Article 2025b

DOI: HTTPS://DOI.ORG/10.23910/IJBSM/2019.10.6.2025b

International Journal of Bio-resource and Stress Management

Crossref

December 2019

Print ISSN 0976-3988

Online ISSN 0976-4038

IJBSM 2019, 10(6):580-586

Research Article *Natural Resource Management*

Efficiency Evaluation of Different Agricultural Machinery in Rice Cultivation at Agricultural Machinery Testing and Research Centre (AMTRC), Nawalpur, Sarlahi, Nepal

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Open Access

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Citation: Jha et al., 2019. Efficiency Evaluation of Different Agricultural Machinery in Rice Cultivation at Agricultural Machinery Testing and Research Centre (AMTRC), Nawalpur, Sarlahi, Nepal. International Journal of Bio-resource and Stress Management 2019, 10(6):580-586. HTTPS://DOI.ORG/10.23910/IJBSM/2019.10.6.2025b.

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Acknowledgement: Authors express their sincere gratefulness to Nepal Agricultural Research Council (NARC) managements for their encouragements and supports during the experiments. Authors also wish to thank Mr. Ram BahadurBhujel (Retired Senior Scientist, NARC) for his valuable suggestion in research paper preparation. Authors are also thankful to all those who directly and indirectly supported to carry out all experiments smoothly.

Abstract

Agriculture is the mainstay of Nepalese economy. Rice is a major staple crop of the country. Mechanization in rice cultivation is the best solution to get rid of labor scarcity and increase production of rice. AMTRC has been carrying out different research works on use of different machineries and cultivation practices in rice farming. During 2017-18/2018-19, it conducted research on uses of different machineries in three replications with five treatments. The mean grain yield due to treatments in pooled analysis of two years data was found significant at 1% level. The highest mean grain yield from two years data was found 3558.33 kg ha^{-1} in the treatment of rice transplanted by mechanical transplanter, the lowest production of 2576.33 kg ha^{-1} by directly seeded with power tiller drill machine and the average yield in farmer's practiceswas recorded as 2977.50 kg ha^{-1}. The average of two years data revealed 12.13% more yield in the treatment-3 than the treatment-5. The variable costs became high in farmer's practices due to more labor requirement, it was 19.36% more in treatment-5 than Treatment-3 and it ultimately affected the gross margin under farmer's practices of rice cultivation which became low. The total gross margin was 136.19% more in treatment-3 than farmers' practices. Thus, among the five treatments, the rice produced from the use of mechanical rice transplanter was found most profitable than other machines used in the trial including farmer's practices in this experiment. Comparatively low gross margin was observed in other treatments.

Keywords: Rice, mechanization, variable costs, gross-margin, treatments

1. Introduction

Agriculture is the mainstay of Nepalese economy which contributes almost one third of the national economy (Anonymous, 2017a). Agricultural crop productivity in Nepal is lowest among South Asian countries (Anonymous, 2018a). The agricultural sector production during 2017-18 was increased by 2.7% which has been estimated as 5.1% in 2018-19 (Anonymous, 2019). Rice is the agricultural commodity with the third highest worldwide production (Rice, 741.5 million tones, in 2014), after sugarcane (1.9 billion tones) and maize 1.0 billion tones (Anonymous, 2017). During the year 2016-17, rice contributed 44.66% to total edible cereal grain production in the country (Anonymous, 2018b). The area increment of rice in 2016-17 over 2007-08 has been counted as only 0.21% while in production and productivity the increment is 21.66 and 21.41%, respectively. The rice in Nepal is transplanted by human labor and animal traction (Upadhyaya, 1996). Using traditional bullocks and

Article History

RECEIVED in 16th August 2019 RECEIVED in revised form 17th November 2019 ACCEPTED in final form 05th December 2019

laborers it takes 64 hr ha^{-1} to prepare land, while the scale appropriate farm mechanization can prepare the same land in approximately 20 hr ha^{-1} (Paudel et al., 2019). Labor migration has created acute labor shortages in the agriculture sector that have affected timely crop establishment and other crop cultivation practices (Anonymous, 2017c; Maharjan et al., 2013b, 2013a). Many studies have shown that the rising labor scarcity and/or increased labor wages as the major driver for adopting farm mechanization (Reddy et al., 2014; Wang et al., 2016; Win and Thinzar, 2016; Yang et al., 2013 and Zhang et al., 2014). Alam (2006) describes mechanization as the interjection of machinery between people and the materials handled by them. Mechanization also includes irrigation systems, food processing and related technologies and equipment (Hegazy et al., 2013). Agricultural mechanization through custom hiring of tractors services has recently been considered as an option to mitigate the impact of rising labor costs for smallholders (Takesima et al., 2016). Japan has been the strongest innovator and technology provider in terms of farm mechanization and farm machinery used in Southeast Asia. (Hegazy et al., 2013).

In 2007, India had 3.2 million agricultural tractors and 0.48 million combine harvesters and threshers. The density of tractors per 1000 ha of cropped area was about 16 compared with the world average of 19, and 27 in the US (Directorate of Economics and Statistics, 2013). The use of laser land levelers on a custom-hire basis is growing, as it saves up to 30 per cent of irrigation water and helps increase productivity. Combine harvesters operating in custom-hire business models gained popularity (Mani et al., 2008). In a study carried out in Bangladesh, Kamruzzaman et al. (2009) reported that the maximum cost in rice cultivation was incurred in transplanting, weeding, harvesting and threshing but only transplanter, weeder, reaper and thresher can reduce the big amount of production cost. Pellizzi (1992) describes The primary objectives and benefits of agricultural mechanization include minimization of production costs; optimization of product quality; protection of the environment; reduction of farm drudgery; timely provision of suitable conditions for plant and animal growth. Adoption and spread of agricultural and rural mechanization technologies are increasing recently in Nepal with liberal import policies, increased connectivity and acute labor scarcity resulting from youth migration (Gauchan and Shrestha, 2017). Since rice is a labor intensive crop, and migration of youth force from rural to urban and urban to gulf and other countries in search of opportunities have created a state of labor scarcity in the country. Mechanization in rice farming is one of the best solutions to replace labor, reduce drudgery and increase income of the rice farmer.

2. Materials and Methods

The study was undertaken in Agricultural Machinery Testing and Research Centre (AMTRC), in Sarlahi district of Province 2, Nepal. Sarlahi district is located between $26^0$45-$27^0$10 North Latitude and $85^0$20-$85^0$50 East Longitude. Mechanization in rice farming has been applied with the uses of different machineries available in the country. Although, there are different machines and cultural practices for rice farming, some of them were identified at AMTRC, Nawalpur, Sarlahi. The cultivation practices for rice cultivation by using different machineries were evaluated in five treatments (Table 1) at AMTRC during 2017-18 and 2018-19.

The experiment was carried out into three replications of five treatments in 2800 m^2 plot size for each treatment. The experiment was laid out in randomized complete block design (RCBD). The variety of rice was Hardinath-1.Seeds were sown in second week of June at the rate of 30 kg ha^{-1}. The crop was harvested in the second week of October.

The fertilizer doses supplied were at the rate of 100:30:30 kg NPK ha^{-1}. The full dose of phosphorous, potash and half dose of nitrogen were applied as basal dose during the time of land preparation while remaining half dose of nitrogen was top dressed. The source of phosphorous was Dia-ammonium phosphate (DAP) and that of potassium was muriate of potash and of nitrogen was DAP and urea.

All intercultural practices were followed as per need and recommendation for this crop. Data were recorded on date of sowing, date of harvesting, plant height, Panicle length, number of plant per square meter area and average number of grain per panicle. Similarly, average number of tiller per hill, thousand grains weight, grain yield and straw yield ha^{-1} were also recorded.

The data were fed into computer and analyzed using ms-excel and Mstat package. The data recorded were analyzed for individual parameters separately for each year. Similarly, the combined analysis was performed for two years data of 2017-18 and 2018-19.

3. Results and Discussion

Data were analyzed using mstat and excel. The results obtained after statistical analysis are discussed according to the headings of different parameters. All results are presented in Table 2.

3.1. Plant height

Plant height of the rice in experiment was found significant at 5% level in 2017-18 and non-significant during 2018-19. It was significant at 1% level in pooled analysis (Table 2). The highest plant height of 104.77 cm was obtained in T_2 where the rice seeds were directly seeded with power tiller drill followed by T_1 which was 100.69 cm in the plot where the rice was directly seeded with zero till drill machine. The lowest height of 93.56 cm was recorded in T_4. During the year 2018-19, the treatment T_2 obtained highest plant height of 105.43 cm and the lowest was 98 cm in T_4.

In pooled analysis, the effect of year in treatments and interaction between year and treatment was found non-

Table 1: Treatments followed in rice experiment at AMTRC, Nawalpur, Sarlahi

Treat-ment no.	Treatments	Practices	Remarks
T_1	Rice direct seeded with zero till drill (DSRZTD)	In this treatment, the dry land was prepared by two-pass as primary tillage performed by cultivators and then secondary tillage was done by the disc harrow to break down the clods of the field. Before land preparation basal dose of nitrogen and potassium fertilizers was applied in the field. After that rice seed of Hardinath-1 variety with phosphorous (DAP) was sown by the zero till seed cum fertilizer seed drill machine followed by the planking of the field. For the weed management, the herbicide pendimethalien 5 ml l^{-1} of water was sprayed within 24 hours of seed sowing in the experiment.	
T_2	Direct seeded rice by power tiller drill (DSRPTD)	No pre land preparation was required in this treatment. Before land preparation basal dose nitrogen and potassium fertilizer was applied in the field while DAP and Hardinath-1 variety of rice seed was sown by machine. The primary and secondary tillage was done in single action along with seed sowing fertigation. The field was leveled by planking in single move with power tiller operated seed drill machine. The herbicide pendimethalin @5 ml l^{-1} of water was sprayed for weed management within 24 hours of sowing.	
T_3	Rice transplanted by mechanical rice transplanter (MRT)	The dry land was prepared by two-pass primary tillage with cultivators, and secondary tillage was done by the disc harrow to break down the clods and make the field soft. The wet land puddling and planking was done by rotavator. Half dose of fertilizers was applied before puddling the field. The prepared land was left overnight before the rice transplantation. In this treatment, the seedlings (seedlings Mat) nursery was prepared in tray. The rice seeds of Hardinath-1 variety which was soaked in water for 24 hours was taken out from water and kept in shade in gunny bag for 8 to 12 hours. After that the germinated seeds were placed in tray with half-filled soil in tray. The seed mat was ready in 15-20 days for transplantation. Weeds were managed by applying herbicide pretilacholor at the rate 1 l ha^{-1} which was used during the puddling of the field.	
T_4	Direct seeded rice by drum seeder (DSRDS)	In this treatment, dry land was prepared in two-pass primary tillage with cultivators. The secondary tillage was performed by the disc harrow to break down the clods into fine soil. The wet land puddling and planking was done by rotavator. The basal dose of fertilizer was applied before puddling the field. The well prepared land by puddlingwas left overnight before rice transplantation. The rice seed of Hardinath-1 was soaked in water for 24 hours and then rice seed was taken out to keep for shade drying in gunny bag for 8 to 12 hours. The germinated seeds were sown by the drum seeder in the field. Weeds were managed through the application of herbicide pretilacholor at the rate 1 l ha^{-1} during the puddling of the rice field for experiment.	
T_5	Check (Farmer's practices)	The dry land was prepared with two-pass primary tillage with cultivators followed by the secondary tillage by the disc harrow to break down the clods in the field. The wet land puddling and planking was operated by rotavator. The basal dose of fertilizers was applied before puddling of the field. The puddle field was left overnight before the transplantation of Hardinath-1 variety of rice. The seed-bed nursery was prepared 20 days before transplantation of seedlings. The seedlings were uprooted from nursery field and transplanted manually by labors. Weeds were managed with the application of herbicide pretilacholor at the rate 1l ha^{-1} during the puddling of the field for rice transplantation.	

significant, while the treatment itself was significant at 1% level. The average of two years plant height was obtained highest in T_2 which was 105.10 cm followed by 100.90 cam recorded in T_1. The treatment T_4 attained lowest plant height of 95.78 cm in the experiment (Table 2).

3.2. Panicle length

The panicle length was non-significant in both of the years of

2017-18 and 2018-19. It was also non-significant in pooled analysis (Table 2). The highest panicle length in 2017-18 and in 2018-19 was 24.89 cm and 26.01 cm in T_1 and T_5, respectively. As an average of two years, the highest panicle length was attained by T_2 which was 25.78 cm followed by 25.23 cm in T_1. The lowest panicle length was recorded in T_5 which was 24.78 cm (Table 2).

3.3. *Plant m^{-2}*

The number of plant per meter square area was significant at 1 per cent level in both of the years and in combined analysis too (Table 2). The treatment T_1 recorded the highest number of plant per meter square in both of the years of 2017-18 and 2018-19 recording a figure of 281.89 and 285.33 cm, respectively.

3.4. *Number of grain panicle^{-1}*

The number of grain panicle^{-1} was found non-significant in 2017-18 but significant at 5% level in 2018-19. In combined analysis it was found non-significant (Table 2). Despite non-significant result in 2017-18, the treatment T_3 recorded highest number of grain panicle^{-1} (61.66) and T_4 recorded the lowest number of 59.33. Similarly in 2018-19, the highest number was observed in T_1 (64.66) followed by T_3 (63.89) and the lowest number was recorded in T_2 (56.55) in the experiment. The average of two years was recorded highest in T_1 which was 63.11 followed by T_3 (62.78) and the lowest number of 56.50 was found in T_4. The effect of year and interaction between year and treatment was found non-significant (Table 2).

Table 2: Performance of different parameters of rice at AMTRC, Nawalpur, Sarlahi, Nepal (2017-18 and 2018-19)

Tr No.	Plant height (Cm)		Panicle length (Cm)		No. of plant m^{-2}		No of grain panicle^{-1}		No. of tillers hill^{-1}		Thousand grain weight (g)	
	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19	17/18	18/19
T_1	100.69^{ab}	101.10	24.66	25.80	195.11^{c}	199.33^{c}	61.56	64.66^{a}	24.89^{b}	26.11^{ab}	18.55	18.17
T_2	104.77^{a}	105.43	25.33	26.22	268.89^{a}	270.00^{b}	60.78	56.55^{bc}	14.79^{c}	18.44^{bc}	17.88	17.86
T_3	95.73^{bc}	99.00	24.89	25.44	281.89^{a}	285.33^{a}	61.66	63.89^{ab}	32.00^{a}	34.33^{a}	17.98	17.72
T_4	93.56^{c}	98.00	23.89	26.01	183.77^{c}	197.50^{c}	59.33	53.67^{c}	12.77^{c}	14.00^{c}	18.01	17.86
T_5	94.44^{c}	98.22	24.78	24.78	222.78^{b}	271.44^{b}	61.55	63.78^{ab}	15.00^{c}	17.22^{c}	18.07	18.15
GM	97.84	100.35	24.71	25.65	230.49	244.72	60.98	60.51	19.89	22.02	18.10	17.95
F test	*	Ns	Ns	Ns	**	**			**	**	Ns	Ns
CV (%)	3.28	2.98	6.49	4.62	2.64	1.54	16.83	6.59	10.84	14.02	2.35	3.19
LSD (1%)	-	-	-	-	16.67	10.31	-	-	5.90	8.46	-	-
LSD (5%)	6.04	-	-	-			-	7.50	-	-	-	-

Pooled analysis (2017-18 and 2018-19

Tr No.	Plant height (Cm)	Panicle length (Cm)	No. of plant m^{-2}	No of grain panicle^{-1}	No. of tillers hill^{-1}	Thousand grain weight (g)
T_1	100.90^{ab}	25.23	197.22^{d}	63.11	25.50^{b}	18.36
T_2	105.10^{a}	25.78	269.44^{b}	58.66	16.61^{c}	17.87
T_3	97.36^{b}	25.17	283.6^{1a}	62.78	33.16^{a}	17.85
T_4	95.78^{b}	24.95	190.64^{d}	56.50	13.38^{c}	17.94
T_5	96.33^{b}	24.78	247.11^{c}	62.66	16.10^{c}	18.11
GM	99.09	25.18	237.60	60.74	20.95	18.03
F test Year (Y)	Ns	Ns	**	NS	Ns	Ns
Treatment (T)	**	Ns	**	Ns	**	Ns
Y x T	Ns	Ns	**	Ns	Ns	Ns
CV (%)	3.13	5.60	2.13	12.81	12.71	2.80
LSD for T (1%)	5.24	-	8.53	-	4.49	-
LSD for Y×T (1%)	-	-	12.06	-	-	-

Table 2 Continue...

Tr. No.	Mean grain yield (mt ha^{-1})		Mean straw yield (mt ha^{-1})	
	17/18	18/19	17/18	18/19
T_1	2514.33[c]	2905.00[bc]	5436.67[a]	4521.67[a]
T_2	2473.67[c]	2679.00[c]	4049.67[b]	3873.3[a]
T_3	3641.67[a]	3475.00[a]	4310.00[ab]	4312.67[a]
T_4	3191.67[b]	3263.33[ab]	3299.67[b]	2930.00[b]
T_5	3016.67[b]	2938.33[bc]	4093.33[b]	4158.67[a]
GM	2967.60	3052.13	4237.87	3959.27
F test	**	**	**	*
CV (%)	3.26	5.64	10.42	12.59
LSD (1%)	264.90	471.90	1210.00	-
LSD (5%)	-	-	-	938.6
Pooled analysis (2017/18-2018/19)				
T_1	2709.67[d]		4979.17[a]	
T_2	2576.33[d]		3961.50[b]	
T_3	3558.33[a]		4311.33[ab]	
T_4	3227.50[b]		3114.83[c]	
T_5	2977.50[c]		4126.00[b]	
GM	3009.87		4098.57	
F test Year (Y)	Ns		Ns	
Treatment (T)	**		**	
Y x T	*		Ns	
CV (%)	4.64		11.49	
LSD for T (1%)	235.50		794.00	
LSD for Y×T (1%)	-		-	

** = Significant at (p=0.01) level, *= Significant at (p=0.05) level, Ns=Non-significant. Any two means having a common letter in superscript are not significantly different at the given level of significance

3.5. Number of tillers hill^{-1}

The number of tiller hill^{-1} was significant at 1% level in 2017-18, 2018-19 and also in combined analysis of these two years (Table 2). The highest number of tiller in 2017-18 was found in T_3 which was 32.00 followed by T_1 (24.89) and the lowest number of 12.77 was observed in T_4. Similarly, in 2018-19 the treatment T_3 recorded the highest number of tiller as 34.33 followed by T_1 (26.11) and the lowest number (14.00) was found in T_4.

In combined analysis, the treatment was found significant at 1% level while the effect of year in treatments and the interaction between year and treatment was found non-significant. The average of two years data revealed the highest number of tiller hill^{-1} in T_3 (33.16) followed by T_1 (25.50) and the lowest number of tiller per hill was recorded in T_4 which was found to be 13.38 in the experiment (Table 2).

3.6. Thousand grain weight

The weight of thousand grains was non-significant in 2017-18 and 2018-19. However, T_1 in 2017-18 and in 2018-19 obtained highest weight of 18.55 and 18.17 gram while the lowest weight of 17.88 gram in 074/075 and 17.72 gram in 2018-19 was found in T_2 and T_3 respectively (Table 2). In combined analysis, T_1 recorded highest mean grin yield of 18.36 gram and lowest of 17.85 gram in T_3 during the experiment.

3.7. Grain yield

The mean grain yield was significant at 1% level in both of the years. It was also significant at 1% level in pooled analysis (Table 2). The highest mean grain yield was obtained in T_3 (3641.67 kg ha^{-1}) followed by T_4 (3191.67 kg ha^{-1}) in 2017-18 and the lowest yield of 2473.67 kg ha^{-1} was found in T_2. Similarly in 2018-19, the treatment T_3 recorded the highest mean grain yield of 3558.33 kg ha^{-1} followed by T_4 (3227.50 kg ha^{-1}) and the lowest yield of 2709.67 kg ha^{-1} was obtained in T_1. In combined analysis, the treatment T_3 obtained highest mean grain yield of 3558.33 kg ha^{-1} followed by T_4 (3227.50 kg ha^{-1}). The lowest mean grain yield of 2709.67 kg ha^{-1} was found in T_1. The effect of year in treatment was found non-significant while the interaction between year and treatment was significant at 5% level (Table 2).

3.8. Straw yield

The mean straw yield was found significant at 1 per cent level in 2017-18 and at 5% level in 2018-19. In pooled analysis it was also found significant at 1% level (Table 10). The treatment T_1 recorded the highest straw yield of 5436.67 and 4521.67 kg ha^{-1} in 2017-18 and 2018-19, respectively. The lowest mean straw yield of 3299.67 kg was found in T_4 during 2017-18 while in 2018-19 the lowest yield of 2930.00 kg ha^{-1} was found in the same treatment of T_4.

In combined analysis, the highest mean straw yield of two years was observed in T_1 which recorded 4979.17 kg ha^{-1} followed by 4311.33 kg ha^{-1} in T_3. The lowest mean straw yield was recorded in T_4 which was 3114.83 kg ha^{-1}. The effect of year in treatments was found non-significant and the interaction between year and treatment was also the same in experiment (Table 2).

3.9. Gross margin

The difference between revenue and variable costs incurred in input expenditures is termed as gross margin. The gross margin is also calculated in percentage terms by dividing the gross margin amount by revenue. Gross margin=(Total revenue–Variable costs)/Total revenue. Thus it can be expressed in percentage too. Gross margin supports to measure the production costs related to the revenue of the farm. If gross margin is low, it may look for the processes that allow the farm to cut in use of the variable cost which seem less productive in generating farm income.

Gross margin in this experiment was calculated based on the expenses incurred in different inputs and farm works related to the farm operations. The different methods of cultivation practices obtained varying quantity of production and thus gross margin was also different for different treatments followed in the trials.

The highest amount of revenue as an average of two years (2017-18 and 2018-19) was found in T_3 where the rice was transplanted with mechanical transplanter which was Rs. 79786.60 ha^{-1} followed by T_4 in which the rice was directly seeded with the use of drum seeder. The check treatment counting the total revenue of Rs. 71709.60 ha^{-1} (Table 3) was third among the treatments. The total variable cost was highest in check (Farmer's practices) which was Rs. 58779.25 followed by T_3 (Rs. 49245.75 ha^{-1}). A gross margin of Rs. 30540.85 ha^{-1} was found highest in T_3 followed by T_4 (Rs. 23733.75 ha^{-1}). The lowest gross margin of Rs. 17016.70 ha^{-1} was calculated in T_1.

Table 3: Average gross margin of two years data from different cultivation practices of rice at AMRTC, Sarlahi

Particulars	T_1 DSRPTD	T_2 DSRDS	T_3 MRT	T_4 DSRZTD	T_5 Check
Land preparation cost (Rs ha^{-1})	2500.00	8385.75	8385.75	3750.00	8385.75
Sowing/transplanting machine hire cost (Rs ha^{-1})	3600.00	1000.00	5000.00	4500.00	0.00
Seed cost (Rs ha^{-1})	1800.00	1800.00	1440.00	1800.00	1800.00
Total fertilizer cost (Rs ha^{-1})	8100.00	8100.00	8100.00	8100.00	8100.00
Herbicide cost (Rs kg^{-1})	750.00	750.00	750.00	750.00	750.00
Total labor cost	25566.60	29185.50	25570.00	28226.60	39743.50
Total variable cost	42316.60	49221.25	49245.75	47126.60	58779.25
Grain yield at 10% m.c. (kg ha^{-1})	2576.34	3227.50	3558.33	2709.67	3173.33
Straw yield (kg ha^{-1})	3959.84	4202.50	4310.00	4975.00	4121.50
Return from grain (Rs ha^{-1})	51526.70	64550.00	71166.60	54193.30	63466.60
Return from straw (Rs ha^{-1})	7919.67	8405.00	8620.00	9950.00	8243.00
Total revenue	59446.37	72955.00	79786.60	64143.30	71709.60
Gross margin	17129.77	23733.75	30540.85	17016.70	12930.35

Source: Rice experiment data of 2017-18 and 2018-19; 1 US $ (Dollar)=116.81 Nepalese Rupee (13 October 2018)

4. Conclusion

The result showed that the mechanization in rice cultivation could be one of the best solutions to overcome labor scarcity problem which has caused to pay more for labor causing comparatively high variable costs in rice farming. It has ultimately affected the gross margin of the farmers with less return than cultivating rice with different machines. In this experiment, the rice transplanted by mechanical transplanter has been found efficient in production among the practices included in the trial.

5. Acknowledgement

Authors express their sincere gratefulness to Nepal Agricultural Research Council (NARC) managements for their encouragements and supports during the experiments. Authors also wish to thank Mr. Ram Bahadur Bhujel (Retired Senior Scientist, NARC) for his valuable suggestion in research paper preparation. Authors are also thankful to all those who directly and indirectly supported to carry out all experiments smoothly.

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