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Influence of different age seedlings mat type characteristics at different speed of self-propelled 8-row rice transplanter in district of Samastipur, Bihar, India

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■ **ABSTRACT :** In south-east Asian countries, paddy is the most important cereal crop and staple food. In India, it is grown on an area of more than 41 million ha with a production of about 111 million tones of paddy. In India establishment of rice basically depends on the availability of moisture, climatic condition, age of the variety, availability of inputs and human labour. Labour shortage and labour costing is one of the major concerns to failure of scheduled transplanting of rice. To overcome, there is a need of mechanization in the field of rice cultivation by using rice transplanter as major tool in this process. The impact of different age seedlings related to paddy cultivation and its influence was studied in the farm of Dr. Rajendra Prasad Central Agriculture University for sustainable farming in Samastipur district. Three different age seedlings were sampled and cultivated along with all necessary cultivation requirements. The survivability and quality efficiency was measured and comparative studies were done. A strong positive correlation between seedlings age and production efficiency was observed. This practice appears useful as the results indicate high production efficiency with 26 days age seedlings transplanted with the help of self propelled 8-row rice transplanter. It can be accomplished by timely updating and application of improved technology, for instance, to uphold the quality and nutritional values of rice. Transplanting mat type seedling is becoming more popular due to its superior performance and reduced labour requirement (50 man-h/ha).

■ **KEY WORDS :** Self-propelled rice transplanter, Different age seedlings, Rice cultivation, Paddy transplantation

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Paddy is the staple food and cereal crop of India. In hot and moist climate it is cultivable. The ideal geographical conditions for rice cultivation include temperature ranging from 16°C to 27°C and rainfall from 100 cm to 200 cm. Generally paddy transplanting is done manually by women labourers. Farmers face acute problem of labour shortage during peak period. Thus, they are unable to transplant paddy in time which result in less yield. Self-propelled rice transplanter will help the farmers to accomplish the job in time. Consequently, higher yield will be achieved. So Japan 8-row riding type rice transplanter using mat type seedling have better

performance and lesser labour requirement (Hoshino, 1974 and Hoshino, 1977). Numbers of seedlings transplanted per hill vary from country to country. While in Burma 1 to 4 seedlings are transplanted per hill, in Srilanka only one seedling is used. Paul (1945) usually 5 to 7 seedlings are transplanted, in Philippines tillers is greater with 3 to 4 seedlings (Headayetullah, 1977). Proper age of seedling for transplanting varies with management practices, growth period, variety and growing season. In case of high yielding varieties, the seedling should be transplanted at 4-5 leaf stage. Seedling mat characteristics such as seedling density, mat moisture content and age of seedlings play a major role for efficient performance of the self-propelled rice transplanter. Worldwide almost 85% global consumption of fresh water is lead by agriculture sector and it is expected that distribute of fresh water in agriculture may be reduced by 8-10% because of urbanization and industrialization (Toung and Bhuiyan, 1994). To meet the growing demand, food production is desirable to ascend by 50% in forthcoming 50 years to maintain our present per capita supply, assuming the productivity of accessible farmland does not decline. Increasing the efficiency of water utilize by crops is of enormous concern because of growing demand of water, yet the desired effects are rarely achieved (Hatfield *et al.*, 2001). Rice-wheat cropping system is dominantly practiced in the Indo-Gangetic plains of India on coarse textured soils. Rice (*Oryza sativa* L.) contributes about 45% of the entire cereal production and hence holds the key to sustainable food security throughout the country (Rai and Kushwaha, 2005). At the same time, the operating speed also influences the performance of this transplanter. The present study was carried out in the sandy loam soil under AICRP on FIM at Dr. Rajendra Prasad Central Agriculture University, Pusa, Bihar with Chinese make 8-row riding type self-propelled rice transplanter. The machine transplanting system was found to be technically viable (Thomas, 2001). Mechanization need be enhanced substantially in order to meet the recommended level and to enhance the productivity (Kumar *et al.*, 2016). Mechanization has been defined as the use of improved hand and animal operated tools (Kumar *et al.*, 2016). India become self sufficient in rice in 1977 achieved a combination of increase in area and cropping intensity. Thus, the country had under gone dramatic changes from that of a net importing country to a potential exporter of quantity rice during the early nineties. Now, India has become second larger producer of rice (134.5 million tonnes) next only China contributing 21 per cent of the global rice production. At the present level of population through (1.9% annum), the rice consumption would require annually 2.5 million tones more of milled rice to sustain the present level of sufficiency and at the same time to achieve targeted production of 135 to 145 million tonnes by 2020 A.D. in order to achieve the production target of coming decades, it is essential to have annual growth rate of rice to 2.5-3.5 per cent (Kumari, 2000). Despite of drastic changes in technologies even today majority of world's rice is grown by transplanting. The labour requirement for this operation is high. Paddy transplantation in India is almost dependent on manual labour causing the operation slow and arduous. Singh *et al.* (2001) reported that about 50 man days is required for transplanting one hectare of land in Samastipur district. During acute shortage of labourers during transplanting period, paddy transplanting is delayed resulting in loss of grain yield. Thus, attempt was made to develop and test the performance of the paddy transplanter as a substitute for manual transplanting. Most often age of seedlings at transplanting mainly depend on availability of water, labour, herbicides and other inputs in farmer's fields. Farmers transplant rice seedlings at distinct ages, mostly from 25 to 25 days after germination (Datta, 1981; Wagh *et al.*, 1988 and Singh and Singh, 1999). Observations from research experiments however were quite contradictory but tended to shore up transplanting as young as 20 days. The mortality of young seedlings (14 days) in subsequent period after transplanting seedlings was reported as a reason for the lower yield compared to that with older seedlings (28 days) (Kewat *et al.*, 2002). Recent studies on system of rice intensification (SRI) shows that transplanting seedlings as young as about 14 days generated higher crop performance than transplanting 21 days to 24 days old seedlings (Makarim *et al.*, 2002 and Thiyagarajan *et al.*, 2002). In Medagascar the 8 to 15 days old seedlings transplanted at 25 hill m^{-2} produces the maximum yields (McHugh, 2002) whereas in Sumatra the maximum yields were got with 10 days old seedlings. There were indications that the longer wait of seedlings in nursery may have affected seedlings development pattern in answer to high seedling competition (Mandal *et al.*, 1984). Observations by Herrera and Zandstra

(1979) also supported that old seedlings enlarged the overall crop duration. This machine reduces drudgery permits better control of plant population and generally facilitates the transplanting operations in the field at lower cost with increases capacity of worker. A lot of worker was done on paddy transplanter at IRRI in Bangkok, China and Japan. India, also research is going on far developing paddy transplanter and being tested in different soil and ecological conditions to determine its economy and suitability in terms of getting optimum productivity. Under AICRP on FIM at Dr. Rajendra Prasad Central Agriculture University, Pusa the testing of 8-row self-propelled paddy transplanter was carried with performance of different age of seedling as well as different speed of transplanter.

METHODOLOGY

The present experiment was conducted at Dr. Rajendra Prasad Central Agriculture University, Pusa Farm with Rajendra Mansuri variety under sandy loam soil.

Independent variables :

– Age of seedling :18, 22, 26 days

– Seed rate of mat: 400, 600, 900, 1200, 1500 g/ mat of 3×6 feet

– Operating speed of transplanter :1.6, 1.9 km/h

Dependent variables :

– No. of seedling per hill

– Missing hills

– Mechanical damage to seedlings

The seedling mat was grown with sandy loam soil following standard practice of nursery rising. The transplanting was run with the tail wheels so that the fingers will not hit the ground but the fingers will drop the seedling of the ground. The experiment was planned in four factors CRD with two replications. The specification of machine presented in the Table A.

Soil properties :

The different soil parameters were measured for experiments. Soil parameter includes bulk density, pH, infiltration rate, water holding capacity, permanent wilting point and availability of water.

Puddling index :

Just after puddling, five samples of the puddle soil from various locations in the field were taken and put into the graduated glass cylinder. The soil particles were allowed to settle for 48 hours. The volume of settled soil was measured and then puddling index was calculated by the following formula to evaluate the quantity of soil tilth,

Table A : Specification of self-propelled walk behind type 8-row rice transplanter

Sr. No.	Particulars	Specification
1.	Model	2ZT – 238 – 8
2.	External dimension L×W×H, mm	2410×2131×1300
3.	Weight, kg	320
4.	Engine provided	165F air cooled diesel engine (2.4kw 2600 rpm)
5.	Walking mechanism	Single wheel driven copying float machine
6.	Working mechanism	Separate crank connecting rod transplanting
7.	Working number of rows	8
	Row spacing, mm	238
8.	Distance between hills, mm	238
9.	Frequency of transplanting	263
10.	Depth of transplanting	Infinitesimal adjustment with screw rod
11.	Operation speed, km/h	1.57 – 1.994
12.	Speed of travel on highway, km/h	1300 – 2200
13.	Paddy driving wheel	15 vanes, inclined angle 22^{O} outside dia – 700mm
14.	Provision for adjustment of row to row spacing	Nil
15.	Arrangement for changing the plant to plant distance	By adjusting the planting fingers
16.	Provision for changing the number of plants per hill	By adjusting the planting fingers.

$$\text{P.I.} = \frac{V_S - V_C}{V_S}$$

where, P.I. = Puddling index (%)

V_S = Volume of sample (Soil+Water) in cc

V_C = Volume of clear water in cc after setting of soil particle for 48 hours

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Project area :

The field experiment was conducted in year 2014 at the experimental farm of Dr. Rajendra Prasad Central Agriculture University, Pusa, Bihar. The experimental area is located between $25^0$42' and $26^0$52' North latitude and $45^0$42' and 86^0 02' east longitudes.

Soil properties :

The different soil characteristics were measured in Department of Soil Science. The soil properties of experimental plot are presented in Table 1.

The research was conducted in factorial R.B.D. design. Three seedling density and three forward speeds were selected. The mat type nursery was prepared by standard method. When the seedling was 12 days old, iron deficiency was observed. As a remedy measure 1% solution of $FeSO_4$ was sprayed twice at 4 days interval. To remove the nitrogen deficiency 1% urea solution was sprayed twice at 7 days interval. The seedling characteristics are presented Table 2.

In general, seedling per hill increased with age however, with older seedling, the number of seedling per hill was found more at higher moisture content compared to lower moisture. It was found that by increasing the operating speed, the transplanting speed also increased which resulted in greater impact forced by the transplanting fingers on the mat. Besides that vibration of the tray at higher speed tends to enhance the downward movement of the mat, which contributes towards more consumption of seedling. This may be the reason of higher number of seedling per hill when operating speed was increased, which is in agreement with the results obtained by (Garg *et al.*, 1982). At lower moisture content, seedling per hill was found age the

Table 1 : Soil properties

Sr. No.	Characteristics	Value
1.	Bulk density, g/cc	1.33
2.	pH	8
3.	Infiltration rate, mm/h	3
4.	Water holding capacity, %	22
5.	Permanent wilting point, %	8.3
6.	Available water, %	11.3

* The data is based on the soil analysis done in the Department of Soil Science, Dr. Rajendra Prasad Central Agriculture University, Pusa, Bihar.

Table 2 : Effect of seedling characteristics and operating speed on seedling per hill

Age of seedling, days	Mat moisture content, %	Seedlings per hill operating speed km^{-1}					
		1.6			1.9		
		Seedling density, No. cm^{-2} (seed rate, g mat^{-1})			Seedling density, No. cm^{-2} (seed rate, g mat^{-1})		
		1.70 (60)	2.10 (80)	2.50 (100)	1.70 (60)	2.10 (80)	2.50 (100)
18	10-15	1.40	2.10	2.36	1.49	2.18	2.40
	20-25	1.48	2.32	2.65	1.75	2.39	2.82
	30-35	1.69	2.45	2.90	1.92	2.52	3.15
22	10-15	1.43	2.23	2.37	1.69	2.38	2.68
	20-25	1.56	2.50	2.74	1.78	2.50	3.10
	30-35	1.82	2.72	2.82	2.10	2.68	3.40
26	10-15	1.48	2.34	2.42	1.58	2.40	2.60
	20-25	1.65	2.66	2.63	2.05	2.56	2.95
	30-35	2.10	2.90	3.10	2.15	2.89	3.40

reason for less number of seedlings at lower moisture content may be due to firmness of the mat in holding the seedlings whereas at higher moisture content.

The data on missing hills with respect to seedlings parameters are presented in Table 3. It is very clear from the table that seedling age, mat moisture content and operating speed had significant effect on percentage missing hill. When operating speed increased from 1.6 to 1.9 km/h, the missing hills decreased marginally with few exceptions were there was increase in missing hills. Density of seedling in the mat had significant effect on missing hills. It was noticed that transplanting finger cut an area of approximately 0.7 to 0.9 cm^2. Since existence of seedlings in each cm^2 area is there, hence missing of hill should not be encountered theoretically. However, there were missing of hills was primarily due to non-uniformity of seedling distribution in the mat the non-uniformity may be greater at lower mat density leading to more missing hills. It was noticed that transplanting fingers did drop some portion of mat in their downward position, irrespective of whether there was seedling in it or not which indicates that hill missing was not due to transplanter. Non-uniformity of seedling also had similar observations on missing hills (Mufti and Khan, 1995). Hence proper care should be taken to maintain optimum seedling uniformity along with density in the mat.

The mechanical damage data parting to seedling are presented in the Table 4. The mechanical damage to seedling varied between 0 to 6.10 per cent during the observation. The lowest mechanical damage was observed 26 days seedling at the 1.6 km/h operating speed of transplanter and highest was in case of 20 days old seedling at 1.9 km/h speed.

It was observed that mat moisture content and seedling density had no significant effect on mechanical damage to seedling whereas age and operating speed influenced it. So far further analysis, mechanical damage at different mat density and moisture content were

Table 3 : Effect of seedling characteristics and operating speed on missing hill

Age of seedling, days	Mat moisture content, %	Missing hill operating speed km^{-1}					
		1.6			1.9		
		Seedling density, No. cm^{-2} (seed rate, g mat^{-1})			Seedling density, No. cm^{-2} (seed rate, g mat^{-1})		
		1.70 (60)	2.10 (80)	2.50 (100)	1.70 (60)	2.10 (80)	2.50 (100)
18	10-15	15.2	8.98	10.05	12.98	10.5	8.70
	20-25	12.45	8.2	7.60	10.92	7.05	7.30
	30-35	10.05	7.26	7.00	9.75	6.95	6.35
22	10-15	13.98	10.05	8.40	14.25	9.40	7.97
	20-25	10.40	8.5	7.20	11.40	6.72	6.83
	30-35	11.05	9.89	9.97	8.35	6.40	3.92
26	10-15	11.97	7.45	5.97	10.72	6.00	4.92
	20-25	13.05	8.88	4.72	8.35	3.90	3.91
	30-35	9.72	7.24	4.35	7.95	6.10	3.10

Table 4 : Effect of seedling characteristics and operating speed on mechanical damage to seedling

Age of seedling, days	Mat moisture content, %	1.6			1.9		
		Seedling density, No. cm^{-2} (seed rate, g mat^{-1})			Seedling density, No. cm^{-2} (seed rate, g mat^{-1})		
		1.70 (60)	2.10 (80)	2.50 (100)	1.70 (60)	2.10 (80)	2.50 (100)
18	10-15	3.15	3.15	3.45	5.50	5.95	4.95
	20-25	4.00	3.51	3.45	5.30	5.48	4.97
	30-35	4.05	2.71	3.91	5.99	6.10	5.81
22	10-15	4.00	3.15	2.53	4.90	4.70	3.95
	20-25	2.40	2.25	2.05	4.50	3.15	4.00
	30-35	2.60	3.25	1.25	3.50	4.10	3.10
26	10-15	2.25	0.00	2.30	3.50	1.75	2.76
	20-25	2.40	3.05	1.50	3.95	3.65	2.15
	30-35	1.60	0.60	1.50	2.45	2.55	1.67

Table 5 : Effect of soil setting time with different operating speed

Sr. No.	Observations	0 hour soil setting time			8 hour soil setting time			24 hour soil setting time			Control
		1.6 km/h	1.75 km/h	1.9 km/h	1.6 km/h	1.75 km/h	1.9 km/h	1.6 km/h	1.75 km/h	1.9 km/h	
1.	Sinkage, mm	4	4	3	3	3	3	3	3	3	
2.	No. of seedling in one hill	3	3	3	3	3	3	3	3	3	
3.	Damage of seedling due to flow of soil		2 row			1 row			Nil		
4.	Depth of transplanting, cm		3.5			3.4			3.4		
5.	Hill distance, mm		12			12			12		
6.	Row spacing		23.8			23.8			23.8		
7.	Plant population, No./m^2	23	19	21	27	25	22	22	24	2	29
8.	Missing hills, No./m^2	8	8	7	3	4	3	3	3	4	
9.	Mortality, No./m^2	2	4	4	4	4	4	6	4	5	6

posted together to present it for the corresponding age and operating speed.

It was found that mechanical damage to seedling higher at lower age and higher operating speed. When operating speed increased from 1.6 to 1.9 km/h mechanical damage at 1.9 km/h speed may be due to more impact force exerted by the transplanter (Table 5).

Conclusion :

In general, seedling per hill increased with age however, with older seedling, the number of seedling per hill was found more at higher moisture content compared to lower moisture. It was found that by increasing the operating speed, the transplanting speed also increased which resulted in greater impact forced by the transplanting fingers on the mat. The 26 days seedlings have good production results comparatively all other ages of seedlings. Seedlings age also affect the crop yielding. It was also observed that mechanical damage of seedlings at lower age and higher operating speed. The observations from present experiment investigate that rice transplanting can be delayed upto July 10 for medium duration cultivar and upto 25 June for long duration cultivar without any disadvantage on crop yield and quality of grains. Around 14% decrease of water application through delay in transplanting from10 June to 4 July, which is economical. This practice appears useful as the results indicate high production efficiency with 26 days age seedlings transplanted with the help of self propelled 8-row rice transplanter. It can be accomplished by timely updating and application of improved technology, for instance, to uphold the quality and nutritional values of rice. Transplanting mat type seedling is becoming more popular due to its superior performance and reduced labour requirement (50 man-h/ha). The mechanical damage to seedling varied between 0 to 6.10 per cent during the observation. The lowest mechanical damage was observed 26 days seedling at the 1.6 km/h operating speed of transplanter and highest was in case of 20 days old seedling at 1.9 km/h speed.

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REFERENCES

Anonymous (2013-14). AICRP on farm machinery (FIM). Dr Rajendra Prasad Central Agricultural University, Pusa, Report.

Datta, D. (1981). *Principles and practices of rice production*. Int. Rice Res. Inst..

David, S., Amarasinghe, U., Molden, D., de Silva, R. and Barker, R. (1998). *World water demand and supply, 1990 to 2025: scenarios and issues* (Vol. 19). Research Report.

Garg, I.K., Singh, C.P. and Sharma, V.K. (1982). Influence of selected seedling mat parameters and planting speed on performance of rice transplanter. AMA,13 (2): 27 – 33.

Hatfield, J.L., Sauer, T.J. and Prueger, J.H. (2001). Managing soils to achieve greater water use efficiency. *Agron. J.*, **93**(2) : 271-280.

Hedayetullah, S. (1977). A study on the effect of cultural factor in transplanted paddy on the behaviour of some plant characteristics influencing the yield. *Indian J. Agric. Sci.*, **17** : 69-80.

Herrera, W.A.T. and Zandstra, H.G. (1979). The use of old seedlings and their effects on the performance of transplanted rice. *Philippine J. Crop Sci.*, **4**(4) : 134-141.

Hoshino, S. (1974). Recent advances on rice transplanters. *JARQ*, **8**(4): 209-213.

Hoshino, S. (1977). New developments in transplanting-rice. *JARQ*, **11** : 1-16.

Kewat, M.L., Agrawal, S.B., Agrawal, K.K. and Sharma, R.S. (2002). Effect of divergent plant spacings and age of seedlings on yield and economics of hybrid rice (*Oryza sativa*). *Indian J. Agron.*, **47**(3) : 367-371.

Kumar, D., Noori, T. and Kumar, M. (2016). Studies on existing mechanization status for fodder and crop in Rajendra Agricultural University region, PUSA, Bihar, India. International Conference on Emerging Technologies in Agricultural and food engineering 27-30 December, 2016. Agricultural and food Engineering Department, IIT Kharagpur, e-Proceedings pp 210-216.

Makarim, A.K., Balasubramanian, V., Zaini, Z., Syamsiah, I., Diratmadja, I.G.P.A., Handoko, A. and Gani, A. (2002). Systems of rice intensification (SRI): evaluation of seedling age and selected components in Indonesia. *Water-wise rice Production*, 129-139.

Mandal, B.K., Sainik, T.R. and Ray, P.K. (1984). Effect of age of seedling and level of nitrogen on the productivity of rice. *Oryza*, **21**(4) : 225-232.

McHugh, O. (2002). Farmer alternative wet/dry, non-flooded and continuously flooded irrigation practices in traditional and intensive systems of rice cultivation in Madagascar M.Sc. Thesis, Cornell University, Ithaca, NY, USA.

Mufti, A.I. and Khan, A.S. (1995). Performance evaluation of Yanmar paddy transplanter in Pakistan. *Agricultural Mechanization in Asia Africa and Latin America*, **26** : 31-31.

Pasuquin, E., Lafarge, T. and Tubana, B. (2008). Transplanting young seedlings in irrigated rice fields: early and high tiller production enhanced grain yield. *Field Crops Res.*, **105**(1) : 141-155.

Paul, W.R.C. (1945). Paddy cultivation, Ceylon Govt. Press, Ceylon.

Rai, H.K. and Kushwaha, H.S. (2005). Performance of upland rice (*Oryza sativa*) under different transplanting dates and soil water regimes in tarai conditions. *Indian J. Agric. Sci.*, **75**(12) : 817-819.

Singh, R.S. and Singh, S.B. (1999). Effect of age of seedlings, N-levels and time of application on growth and yield of rice under irrigated condition. *Oryza*, **36**(4) : 351-354.

Singh, S.K., Varma, S.C. and Singh, R.P. (2001). Effect of integrated nutrient management on yield, nutrient uptake and changes in soil fertility under rice (*Oryza sativa*) – lentil (*Lens culinaris*) cropping system. *Indian J. Agron.*, **46**(2): 191-197.

Swain, S. and Maity, S.P. (1989). Influence of manually operated rice transplanter. *J. Agric. Engg.*, **26**(2): 173-181.

Thakur, R. (1996). Recent varietals development in rice for Bihar Plains (Mimeo). Rajendra Agricultural University, Pusa (Bihar).

Thiyagarajan, T.M., Velu, V., Ramasamy, S., Durgadevi, D., Govindaranjan, K., Pryadarshini, R., Sudhalakshm, C., Senthikumar, K., Nisha, P.T., Gayathry, G., Hengsdijk, H. and Bindrahan, P.S. (2002). System of rice intensification (SRI): evaluation of seedling age and selected components in Indonesia. In : Bouman, B.A.M., Hengsdijk, A., Hardy, B., Bindraban, P.S., Toung, T.P., Ladha, J.K. (Eds.), Water - Wise Rice Production, IRRI, Philippines. pp. 119-127.

Thoms, E.V. (2001). Development of a mechanism for transplanting rice seedlings. *Mechanism & Machine Theory*, **37** (2002) : pp. 395–410.

Toung, T.P. and Bhuiyan, S.I. (1994). Innovations towards improving water-use efficiency in rice. In : World Bank's 1994 Water Resource Seminar. pp. 13-15.

Wagh, R.G., Khanvilkar, S.A. and Thorat, S.T. (1988). Effect of age of seedlings at transplanting, plant densities and nitrogen fertilization on the yield of rice variety R711. *Oryza*, **25** : 188-190.