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REVIEW ARTICLE

EFFECT OF DIFFERENT CROP ESTABLISHMENT METHODS ON RICE (*ORYZA SATIVA* L.) GROWTH, PRODUCTIVITY AND PROFITABILITY- A REVIEW

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ABSTRACT

Rice is the staple food crop for more than half of the world's population though it is cultivated in only 11% of the world's cultivable land. It is a good source of energy, vitamins, minerals, amino-acids, anti-oxidants etc. Rice is commonly grown by transplanting seedling into the puddled soil, which is labour, water-, energy-intensive and is becoming less reliable to the resource-poor farmers. Also, repeated puddling deteriorates soil quality thus farmers are shifting the puddled transplanting method (TPR) to direct seeding method (DSR) as this method has emerged as feasible alternative establishment method to deal with the water and labour shortages. Though DSR method of rice cultivation suffers from lower grain yield compared to traditional transplanting method, the grain yield can be increased through proper weed control and crop management practices. Farmers can be benefitted by the less cost, higher yield, lower drudgery of transplanting and the quick maturity of DSR as they can plant succeeding crops early. System of Rice Intensification (SRI), a method emerged from Madagascar uses single and young seedlings at wider spacing and is one of the water-saving rice production technology which yield is nearly twice to that of conventional transplanting method. Recent studies and experiment should focus on the optimization of management practices for each method to improve rice growth and narrow the yield gap between them along with with the reduction of inputs (water and labour) costs. The main aim of this review article is to provide comparisons between different rice planting methods on the growth parameters, productivity and economics. Moreover, this article presents the different statistical relationship between the crop establishment methods of rice and its growth, productivity and economics.

KEYWORDS

Puddled Transplanted Rice (TPR), Direct Seeded Rice (DSR), SRI, Benefit-Cost Ratio.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple nourishment of over half of the world's population. It is the excellent dietary vitality source for seventeen nations in Asia and the Pacific, nine nations in the north and South America and eight nations in Africa. Rice gives 20% of the world's dietary energy supply, whereas wheat supplies 19% and maize (corn) 5% (FAO Food and Nutrition Division, 2004). Cooked, white, long-grained rice is composed of 68% water, 28 % carbohydrates, 3% protein and irrelevant amount of fat (United States Department of Agriculture, n.d.). In a 100 gram serving, it gives 130 calories and a good source of vitamins (thiamine, riboflavin and niacin), minerals and amino-acid (except lysine) and anti-oxidants (Arnarson, 2017).

Crop establishment is a sequence of events that include seeding, seed germination, seedling emergence and development to the stage where seedlings could be expected to grow to maturity (Jat et al., 2010). Rice production methods in any area depend on the environment, ecological and the socio-economic conditions of that area. Majority of the people practices the techniques such as conventional transplanting after puddling in lowland areas whereas DSR in upland areas (Chauhan et al., 2017). About 77% of the global rice production in the world is done by

conventional transplanting methods in puddled soil (Chakraborty et al., 2017; Xu et al., 2019). Conventional transplanting system (TPR) of rice crop production requires labour, water, capital, and energy in large amount so that it has become less profitable at present due to the lack of these resources (Chakraborty et al., 2017). Tuong and Bouman reported that in a conventional transplanted system (TPR) requires about 2500 L (average) of water to produce 1kg of rice (Tuong and Bouman, 2003). Out of 70-80 percent freshwater used in agriculture, rice accounts for 85 % in total and 30 % in puddling only (Chauhan and Opeña, 2012). In traditional transplanting system (TPR), puddling leads to high losses of water, creates hard pan formation, reduces soil permeability thus deteriorating the physical structure of soil (Muhammad Farooq et al., 2009). A group researchers on the other hand, puddling benefits rice by reducing water percolation losses, suppressing weeds, facilitating the quick seedling establishment and enhancing nutrient availability by creating the anaerobic condition (Kumar and Ladha, 2011; Gathala et al., 2011).

Because of the enormous water requirement, expensive labour charges for the TPR system, it has become less economical to the farmers. Due to increased labour demand in non- agricultural sectors; there is reduced availability of labours during the peak season of farming works. Also, in

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Asia, the rice transplanting job is done manually, mostly by the women and the drudgery often leads to the occupational hazards for them (Chakraborty et al., 2017). These factors have caused the shift in rice cultivation system from TPR to DSR in several countries of South-East Asia (Balasubramanian and Hill, 2002). Cheap labour charges and sufficient water availability favours TPR, whereas expensive labour charges and shortage of water favours DSR (figure 1) (Pandey and Velasco., 2005).

Figure 1: Wage rate and water availability as determinants of crop establishment methods.

DRS = direct-seeded rice, TPR = transplanted rice.

Direct seeding of rice refers to the process of establishing rice crop by sowing dry seeds directly in dry soil (dry seeding) pre-germinated seeds on wet puddled soil (wet seeding) and into standing water (water seeding) (Farooq et al., 2011). Direct seeding probably is one of the oldest method of crop establishment which is now practiced in about 21% of total rice area in Asia. It is practiced in upland and submergence-prone areas where transplanting methods cannot be performed (Pandey and Velasco, 2002). DSR has many advantages to the farmers such as higher economic returns, faster and easier technology, less labor and water requiring, suitable for mechanization, short crop duration and have less methane emission (Farooq et al., 2006; Balasubramanian and Hill, 2002; Pandey and Velasco, 2002). Thus, it has become a viable alternative to the drudgery and labour-intensive TPR system. DSR also has several potential disadvantages such as low yield, poor and uneven crop establishment and high infestation of weeds etc. Weed control cost for DSR can be as high as 20% of the total pre-harvest cost and the use of excessive chemicals for weed control can be harmful to the human health and environment (Pandey and Velasco, 2002).

System of Rice Intensification (SRI) is another method developed from Madagascar which uses single young seedlings of 8-12 days old, reduces plant densities (16 hills/m²), alternate wetting and drying of the field and use of mechanical weeder which aerates the soil aiming of providing favourable growth environment for the plant during establishment to get better yield and productivity (Kumar et al., 1997; Kumar et al., 2013). SRI method has been boon for poor farmers because of higher yield nearly twice than conventional transplanting method with fewer inputs like water, fertilizers, seeds and labour used. Hundreds of on-station & on-farm trials should be conducted to determine the yield differences between DSR and TPR under various climates, soil and management conditions and attempts should be made to shorten the yield gap between DSR and TPR along with the articulation of policy and institution measures to facilitate large scale adoption of DSR system.

1.1 Aim of the study

The aim of this study is to provide clear information about the effects of different rice crop establishment methods on the growth parameters, productivity and profitability.

2. METHODOLOGY

This article was prepared by collecting data from secondary sources. The relevant data related to the effects of crop establishment methods on rice enterprise were collected from the thorough study of journal articles, research papers, annual reports, thesis, review articles, survey reports, books, proceedings etc. and extensive evaluations was done.

3. RESULT AND DISCUSSION

3.1 Effect of rice establishment methods on rice growth parameters

A group researcher reported the highest plant height (130.04 cm) and the

number of sterile spikelet panicle⁻¹ (17.67) in conventional transplanting system compared to the SRI method (Hossain et al., 2003). A group researchers found higher plant population per unit area but a lesser number of tillers per m² in DSR method compared to the transplanted method which is similar to the results obtained (Sasaki et al., 1999; Javaid et al., 2012). In other studies recorded highest plant height (171.09 cm), effective tillers (360.58), dry matter accumulation (1371.92 m⁻²) and straw yield (47.42 qha⁻¹) in line transplanting method (Kumhar et al., 2016).

In other studies reported in two years experiment that transplanting method recorded significantly higher plant height (102.5 cm, 109.7 cm) compared to direct-seeded crop (98.9 cm, 99.3 cm) but effective tillers were observed high in DSR method than transplanting method (Rahman et al., 2019; Kumar and Jnanesh, 2017). A group researcher conducted an experiment using four different rice establishment method as treatments and found that highest germination percentage in treatment transplanting after puddling (95%) and minimum in dry seeded rice with drum seeder (DSR) (Kumar et al., 2018). A study reported that highest plant height (39.36 cm, 43.02 cm, 43.91 cm, 102.28 cm) in transplanting method measured at 15 days interval till harvest compared to SRI method (Bhandari et al., 2020).

3.2 Effect of crop establishment method on yield & yield attributing characters

A studies reported that SRI method produced significantly higher yield attributes viz. total tillers hill⁻¹ (12.29), effective tillers hill⁻¹ (11.31), panicle length (25.74 cm), number of grains panicle⁻¹ (142.28), grain yield (5.67 tha⁻¹), straw yield (5.48 tha⁻¹) and harvest index (48.62%) (Hossain et al., 2003). A record yield of 19 tones/ha has been reported by China while 50-100% increase in yield by India in SRI method over conventional transplanted method. Other researchers reported that DSR by power till drill produced 24% higher grain yield (5287 kg/ha) compared to transplanted rice (4265 kg/ha) (Sah et al., 2007). Some researchers also suggested that DSR matured 3 weeks earlier than transplanted rice which allows farmers for early planting of succeeding crops (Sah et al., 2007). He also reported higher number of effective tillers / m² (290), thousand-grains weight (22.17 gm) in DSR method compared to the transplanted method.

Hugar et al., (2009) reported that SRI method recorded significantly higher grain yield (6140 kgha⁻¹), straw yield (9306 kgha⁻¹), number of tillers (448 m⁻²), effective tillers (376.5 m⁻²), panicle length (23.5 cm), number of seeds per panicle (94.5), thousand grain weight (27.5 gm), net returns (Rs. 37086 ha⁻¹) and B:C ratio (2.03) compared to other methods. Javaid et al., (2012) reported that conventionally transplanted rice produced significantly higher yield attributes viz. number of spikelet panicle⁻¹, sterility percentage and grain yield but lower test weight compared to DSR method.

A study reported higher panicle length, test weight and grain yield (64.8 q/ha) in transplanted method compared to DSR method (Kumar and Jnanesh, 2017). A group researchers found higher panicle length (21.07 cm), test weight (22.24 gm), weight of grains per panicle (2.25 gm), number of filled grains per panicle (97.08) in line transplanting method (Kumhar et al., 2016). Lama and Marahatta in her technical paper found higher number of effective tillers by 14.94 %, test weight, grain sterility percentage and grain yield but lesser number of grains per panicle in direct seed rice than puddled transplanted rice (Lama and Marahatta, 2017). Kumar et al., (2018) found higher panicle number per m² and grain yield in transplanting after puddling method compared to DSR method (Kumar et al., 2018). This may be due to the optimum spacing between the crops which ensure air circulation and water and light for photosynthesis in transplanting method (Baloch et al., 2002).

Rahman et al., (2019), in her experiment revealed that the highest grain yield (5.54 t/ha) and harvest index (46.69%) was obtained in puddle transplanting method due to the higher production of effective tillers per hill and the higher number of grains per panicle compared to DSR, unpuddled transplanting and AWD (Alternate wetting and drying). The creation of ideal rhizosphere environment by the puddling process in transplanting methods might help for the higher and efficient nutrient uptake and translocation of photosynthates may be the cause for the higher yield in PTR (Bhardwaj et al., 2018). A study reported the highest average number of tillers / m² (294.4), effective tillers/m² (254.8), test weight (22.87 g), panicle length (25.53 cm) and grain yield (4.475 t/ha) and low grain sterility percentage (16.73%) in SRI method compared to others transplanting method (Bhandari et al., 2020).

3.3 Economics of different crop establishment methods

A study reported that DSR showed 60% higher net returns compared to transplanted/farmer's practice method (Sah et al., 2007). Kumar and Jnanesha recorded significantly higher gross returns during both years (Rs. 110304 and Rs. 104950) from the transplanted method but net returns (Rs. 73232 and Rs. 70895) and benefit-cost ratio (2.29 and 2.22) from DSR method (Kumar and Jnanesha, 2017). A study recorded higher B:C ratio (1:2.23) in line transplanting technique which is similar to the findings of Rahman et al., (2019) (Kumhar et al., 2016). A study reported labour and cost savings of 97% and 81% respectively and B:C (4.0) in direct-seeded rice as compared to puddled transplanted rice (3%) (Choudhary et al., 2016).

Lama and Marahatta suggested significantly higher B: C ratio (45%) for DSR compared to the transplanted method (Lama and Marahatta, 2017). A study reported higher net income and benefit-cost ratio in DSR method compared to the TPR method in both years (Kumar et al., 2018). This may be due to lower cost of cultivation as compared to other methods of crop establishment. Ahmed and Latiful reported that the total production cost in DSR was 15-18% lower than the PTR and net profit was significantly lower in TPR due to higher production cost involvement during land preparation, transplanting and irrigation (Ahmed and Latiful, 2018). SRI method is a boon for small and marginal farmers since it reduces the cost of seeds by 60%, irrigation cost by 40%, fertilizers cost by 30 % and increase production by 35% over traditional transplanted rice (Pyngrope et al., 2019).

4. CONCLUSION

Despite being ubiquitous around the world and popular among the farmers, puddled transplanting method (TPR) is a laborious, water-, cost-intensive method than the DSR and SRI methods. Among the different crop establishment methods DSR required significantly lower water compared to transplanted method but DSR recorded significantly higher water productivity compared to transplanted method. The DSR method has higher net income and B:C ratio compared to other methods but has about 12% lower yield than that of TPR which might result from the weed infestation, climatic stress occurrences and improper water management. So, to obtain comparable yield with TPR & SRI, an integrated package of management technologies should be applied to deal with major constraints of DSR. The research should be based on developing optimized seeding time and suitable rice variety for direct seeded rice (DSR). DSR is a promising alternative planting method in present water scarcity and labour shortage situations, but more effort should be made to implement appropriate management strategies and breeding programs.

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REFERENCES

- Ahmed, S., Latiful, B., 2018. Performance of Aus Rice in Different Tillage Systems and Crop Establishment Method in Southwest Bangladesh. *Journal of Experimental Sciences*, 9, Pp. 05–09. <https://doi.org/10.25081/jes.2018.v9.3577>
- Arnarson, A.P.D., 2017. What to know about rice. *Medical News Today*. <https://www.medicalnewstoday.com/articles/318699#Fiber>
- Balasubramanian, V., Hill, J., 2002. Direct seeding of rice in Asia: emerging issues and strategic 15 research needs for the 21st century. In S Pandey, M. Mortimer, L. Wade, T. Tuong, K. Lopez, & B. Hardy (Eds.), *Direct seeding: research issues and opportunities*. (2002nd ed., pp. 15–39). International Rice Research Institute, Los Banos, Philippines.
- Baloch, A., Soomro, A., Javed, M., Ahmed, M., Bughio, H., Bughio, M., Mastoi, N. 2002. Optimum Plant Density for High Yield in Rice (*Oryza sativa* L.). *Asian Journal of Plant Sciences*, 1(1), Pp. 25–27. <https://doi.org/10.3923/ajps.2002.25.27>
- Bhandari, S., Sapkota, S., Gyawali, C., 2020. Effect Of Different Methods Of Crop Establishment On Growth And Yield Of A Spring Rice At Janakpurdham-17 , Dhanusha. *Malaysian Journal of Sustainable Agriculture*, 4(1), Pp. 10–15. <https://doi.org/10.26480/mjsa.01.2020>
- Bhardwaj, R., Singh, M., Singh, C., Singh, A., 2018. Efficacy of crop establishment methods on yield and economics of rice (*Oryza sativa* L.) under puddled condition. *International Journal of Current Microbiology and Applied Sciences*, 7, Pp. 3625–3631.
- Chakraborty, D., Ladha, J.K., Rana, D.S., Jat, M.L., Gathala, M.K., Yadav, S., Rao, A.N., Ramesha, M.S., Raman, A., 2017. A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production. *Scientific Reports*, 7(1), Pp. 1–11. <https://doi.org/10.1038/s41598-017-09742-9>
- Chauhan, B.S., Opeña, J., 2012. Effect of tillage systems and herbicides on weed emergence, weed growth, and grain yield in dry-seeded rice systems. *Field Crops Research*, 137, Pp. 56–69. <https://doi.org/https://doi.org/10.1016/j.fcr.2012.08.016>
- Chauhan, Bhagirath, S., Jabran, K., Mahajan, G., 2017. Rice Production Worldwide. In Springer International Publishing (Issue February 2018). <https://doi.org/10.1007/978-3-319-47516-5>
- Choudhary, R., Prem, G., Kumar, A., Singh, U., Jat, H.S., Yadav, A.K., 2016. Comparative Study on Productivity and Profitability of Rice (*Oryza Sativa* L.) Under Different Crop Establishment Methods in Amabala, Haryana. *Progressive Agriculture*, 16(2), Pp. 183–189. <https://doi.org/10.5958/0976-4615.2016.00035.1>
- FAO Food and Nutrition Division. 2004. Rice is life. <http://www.fao.org/rice2004/en/f-sheet/factsheet3.pdf>
- Farooq, M., Siddique, K.H.M., Rehman, H., Aziz, T., Lee, D.J., Wahid, A., 2011. Rice direct seeding: Experiences, challenges and opportunities. *Soil and Tillage Research*, 111(2), Pp. 87–98. <https://doi.org/10.1016/j.still.2010.10.008>
- Farooq, Muhammad, Barsa, S.M.A., Wahid, A., 2006. Priming of field-sown rice seed enhances germination, seedling establishment, allometry and yield. *Plant Growth Regulation*, 49(2–3), Pp. 285–294. <https://doi.org/10.1007/s10725-006-9138-y>
- Farooq, Muhammad, Wahid, A., Lee, D.J., Ito, O., Siddique, K.H.M., 2009. Advances in drought resistance of rice. *Critical Reviews in Plant Sciences*, 28(4), Pp. 199–217. <https://doi.org/10.1080/07352680902952173>
- Gathala, M.K., Ladha, J.K., Saharawat, Y.S., Kumar, V., Kumar, V., Sharma, P.K., 2011. Effect of Tillage and Crop Establishment Methods on Physical Properties of a Medium-Textured Soil under a Seven-Year Rice–Wheat Rotation. *Soil Science Society of America Journal*, 75(5), Pp. 1851–1862. <https://doi.org/10.2136/sssaj2010.0362>
- Hossain, M., Hossain, S.M., Anwar, M., Sarkar, M.R., Mamun, A., 2003. Performance of BRRI Dhan in SRI and Conventional Methods and their Technology Mixes. *Pakistan Journal of Agronomy*, 2(4), Pp. 195–200.
- Hugar, A., Chandrappa, H., Jayadeva, H., Sathish, A., Mallikarjun, G., 2009. Influence Of Different Establishment Methods On Yield And Economics Of Rice.
- Jat, M., Singh, R.G., Sidhu, H., Singh, U., Malik, R., Kamboj, B., Jat, R., Singh, V., Hussain, I., Mazid, M., Sherchan, D., Khan, A., Singh, V., Patil, S., Gupta, R., 2010. Resource Conserving Technologies in South Asia : Frequently Asked Questions.
- Javaid, T., Awan, I.U., Baloch, M.S., Shah, I.H., Nadim, M.A., Khan, E.A., Khakwani, A.A., Abuzar, M.R., 2012. Effect of planting methods on the growth and yield of coarse rice. *Journal of Animal and Plant Sciences*, 22(2), Pp. 358–362.
- Kumar, A., Jnanesha, A.C., 2017. Effect of Crop Establishment Methods on Growth Yield And Water Productivity of Rice. *International Journal on Agricultural Sciences*, 8(1), Pp. 40–45.
- Kumar, M.R., Rao, R.P., 2013. SRI-A Method for Sustainable Intensification of Rice Production with Enhanced Water Productivity. *Agrotechnology*, 01(S11). <https://doi.org/10.4172/2168-9881.s11-009>
- Kumar, M.R., Surekha, K., Padmavathi, C., Rao, L.V.S., Latha, P.C., Prasad, M.S., Babu, V.R., Ramprasad, A.S., Rupela, O.P., Goud, V., 1997. Research Experiences on System of Rice Intensification and Future Directions. *Journal of Rice Research*, 2(2), Pp. 61–71.

- Kumar, Vinay, Singh, S., Sagar, V., Maurya, M.L., 2018. Evaluation of different crop establishment method of rice on growth , yield and economics of rice cultivation in agro-climatic condition of eastern Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*, 7(3), Pp. 2295–2298.
- Kumar, Virender, Ladha, J.K., 2011. Direct Seeding of Rice. Recent Developments and Future Research Needs. In *Advances in Agronomy* (1st ed., Vol. 111). Elsevier Inc. <https://doi.org/10.1016/B978-0-12-387689-8.00001-1>
- Kumhar, B.L., Chavan, V.G., Rajemahadik, V.A., Kanade, V.M., Dhopavkar, R.V., Tilekar, R.N., 2016. Effect Of Different Rice Establishment Methods On Growth , Yield And Different Varieties During Kharif Season Department Of Agronomy , College Of Agriculture , Dapoli . Dr . Balasaheb Sawant Konkan Krishi Vidyapeeth , Dapoli – 415 712 , Distt . Ratnagiri. *International Journal of Plant, Animal and Environment Sciences*, 6(2), Pp. 127–132.
- Lama, C., Marahatta, S., 2017. Assessment of productivity and resource use efficiency of rice under different establishment methods and nutrient management in Chitwan condition, Nepal. *Journal of Agriculture and Environment*, 18, Pp. 41–50. <https://doi.org/10.3126/aej.v18i0.19888>
- Pandey, Sushil, Velasco, L., 2002. Economics of direct seeding in Asia: patterns of adoption and research priorities. In S. Pandey, M. Mortimer, L. Wade, T. P. Tuong, K. Lopes, & B. Hardy (Eds.), *Direct Seeding: Research Strategies and Opportunities*. International Rice Research Institute, Los Banos, Philippines.
- Pandey, Sushil, Velasco, L., 2005. Trends in crop establishment methods in Asia and research issues. In K. Toriyama, K. Heong, & B. Hardy (Eds.), *Rice Is Life: Scientific Perspectives for the 21st Century*. International Rice Research Institute, Los Banos, Philippines and Japan International Research Center for Agricultural Sciences, Tsukuba, Japan, Pp. 178-181.
- Pynogrope, D., Mithare, P., Ghosh, G., 2019. Influence of Different Planting System and Levels of Nitrogen on Growth, Yield, Quality and Economics of Rice (*Oryza sativa* L.) - A Review. *International Journal of Current Microbiology and Applied Sciences*, 8(01), Pp. 2161–2172. <https://doi.org/10.20546/ijcmas.2019.801.226>
- Rahman, A., Salam, M.A., Kader, M.A., 2019. Effect of crop establishment methods on the yield of boro rice. *Journal of the Bangladesh Agricultural University*, 17(4), Pp. 521–525. <https://doi.org/10.3329/jbau.v17i4.44621>
- Sah, G., Bhurer, K. ., Upadhyay, I. ., Ansari, N., Caudhary, D., Karna, P. ., Adhikari, S. ., Erenstein, O., Justice, S., 2007. On-Farm Performance Evaluation Of Aerobic Rice Ecologies And Its Impact. Anonymous, Pp. 350–356.
- Sasaki, R., Yamaguchi, H., Matsuba, K., 1999. Theoretical analysis of the tillering capacity for the lower density of seedling establishment in direct seeding cultivation of rice (*Oryza sativa* L.). *Japanese Journal of Crop Science*, 68(1), Pp. 10–15.
- Tuong, T.P., Bouman, B.A.M., 2003. Rice Production in Water-scarce Environment. *Comprehensive Assessment of Water Management in Agriculture Series*, Pp. 53–67. Wallingford, UK: CABI Publishing.
- United States Department of Agriculture. 2020. USDA Food Composition Databases. Retrieved March 13, 2020, from <https://fdc.nal.usda.gov>
- Xu, L., Li, X., Wang, X., Xiong, D., Wang, F., 2019. Comparing the grain yields of direct-seeded and transplanted rice: A meta-analysis. *Agronomy*, 9(11). <https://doi.org/10.3390/agronomy9110767>