated using the actual data at farmers' level.

Farmers practice

The conventional rice cultivation in the Gajapati district was mostly done by using traditional tools and equipments. For field preparation farmers generally use *desi* plough made up of wood and a piece of iron share. This plough is generally meant for intercultural operation but farmers use this plough for all types of tillage operation like primary and secondary tillage. Therefore, the depth of tillage is very less and not uniform with the use of *desi* plough having an actual field capacity of 0.24 ha/h. The puddling operation is conventionally done by 3 to 4 passes of *desi* plough in submerged conditions. Leveling is done using a wooden plank after puddling. However, due to improper mixing of water and soil the rain in this practice, water does not remain in the fields for a longer time and creates water stress in rice.

The field capacity of *desi* plough and plank for puddling has been recorded as 0.012 ha/h. Transplanting is done by manually involving mostly farm women. The field capacity for manual transplanting operation is 0.0066 ha/h. It is considered as one of the tedious operation which involves high drudgeries (ICAR, 2012). Weeding is generally done by female workers and round 10 man-days per acre are required for this operation. Need-based application of pesticides is carried out by using a hand-operated Knapsack sprayer, which has a coverage of 0.09 ha/h. Harvesting of paddy is usually done by local sickle which involves high drudgeries.

The field capacity is 0.0066 ha/h using local sickle. The threshing and winnowing of rice is done manually. At some places, bullock trading is practiced for threshing of grains. The details of field capacity and cost of operation recorded during different unit operation are shown in Table 1.

Table.1 Machinery used for package demonstration in rice cultivation

Sl. No.	Name of unit operation	Farmers practice	Name of farm machinery	Source of power	Source of Technology	Capacity	Approximate cost in Odisha (Rs)
1.	Field preparation	Using *desi* plough	OUAT mouldboard plough	Bullock drawn	AICRP on UAE, OUAT	0.016 ha/h	850/-
2.	Puddling	Using *desi* plough and plank	OUAT Puddler	Bullock drawn	AICRP on UAE, OUAT	0.087 ha/h	4300/-
3.	Transplanting	Hand transplanting	Three-row manual transplanter	Manually operated	AICRP on ESA, OUAT	0.018 ha/h	9000/-
4.	Weeding	Manual weeding	Mandvaweeder	Manually operated	AICRP on ESA, OUAT	0.014 ha/h	1080/-
5.	Plant protection	Spaying using hand-operated Knapsack sprayer	Battery operated sprayer	Battery operated	AICRP on ESA, OUAT	0.15 ha/h	4000/-
6.	Harvesting	Local sickle	Improved sickle	Manually operated	CIAE, Bhopal	0.012 ha/h	110/-
7.	Threshing	Manual beating	Pedal thresher	Manually operated	AICRP on ESA, OUAT	45 kg/h	6225/-
8.	Winnowing	Winnowing in natural wind	Manual hand winnower	Manually operated	AICRP on ESA, OUAT	250 kg/h	4250/-

Table.2 Performance of machineries used in farmers practice (FP)

Sl. No.	Name of unit operation	Framers practice	Capacity	Cost of operation (Rs/ha)
1.	Field preparation	Using desi plough	0.024 ha/h	2628
2.	Puddling	Using desi plough and plank	0.012 ha/h	5257
3.	Transplanting	Hand transplanting	0.0066 ha/h	7500
4.	Weeding	Manual weeding	0.008 ha/h	6250
5.	Plant protection	Spaying using hand-operated Knapsack sprayer	0.09 ha/h	444
6.	Harvesting	Local sickle	0.0066 ha/h	7500
7.	Threshing	Manual beating	22kg/h	9193
8.	Winnowing	Winnowing in natural wind	46 kg/h	4374
			Total cost (Rs)	43146

Table.3 Performance of machineries used in package demonstration (PD)

Sl. No.	Name of unit operation	Machineries for Package demonstration	Capacity	Cost of operation (Rs/ha)
1.	Field preparation	OUAT mouldboard plough	0.045 ha/h	1130
2.	Puddling	OUAT Puddler	0.087 ha/h	784
3.	Transplanting	Three-row manual transplanter	0.018ha/h	2833
4.	Weeding	Mandvaweeder	0.014 ha/h	2714
5.	Plant protection	Battery operated sprayer	0.15 ha/h	300
6.	Harvesting	Improved sickle	0.008 ha/h	6250
7.	Threshing	Pedal thresher	45 kg/h	5062
8.	Winnowing	Manual hand winnower	250 kg/h	850
Total cost (Rs)				19923/-

Table.4 Growth and yield attributes of rice

Treatments	Plant height, mm	Number of tillers	Number of grains per panicles	Yield (t/ha)
PD	809.3[a]	21.7[a]	102.6[a]	4.0[a]
FP	760.3[b]	18.0 [b]	90.9[b]	3.9[b]
F cal	2.91	2.76	3.13	6.30
t cal (0.05)	10.71	1.41	6.36	1.51

Note: Mean values within a column followed by the different letter are significantly different at 5 % level of significance, F tab=2.39, t tab=1.70

Table.5 Cost economic analysis

Treatments	Gross Return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
PD	72000	28000	44000	2.5
FP	70200	45000	25200	1.5

Fig.1 Location of Gajapati District

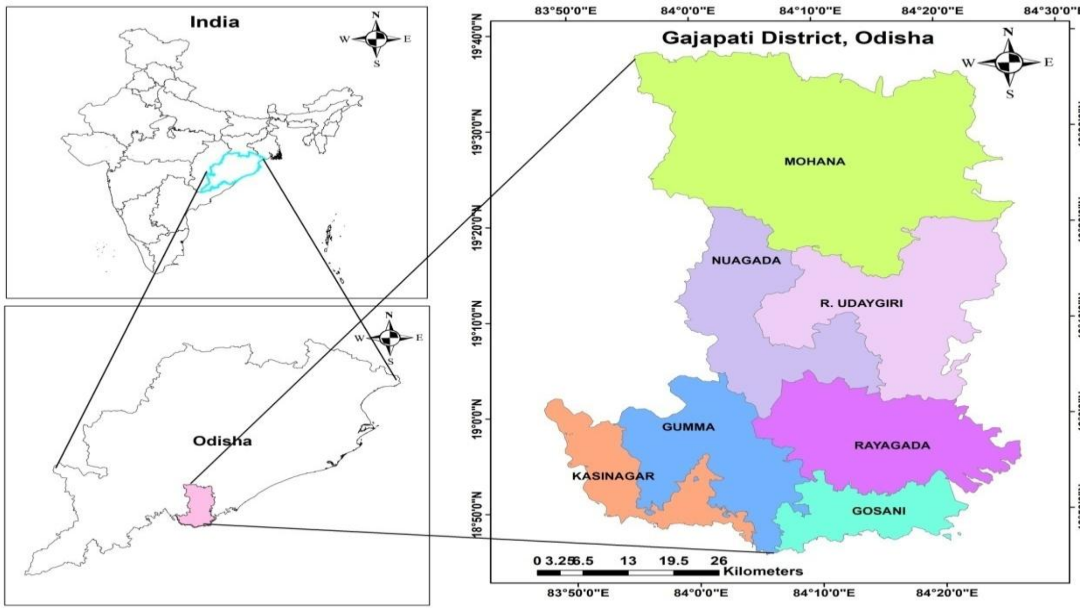

Fig.2 OUAT mouldboard plough

Fig.3 OUAT Puddler

Fig.4 Three-row manual transplanter

Fig.5 Mandva weeder

Fig.6 Manually operated sprayer

Fig.7 Improved sickle

Fig.8 Pedal-operated paddy thresher

Fig.9 Use of hand winnower

Package demonstration

In this study, individual implements were demonstrated and their performance has been assessed through data analysis. All the efficient implements suitable for small landholding have been selected and demonstrated in rice cultivation. The main aim of the study is to bring the benefits of package demonstration in rice cultivation, particularly for small and marginal farmers. In the current study, for land preparation, the traditional *desi* plough was replaced by OUAT Iron mouldboard plough which gives better depth and pulverization than *desi* plough. A single operation of this plough is equivalent to two operations of *desi* plough. Therefore, the field capacity of OUAT iron plough has been recorded as 0.045 ha/h which is around two times higher than *desi* plough (UAE, 2019). Puddling operation was carried out by using OUAT puddler which gives thorough mixing of soil and water that ultimately helps for water conservation in rice fields. The actual field capacity of puddler operation has been recorded to be0.087 ha/h and its cost of operation is quite low than the traditional puddling operation. Transplanting of rice was carried out after puddling by OUAT three-row rice transplanter. Its actual field capacity was recorded as 0.018 ha/h which is around 3 times higher than manual transplanting. Besides this, the operator has to operate the transplanter in standing posture which is ergonomically suitable and involves low drudgeries than the bending posture of manual transplanting. Weeding was easily carried out by Mandvaweeder because there was a clear row to row to spacing maintained after transplanting of rice using manual rice transplanter. The field capacity of Mandvaweeder was recorded as 0.014 ha/h which is 1.75 times higher than manual weeding. Accordingly, around half of the manpower involved in manual weeding is saved using the Mandvaweeder for weeding. Use of battery operated sprayers reduce the extra workload of operating the handle for spraying, hence, the work output in terms of field capacity increases up to 0.15 ha/h and refrain the operator developing fatigue. Harvesting, of rice, was carried out using improved sickle which reduces the chances of injuries and also reduces the pulling force during cutting the rice stalk. Threshing of paddy has been carried out by pedal-operated paddy thresher with a capacity of45 kg/h which is twice the manual practices. Another benefit is that using pedal threshers farmers can avoid mixing of foreign material with rice grains that ultimately increases the quality of the output. Winnowing of rice has been carried out using hand winnower with 250 kg/h capacity which is five times higher than winnowing in natural wind. The use of hand winnower makes the operation very quick and also the cleaning efficiency reaches up to 98% which was recorded as 85% in natural wind winnowing.

The details of capacity and cost of operation of individual machines are shown in Table 2. It is observed that using improved farm machineries the overall of cost of operation becoming 2.1 times lower than the traditional practice as depicted from Table 1 and 2.

Crop growth and yield attributes

Various plant growth parameters like plant height, number of tillers, and yield parameters like the number of grains per panicles and grain yield have been recorded during the study to assess the effect of mechanization on crop performance as shown in Table 3. Data analysis using students' t-test revealed that there is a significant difference in plant height, number of tillers, number of grains per panicles, and grain yield between package demonstration and farmers practice treatments, shown in Table 3. The average plant height was recorded as 809.3 mm and 760.3 mm in PD and FP, respectively. The average number of tillers was also found significantly higher in PD than FP. Higher plant height and number of tillers represents better plant growth under PD treatment. This may be since a suitable soil environment has been provided in PD due to the use of MB plough and puddler. It does not allow the water to percolate down due to the formation of hardpan below the field surface and helps to keep moisture in the plant root zone for a longer time than conventional farmers practice.

Yield attributes like number grains per panicles and yield have been recorded significantly higher in package demonstration than farmers practice. The average rice yield has been recorded as 4.0 t/ha and 3.9 t/ha from PD and FP treatments, respectively. The higher grain yield ultimately leads to higher gross income from package demonstration of farm machineries.

Cost economics

The cost economics of both the treatments has been calculated and presented in Table 4. The analysis revealed that package demonstration provided much higher economic benefits to the farmers than the traditional farmers practice. This because the use of efficient farm machineries is largely decreasing the number of labor requirements and accordingly decreasing the cost of cultivation. The benefits to cost (B:C) ratio has been estimated as 2.5 in case of package demonstration and 1.5 in case of farmers practice. This indicates that the using package of efficient farm machineries for all unit operations in rice cultivation can economically benefit the small and marginal landholdings that ultimately strengthen their livelihoods. The study is also giving a clear message that doubling the income of small and marginal farmers is possible though the popularization of small farm mechanization in the country (Table 5).

The study was concluded with the evidence that package demonstration of improved farm machineries for various unit operations in rice cultivation is highly beneficial to small and marginal landholdings of Gajapati district. It not only reduces the cost of cultivation but also increases the quality of work and crop yields. It is observed that the net return of farmers increases up to 1.75 times by adopting package demonstration in rice. It was found that the B: C ratio is reaching up to 2.5 under package demonstration which is rarely observed in the rice farming. Hence, it is suggested that to meet the target of doubling the income of small and marginal farmers, small farm mechanization using animal or manually operated farm machineries should be popularised on a large scale in different parts of the country.

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