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Mechanized transplanting and harvesting in rice: An on-farm study

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Abstract
An on-farm survey was conducted during *kharif* 2019 and 2020 in Siddipet district of Telangana, India to study the comparative analysis and impact of conventional and machine transplanting and harvesting/threshing in rice on labour, time and energy use pattern besides productivity and economics. The survey results revealed that mechanical transplanting helped in timely completion, better yield attributes like more no.of tillers/ hill (21), no. of panicles/ hill (21), grains /panicle (215) and 1000 grains weight (17.4.0 g) and yield besides less incidence of insect pests and diseases due to maintenance of proper and uniform spacing (30cm×14 cm) and less no. of hills /m^2 (22). Machine transplanting and harvesting saved 6.25 hours' time, 70 man days, cost of cultivation of Rs. 9,154 per hectare besides higher yield (4%) and energy use efficiency (5%) over conventional methods.

Keywords: Economics, energy budgeting, labour requirement, mechanization, time, yield

Introduction
Rice (*Oryza sativa L.*) is the world's second most important cereal crop in area and production, next to wheat. Globally, it is cultivated in an area of 162 Mha with a production of 755 MT (FAOSTAT, 2019) [6]. Rice is a major staple food crop of India as 60% population depends on it. In India, rice crop is cultivated in 44 M.ha area with a production of 178 M.tonnes and a productivity of 4057 kg ha^{-1} (FAOSTAT, 2019) [6]. Though, India is the second largest producer of rice, but stands fifth productivity in the world (Agricultural Statistics at a Glance, 2019) [1]. Low productivity on one hand and increasing labour scarcity for performing various agronomic operations especially transplanting, harvesting and threshing thus cost of cultivation on the other hand are the main concerns in rice cultivation in India. Furthermore, ever increasing population necessitates enhancing production and productivity of rice from diminishing land and water resources.

Conventional transplanting of paddy completely depends on manual labour in India. Traditionally, it is carried out on a labour contract basis per unit area in the villages and labour always resort to *zigzag* planting without following recommended spacing leading to higher plant density than optimum (Mann and Ashraf, 2001) [12]. Often, transplanting is delayed due to labour shortage and increase in labour wages during peak season resulting in increase in cost of transplanting, flare up of pest and diseases and decline in productivity. This has been the continuous problem over the decades in rice growing zones across the country. Of late, power operated transplanters have been introduced with a view to reduce the labour, complete transplanting in a short time besides maintaining proper spacing, plant stand and reduces the cost of cultivation. In fact, the machine transplanting technology was introduced from Japan (Singh and Garg 1976) [18] and China (Singh *et al.*, 1990) [17] into India, various transplanters *viz.*, NPS-4W (no. of planting rows 4), NPS-6W (no. of planting rows 6), NPSU-68C (no. of planting rows 6), NSD-8 (no. of planting rows 8), SPV-6MD (no. of planting rows 6) are the types of transplanters from Kubota agricultural machinery India PVT. Limited and VP6-D (no. of planting rows 6), VP8DN (no. of planting rows 8), AP4 (no. of planting rows 4) and AP6 (no. of planting rows 6) from Yanmar company are being used in various rice growing areas in the country.

Traditionally rice harvesting and threshing was performed with the help of labour. Threshing was done by using traditional tools such as threshing racks, simple treadle threshers and animals for trampling, then cleaned off. A labour with reaper cuts and lays the crop in a line. Then threshing and cleaning can be performed either manually or mechanically.

This manual harvesting and threshing often leads to delay in operations and it required more labour and time. Whereas under mechanical harvesting and threshing both the operation were done with help of combine rice harvester. A combine rice harvester can finish the whole processes from harvesting to grain cleaning at a time. By adopting mechanical harvesting and threshing can reduce work load, also save more no. of labour and time. Mechanical harvesting and threshing enable to farmer in timely operations under peak demand period.

However, its' adoption rate is not only low but also slow due to poor socio-economic conditions of farmers (Guru, *et al*., 2018) [8], fragmented land holdings, less availability of machines, lack of awareness and custom hiring centres. Lack of scientific data on advantages of machine transplanting is also another reason why the technology could not be up scaled and out scaled. Keeping this in view, an on-farm survey was planned to scientifically document the information regarding comparative performance of mechanized transplanting and harvesting vis-à-vis manual/conventional methods.

Materials and Methods

An on-farm survey (OFS) was conducted at Rangadhampally village, Siddipet district, Telangana for two consecutive years i.e., *kharif*, 2019 and 2020 with an aim to study, analyse and document the comparative advantages and disadvantages associated with manual and machine transplanting and harvesting of rice. Two farmers (2.6 ha) during *kharif*, 2019 and three farmers (5.2 ha) *kharif*, 2020 were selected for the study and the details are furnished below in Table 1.

Table 1: Details of farmers and cultivars under investigation

S. No.	Name of the farmer	Cultivar	Characters of cultivars	Area (ha)
***Kharif*, 2019**				
1	Janardhan Reddy	RNR-15048	This variety is of short duration (120-130 days) type, suitable to both *kharif* &*rabi* with a productivity of 6.8-7 t/ha and it was release by Rice Research Centre (RRC), Rajendranagar during 2015.	1.0
2	Linga Reddy			1.6
			Total area (ha)	2.6
***Kharif*, 2020**				
1	Janardhan Reddy	RNR-15048	This variety is of short duration (120-130 days) type, suitable to both *kharif* &*rabi* with a productivity of 6.8-7 t/ha and it was release by Rice Research Centre (RRC), Rajendranagar during 2015.	2.0
2	Linga Reddy			1.2
3	B. Malla Reddy	KNM-118	This variety is of short duration (120-125days) type, having long slender grain and suitable to suitable for both *kharif* &*rabi* seasons with a productivity of 7-8 t/ha. It was released from ARS, Kunaram, PJTSAU during 2014.	2.0
Total area (ha)				5.2
Grand total area (ha)				7.8

Nursery was raised by farmers of MT

A plastic sheet (gauge of 60 microns) was spreaded equally on puddled soil by removing clods, stones with the help of hands. This sheet helped in preventing roots growing into soil and inter locking of roots. Then a wooden frame was placed on the plastic sheet, and the frame almost filled with the mixture of 70-80% soil + 15-20% well decomposed organic manure up to the top. The seeds (30-35 kg/ha for large seeded varieties and 20-25 kg/ha for small seeded varieties) were soaked in water for 24 hours. Drained, covered and kept moist the soaked seeds for another 24 hours. At this time, the seeds sprouted and the first seed root grew. The pre-germinated seeds were sown uniformly in wooden frame and covered by a thin layer of soil mixture. The process (i.e., fill soil mix-sow seed-cover seed-water) continued until the required nursery area was completed. Then the water sprinkled to soak the bed. Irrigation was provided as and when needed to keep the soil moist. Nursery was protected from heavy rains for the first 5 days by covering with shed nets. Need based nutrient and weed management practices were taken in time. The water drained out at lj58hu 7ygt feast two days before removing the seedling mats for transplanting**.** Seedlings were reached sufficient height with 3 leaf stage in 14 -17 DAS is suitable to transplant through machine. The seedling mats lifted and transported to the main field, further transplanting was done with the help of machine by keeping mats in racks of transplanter.

Nursery was raised by farmers of CT

The seeds (62.5 kg/ha in large seeded varieties, where as in case of small seeded varieties it was 50 kg/ha) were soaked in water for 24 hours. Drained, covered, and kept moist the soaked seeds for another 24 hours. At this time, the seeds sprouted and the first seed root grew. Sowing was done with pre-germinated on fine seed bed which was prepared simultaneously. Irrigation was supplied based on need. Protection measures were given to the nursery from heavy rains for the initial few days by covering with shed nets or gunny bags. Need based nutrient and weed management was followed. Regular monitoring was done for irrigation and to identify pest and diseases. In this method, seedlings were ready to transplant within 25 DAS. Then the seedlings uprooted from nursery and transplanted in main field with the help of labour.

Farmers were also explained about agronomic operations to be carried out under both the planting methods through a pre-season interaction meeting. Further, a survey questionnaire was prepared by covering the details of no. of hills /m^2, no of tillers/ hill, no. of tillers m^{-2}, no of panicles /m^2, no. of grains /panicle, 1000 seed weight (g)**,** percent incidence of weed, insect pest and disease, grain yield/ha, time and labour requirement for each operation for the purpose of documentation and it was used for interacting with all the farmers selected for the study. One week before harvesting, observations were made in the selected farmers' fields on the ancillary characters *viz*., plant height, no. of hills m^{-2}, total no. of tillers $hill^{-1}$, no. of productive tillers $plant^{-1}$, no. of panicles m^2 on 10 selected plants from a quadrat (1m×1m). Later, no. of filled and unfilled grains $panicle^{-1}$, 1000 grain weight were recorded after threshing the selected plant from the quadrat.

The grain yield was recorded from the entire field of farmers after completion of conventional/machine harvesting and threshing. The qualitative information regarding weed, pest and disease incidence and also water requirement, quantitative information for labour and time requirements and finally cost of cultivation, were collected through scientist and farmer interaction.

Results and Discussion

The method of transplanting and establishment is one of the important agronomic practices, which influences the crop growth and development (Gopi *et al*. 2006) [7]. It also helps the crop to maintain proper spacing, optimum population and supports in vigorous growth put forth more production. Harvesting with machine also saves much of the time and labour. A specially labour drudgery in harvesting, threshing and cleaning operations.

Effect of method of transplanting on yield attributes

Different farmers followed different spacing but on an average, the spacing adopted under CT was 25-27cm ×15-16 cm with 400 tillers/m^2, while, in case of MT, it was 30 cm ×14 cm with 449 tillers/ m^2 (Table. 2).

On an average, RNR-15048 recorded less no. of hills/m^2, higher plant height, no. of tillers / hill, panicles/ hills, grains/panicle and 1000 seed weight (22, 67 cm, 22, 21, 215 and 15.3 g) as under machine as compared to that of conventional transplanting (28, 64 cm, 15, 15, 204 and 14.9 g). Whereas, KNM-118 under machine transplanting performed better by providing less no. of hills/m^2 and higher plant height, no. of tillers/hill, panicles / hill, no. of grains/ panicle and 1000 seed weight (22, 67 cm, 21, 21, 215 and 26.1 g) than conventional transplantation (28, 64 cm, 14, 15, 204 and 25.8 g).

The reduction in hills/m^2 depends on spacing, machine transplantation allowed optimum spacing and density resulted more no. of tiller, panicles and grains, this results were in line with Vijayalaxmi *et al.,* (2016) [22]. The optimum plant density produces higher dry matter with highest partitioning towards panicle followed by stem and leaf. Hence, planting of less no. of seedlings arises in higher grain yield, such increase in yield contributing parameters with fewer number of seedlings per hill were also reported by Rasool *et al.,* (2013) [14]. Manual transplanting required more manual labour (70 labour/ha) and more time (3.75 hours/ha) as compared to that of machine transplanting. This results were in line with Vasudevan *et al*., (2014; Venkateswarlu *et al*., (2011) [20, 21].

Effect of method of transplanting and harvesting on grain yield

The average grain yield of the all two varieties under machine transplanting of rice would increase about 4% by producing 6.2 t/ha against to 6.0 t/ha in conventional transplanting.

Machine transplanting with an optimum row to row and plant to plant spacing of 30 cm ×14 cm resulted in less no. of hill/ m^2 (22) but resulted in more no. of tillers/ hill (22), no. of panicles/ hill (21), grains /panicle (215) and 1000 grains weight (17.4 g) vi-a-vis CT due to sufficient aeration and less competition for air, water and nutrients. Similar results were reported by Salahuddin *et al*., (2009) [16] and Uddin *et al*., (2010) [19], who reported more number of grains per panicle under MT due to maintenance of wider spacing provided and minimum competition. Machine transplanting in rice reduces work load and ensures uniform spacing and maintains plant density, seedlings recover very fast, tiller vigorously and mature uniformly (Bell, *et al*., 2007) [3].

Effect of method of transplanting on weed, pest and disease incidence

According to the selected farmers for OFS, though the incidence of pest and diseases was less, but 20-30% more weed infestation was observed in MT rice compared to that of CT rice fields in both the years. Different results were reported earlier by Balasubramanian *et al*., 2003 [2]; Cairns *et al*., 2009 [4] proved less no. of seedlings/hill will support rapid early growth increases, stand establishment and weed competitiveness, both of which are important components for high yields (Zhao *et al*., 2006) [23].

Tables: 2 Yield attributes of rice under machine and conventional transplanting methods

S. No.	Name of the farmer	Variety	Plant height (cm)		No.of hills/m^2		No of tillers /hill		No. of tillers/m^2		No of panicles/hill		No. of grains/panicle		1000 grains weight (g)		Grain yield (t/ha)	
			MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT
***Kharif*, 2019**																		
1	Janardhan Reddy	RNR-15048	65	62	22	27	22	15	475	406	21	15	217	205	15.1	14.9	6.0	5.9
2	Linga Reddy		67	64	22	28	22	15	482	410	21	14	208	198	15.3	15.0	6.3	6.1
***Kharif*, 2020**																		
1	Janardhan Reddy	RNR-15048	68	65	22	27	21	14	475	406	21	15	220	210	15.2	14.8	6.0	5.9
2	Linga Reddy		66	63	22	28	22	14	482	410	21	17	215	204	15.4	15.0	6.3	6.1
Average of RNR-15048			67	64	22	28	22	15	479	408	21	15	215	204	15.3	14.9	6.2	6.0
Malla Reddy		KNM-118	70	65	23	27	19	14	464	423	19	15	217	205	26.1	25.8	6.3	5.8
			67	64	22	27	21	14	476	411	21	15	215	204	17.4	17.1	6.2	6.0

MT= Machine transplantation; CT=Conventional transplantation

Effect of machine transplanting and harvesting on labour requirement and time

Manual transplanting and harvesting required 114 labours, 74 hours of time, cost of cultivation of Rs. 53,653 in bold seeded cultivars and Rs.53,063/ha in fine seeded varieties to finish seed to seed works in one hectare. Whereas, machine transplanting and harvesting required 44 labours, 67.8 hours of time and cost of cultivation of Rs.44, 409/ha in bold seeded cultivars and Rs.44,009/ha in fine seeded varieties per hectare. Finally the farmer could minimizes 70 labour, 6.25 hours of time and cost of cultivation of Rs.9,154 ha^{-1} through machine transplanting and harvesting. This results are line with Dixit and Khan (2011) [5] and Manjunatha *et al*., (2009) [11] reported that mechanical transplantation and harvesting required 3 man days/ha against 33 man days/ ha in case of manual transplanting, thus the machine transplanting and harvesting saved 30 labour/ha.

Table 3: Requirement of labour, time and cost of cultivation under Machine Vs Manual transplantation

Operation	Labour		Time		Cost (Rs.)	
	MT	CT	MT	CT	MT	CT
Land preparation	Tractor	Tractor	10	10	10,000	10,000
Nursery preparation	2.5+2.5	2.5+2.5	6	3	1,635	817
Seed cost	NA	NA	NA	NA	1,300	2,500
Polythene sheet cost	NA	NA	NA	NA	175	NA
Transplanting	2+0	5+30	3.75	6	7,380	10,050
Fertilizer cost & application	2+0	2+0	6	6	6,376	6,376
Irrigation	1+0	1+0	25	25	2,100	2,100
Hand weeding	0+30	0+25	6	6	7,560	6,300
Plant protection	1+1	1+1	2.5	6	2,127	2,568
Harvesting	Harvester**	0+30*	2.5	6	5,000	7,560
Post- harvest operation	1+1***	7+7****	6	6	756	5292
Total (Rs./ha.)	9.5+34.5 (44)	18.5+95.5 (114)	67.8	74	44,409	53,653
Difference / ha	(9+61) 70		6.25		9,154	

*- Harvesting; **- Harvesting & Threshing; *** - Bagging; ****- Threshing + Bagging

Effect of machine transplanting and harvesting on Energy Budgeting

The total energy output recorded about 2% more in machine transplanting and harvesting (1, 82,236MJ/ha) than conventional transplanting and harvesting (1, 78,111 MJ/ ha). Three percent less total energy inputs consumed under machine transplanting and harvesting (28,123 MJ/ ha) as compared to that of conventional method (28,892 MJ/ha). Machine transplanting and harvesting produces 3% additional net energy (1, 54,213 MJ/ha) than conventional transplanting and harvesting (1, 49,219 MJ/ha). Machine transplanting and harvesting of rice gave 5% supplementary energy use efficiency (6.48) than conventional method (6.16). Almost 10% additional specific energy needed by conventional transplanting and harvesting (4.59 J/kg) over machine transplanting and harvesting (4.15 J/kg) and comparatively about 9% more energy productivity was obtained under machine transplanting and harvesting of rice (0.24 kg/ha) than conventional transplanting and harvesting (0.22 kg/ha).

Table 4: Impact of transplanting method on energy budgeting (Average of 2018 and 2019)

Particulars	MT	CT
Land preparation	684	684
Nursery preparation	59	29
Seed cost	478	919
Polythene sheet cost	175	175
Transplanting	328	412
Fertilizer cost & application	22,824	22,824
Irrigation	98	98
Hand weeding	353	294
Plant protection	3,023	3,025
Harvesting	157	353
Post- harvest operation	14	165
Total Energy Input		
Bold seeded	28,191	28,977
Fine seeded	28,044	28,793
Average		
Total Energy Output (MJ/ha)	1,82,236	1,78,111
Total Energy Input (MJ/ha)	28,123	28,892
Net Energy (MJ/ha)	1,54,213	1,49,219
Energy Use Efficiency (J)	6.48	6.16
Specific Energy (J/kg)	4.15	4.59
Energy Productivity (kg/ha)	0.24	0.22

Effect of machine transplanting and harvesting on Economics

On an average, the additional cost of cultivation under conventionally transplanted and harvested rice was about 17% more (Rs.44, 409/ha in bold seeded varieties and Rs. 44,009/ha in fine seeded rice cultivars) when compared to that of machine transplanted and harvested rice (Rs.53563/ha in bold seeded varieties, Rs. 53063/ha in fine seeded rice). The variety RNR-15048 gave with greater gross returns (3%), net returns (20%) and benefit: cost ratio (17%) when grown under machine transplanting and harvesting (Rs.1, 11,623/ha, Rs.57, 322/ha and 2.10) as compared to that of conventional method (Rs.1, 08,446/ha, Rs.45, 583/ha and 1.75). The variety KNM-118 has given greater gross returns (3%), net returns (20%) and benefit: cost ratio (17%) when grown under machine transplanting and harvesting (Rs.1, 11,623/ha, Rs.57, 322/ha and 2.10) as compared to that of conventional method (Rs.1, 08,446/ha, Rs.45, 583/ha and 1.75). On an average all the two cultivars attained additional gross returns (4%), net returns (23%) and benefit cost ratio (17%) under machine transplantation and harvesting of rice than conventional method, similar results were reported by Mohanty and Barik (2010) [13]. Among the two different transplanting methods, greater gross returns and net returns would be realized in machine transplanting and harvesting (Jha *et al.* 2011 and Kumar *et al*., 2009) [9, 10]. Hence, machine transplanting and harvesting of rice seems to be most appropriate and promising technique, as it minimizes labour requirement and saves much of the time during peak season. Further this technique is helps to enhance productivity too.

Table 5: Grain yield and economics of different varieties under Machine Vs Manual transplantation

S. No.	Variety	Grain yield (t/ha)		(%) Improvement of yield in MT over CT	Cost of cultivation (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		Benefit cost ratio	
		MT	CT		MT	CT	MT	CT	MT	CT	MT	CT
1	RNR -15048	6.2	6.0	3.3	44009	53063	112530	108900	68521	55837	2.56	2.05
2	RNR -15048	6.0	5.9	2.1	59446	67763	108900	106631	49454	38868	1.83	1.57
3	RNR -15048	6.3	6.1	3.3	59446	67763	113438	109808	53992	42045	1.91	1.62
Average of RNR -15048		6.2	6.0	2.9	54300	62863	111623	108446	57322	45583	2.10	1.75
3	KNM -118	6.3	5.8	8.6	60553	68567	118944	109504	58391	40937	1.96	1.59
Average of all		6.2	6.0	4.3	55864	64289	113453	108711	57590	44422	2.07	1.71

MT= Machine transplantation; CT=Conventional transplantation

Conclusion

Machine transplanting and harvesting enhanced the productivity (4%), reduced pest and diseases and cost of cultivation of Rs. 9,154/ha (17%), added the additional net returns of Rs.13,168/ha (23%) by saving 70 man days and 6.25 hours' time/ha over conventional transplanting and harvesting depending on the variety, soil condition and management practices. Further, machine transplanting and harvesting was made possible with less energy input (3%) and specific energy (10%) and produces additional energy productivity (9%) and energy use efficiency (5%). Hence, awareness has to be created to replicate adoption of this technology across rice growing zones in the country. Custom hiring centres have to be established at village/mandal level to take the technology forward.

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