Chapter

Recent Advances in Crop Establishment Methods in Rice-Wheat Cropping System: A Review

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Abstract

Traditional practices of growing rice and wheat in Asian countries involve a huge cost in establishment methods adopted by farmers which not only limit the yield and return but also degrade soil and require more water. Adaptation of improved crop establishment methods suitable under adverse climatic conditions is of utmost importance for scientific utilization of natural resources and to maintain the sustainability of rice- wheat cropping system Therefore, an attempt has been made in this chapter to review precision rice establishment methodology viz., direct seeding, non-puddle/unpuddled transplanting, bed transplanting, strip tilled and single pass shallow tilled rice, double transplanting and system of rice intensification (SRI) and wheat establishment methods viz., zero tilled, strip tilled and bed planted wheat. These are recent improved crop establishment techniques that can be used under specific agro-ecological conditions for enhancing yield and resource conservation in Indo-gangetic plains of Eastern India.

Keywords: Direct seeded rice, resource use efficiency, single pass shallow tilled rice, SRI, strip tilled rice, unpuddled transplanted rice

1. Introduction

Rice–wheat cropping (RWC) system is of immense importance for the food security and livelihood of people residing in South Asian countries [1]. It occupies an area of about 18Mha in Asia, out of which 13.5 Mha lies in the Indo-Gangetic Plains (IGP) and feeds about a billion people (20% of the world population). Rice (*Oryza sativa* L.) is a staple food of more than 50% of the world's population [2] and supplies 20% of total calories required by world and 31% required by the Indian population [3]. Presently, rice is cultivated in 43.79 Mha area with 112.91 Mt. production while wheat is cultivated in 29.58 Mha area with a production of 99.70 Mt. [4]. Introduction of high-yielding varieties along with improved crop management practices, access to irrigation water and chemical inputs during the green revolution period has led to impressive increase in system productivity. But recent evidences indicate a plateau in productivity and decline in total factor productivity because of continuous environmental degradation and socio-economic changes seen in the IGP [5, 6] highly risking the sustainability of the system [1]. Crop establishment methods are important aspects of rice wheat production technology. It refers to the sequence of events starting from sowing of seed of the crop, germination of seed, emergence of the seedling and development of seedling to a stage from where it could be expected to grow to maturity [7]. Precision crop establishment is very vital for realizing optimum plant population and agro-ecological sustainability, lack of which substantially reduces crop yield. Traditional practices not only consume more time and money but also deplete natural resources and may result in unsatisfactory crop stand. Various improved establishment methods for rice and wheat crop are reviewed and discussed in this paper.

2. Major challenges in puddle transplanted rice establishment

Increasing futuristic demand of water with increasing population and industries along with decreasing rainfall activity and labor scarcity are the major factors that challenge the sustainability of highwater demanding rice-wheat cropping system especially in South-Asian countries. Although puddling creates proper anaerobic condition for rice growth and reduces weed emergence but puddling and transplanting are highly labour, water, time and energy intensive leading to higher cost of cultivation. Puddling (wet tillage) consumes upto 30% of total irrigation water application in rice in case of light textured soils [8]. Also, it has been reported that on an average wheat yield is reduced by 8% when sown after puddled transplanted rice compared to wheat sown after direct-seeded rice in unpuddled conditions [9] as puddling results in destruction of soil structure and creation of hard pans at shallow depth which affect the performance of succeeding wheat crop [10]. Puddling operation in rice delays wheat planting which results in wheat yield loss of 35–60 kg day^{-1} ha^{-1} in the IGP [11]. Disturbing the flora and fauna of ecosystem regularly in cropping site fails to attain the climax community which provide ample opportunity of invading alien pests. Thus, the adoption of some new crop establishment techniques with higher resources conservation/use efficiency and ecological stability is of vital importance for the sustainability of the agro ecosystem.

3. Advances in crop establishment methods of rice

The alternative tillage and crop establishment methods are site-specific and therefore evaluations under wider agro-ecological conditions are needed to have significant adoption. The crop establishment methods which had got renewed interest in case of rice have been discussed below.

3.1 Direct seeded rice (DSR)

Direct seeded rice (DSR) involves the establishment of a rice crop from seeds directly sown in the field by any suitable sowing method rather than by transplanting the seedlings from nursery [12]. Three techniques of DSR viz. dry seeding, wet seeding and water seeding are known. Dry seeding involves the sowing of seeds into prepared seed bed under unpuddled and unsaturated soil conditions by broadcasting, drilling or dibbling, which is suitable for rainfed areas with severe water shortages. Dry direct-seeding with 22% increase in grain yield [13] and 35–57% of water saving [14, 15] as compared to flooded system and over 80% NUE [16], is generally adopted for upland rice [17]. The wet seeding method of DSR is suitable for irrigated areas [18] with relatively fair amount of rainfall in which pre-germinated seeds are sown into well puddled field either by broadcasting or by using drum seeder. Drum seeding refers to the process of direct sowing of pre-germinated (sprouted) paddy seeds in puddled and leveled field after draining out the excess water by using an equipment known as drum seeder, which generally consists of 4 hyperboloid shaped drums capable of sowing 8 lines in one pass with 20 cm row to row spacing [19]. However, handling of the equipment is a problem which may lead to uneven seed distribution due to clogging of holes of the drum. In case of water seeding suitable for high rainfall areas, seeds are sown in standing water in fields where ridges and furrows are prepared prior to submergence. The depressions are created to prevent the seeds from getting drifted away and maintain favorable crop geometry.

DSR facilitates saving of resources as well as their efficient utilization and timely sowing of the subsequent crops. Although, the yield obtained in transplanted method of rice is more than that of DSR, but the net return as well as the B-C ratio is higher in case of DSR as reported by Kumar and Batra (**Table 1**) [20]. In the absence of water deficit stress, the faster development of DSR than transplanted rice is consistent over many findings as reported by Alam *et al*. [21]. And drum seeding which is a type of direct seeding is also beneficial in the same way as reported by [22] who found that the B:C ratio was higher in dry seeded rice with drum seeder (1.70) as compared to transplanting after puddling (1.54). However, the main constraint of direct seeding is the preponderance of weeds and proper crop emergence followed by establishment. The risk of yield loss in DSR is much greater (50–91%) as compared to that of conventional transplanted rice [23].

3.2 Non puddled/unpuddled transplanted rice

In case of unpuddled transplanting, the field is made ready for transplanting by a single pass strip tillage (or without tillage) followed by inundation of the field for nearly 2 days to make the land sufficiently soft for transplanting [24]. Thus, in this process the travail of puddling is omitted while the advantages of transplanting are obtained. It saves 31–76% of fuel, 25–26% of water [25] and time required for field preparation. Problems of proper establishment of the seedlings at the initial stage of germination and infestation of diseases, pest and weeds are few threats to the rice crop established by this method. Thus, growing rice by this method requires proper care and vigilance. Hossain *et al*. [26] reported greater yield (5.47 t ha^{-1}) and lesser fuel consumption (4.38 l ha^{-1}) in unpuddled transplanted rice as compared to the puddled transplanted rice. However, similar rice yield under puddled transplanted rice and unpuddled transplanted rice under zero tilled condition was reported in the Eastern gangetic plains [27]. Also, there was a trend of increasing grain yield in zero tilled unpuddled transplanted rice over that of puddled transplanted rice in the

Particulars	TPR	DSR
Production (q ha^{-1})	41.90	38.30
Gross Return	107244.25	98142.25
Net Return	87.28	1803.27
Cost of Production (Rs per quintal)	2517.95	2472.94
B-C Ratio	1.00	1.02
Source: Kumar and Batra [20].		

Table 1.
A study showing economics of TPR and DSR in Haryana (Rs ha^{-1}).

second season [28]. The practice of transplanting on unpuddled soil, suitable for low land areas, is a potential technology for those farmers who are skeptical about direct-seeded rice to avoid adverse effect of puddling on succeeding wheat crop.

3.3 Bed transplanted rice

Rice is also transplanted in bed with 15 cm height, 35 cm top width, 60 m bottom width and 25 cm furrow length [29] with rice seedlings are transplanted at the edges of beds. This method increases yield by 16% as compared to the conventional method [29]. The yield attributing characters *viz*. plant height, productive tillers/m^2, number of grains/panicle and test weight in case of rice grown on beds have been found to be at par with that of rice grown under conventional puddling as reported by Aslam *et al*. [30], however the B:C ratio was higher in case of bed transplanting as compared to conventional transplanting. Two types of nursery bed are possible in this method *viz.* dry bed and wet bed. Bed transplanting has many advantages out of which border effect on majority of the seedlings is most important. Also, irrigation can be applied efficiently in the furrows with comparatively less amount of water. The same beds can be used consequently for 5–6 years which is profitable in monetary terms. Irrigation water productivity (IWP) was significantly higher in beds to the tune of about 13% than flat transplanting during both the years of study by Sandhu *et al*. [31]. However, labour required for bed construction is more in this case. It is generally suitable for medium upland under irrigated condition.

3.4 Strip tilled rice

In unpuddled strip tilled rice, 4–6 cm wide and up to 6 cm deep tilled zones are made just after a little rain shower and seedlings are transplanted at a spacing of 25 cm × 20 cm which may vary according to soil conditions [24]. In this method, only 16–25% of the surface soil is disturbed and the rest remain conserved as it is which reduces the mechanical impedance on the soil surface and allows efficient use of resources as fertilizers are applied as band placement. Hossain *et al*. [32] reported that the yield and B-C ratio of rice was increased by 9% and 25%, respectively in the *kharif* season and 13% and 23%, respectively in the *rabi* season for strip tillage as compared to conventionally tilled rice. Adhikari *et al*. [33] reported that the rice grain yield under strip tillage without mulch was significantly higher than rice grown under full tillage with mulch.

3.5 Single pass shallow tilled rice

Single pass shallow tillage refers to tilling the entire soil surface upto 4–6 cm depth by using Versatile Multi-crop Planter (VMP) [34] and incorporating the residues into the field in one single go of the equipment. After tillage, irrigation is done to inundate the field for 24 hours before transplanting. Significant differences were not reported for grain yield under single pass shallow tilled (SPST) and conventional tilled rice but the gross margin was significantly higher for SPST as compared to conventional transplanting (**Table 2**) [24]. This method of sowing rice may be followed in both upland and medium land conditions where soil is compacted and impermeable.

3.6 Double transplanted rice

Double transplanting is a crop establishment system in which rice seedlings are transplanted twice, first on secondary nursery and then in the main field [35]. In this method, seeds are first sown in the primary nursery and subsequently after

Parameters	Tillage treatments	
	Traditional puddled	Single pass shallow tillage
Grain yield (t ha^{-1})	4.91	4.98
Gross return (US \$ ha^{-1})	1416	1436
Gross margin (US \$ ha^{-1})	1122b	1209a

Source: [24].

Table 2.
A study showing mean effect of tillage types on grain yield and economic return of rice.

3 to 4 weeks, rice seedlings from secondary nursery are again uprooted and transplanted in the main field [36]. In situations where the main field is not ready for transplanting at appropriate time due to late onset of monsoon or continuous stagnation of flood water, double transplanting is advantageous producing healthy and taller seedlings that can easily overcome the adverse situation like high water depth at the time of transplanting [37, 38]. Satapathy *et al*., [35] reported that double transplanting resulted in higher net returns and benefit–cost ratio than normal transplanting which is owing to higher grain yield. Kumar *et al*. [39] also reported higher B-C ratio of 1.99 in double transplanting as compared to single transplanting with a B-C ratio of 1.27. However, this method is quite labor intensive due to the involvement of a second stage nursery and transplanting without proper skill from smaller to larger polybags could give rise to severe transplanting shock. This system is suitable for long duration rice varieties in shallow low land areas.

3.7 System of rice intensification

System of Rice Intensification (SRI) is one of most revolutionary method of rice establishment which is being adopted in many countries. It consistently outperforms conventional practices providing new possibilities for food security and poverty reduction [40]. The four main principles of SRI are early, quick and healthy plant establishment, reduced plant density, improved soil conditions through enrichment with organic matter, reduced and controlled water application. Unlike conventional method, in SRI, seedlings are transplanted at 2 leaf and 3rdphyllocron stage [41] at 8–12 days age under square planting. Latif and Abdullah [42] reported that the use of irrigation water was reduced by 52.7% in comparison to transplanted rice. In 2002, at the first international conference on SRI, 15 countries reported that the average yield of rice was twice the current average with the use of this system of rice cultivation [43]. Kumar et al. [44] reported higher grain yield and total water productivity of rice grown in SRI method as compared to normal transplanting method. Hossain *et al*. [45] also reported a handsome grain yield of 7.62 t/ha in SRI as compared to 6.59 t/ha in traditional method. SRI is generally suitable for areas where the soil is fertile, fine textured, well drained and maintenance of alternate wetting and drying conditions is possible. However, high labour requirement and problems faced at the time of transplanting of young seedlings are some of the constraints of this method.

4. Recent advances in crop establishment methods of wheat

The main constraint faced by wheat crop in the rice-wheat cropping system is delayed planting leading to terminal heat stress due to growing of long duration rice varieties and the time required for land preparation after harvesting of the submerged rice crop. The crop establishment practices mentioned below are devised to manage those problems.

4.1 Zero tilled wheat

Zero tillage is an already proven resource conserving technology for wheat crop and it was found that it results in increase in crop yield by 5–7% (140–200 kg ha^{-1}) and food production by 0.7% (343000 tonnes ha^{-1}) in the Indo Gangetic plains [46]. Seed and fertilizers are placed by opening the furrows with the help of equipments like zero till ferti seed drill or Happy seeder in a single go in standing crop residues by completely avoiding the primary tillage operations. Singh *et al.* [47] reported that the grain and straw yield obtained by sowing of wheat by happy seeder is higher than the farmers practice in one of the two experimental locations (**Table 3**). This method reduces the tillage operations with a single pass and saves fuel, labour, farm machinery cost, water, fertilizers etc. [48], permits earlier wheat planting in rice-wheat system and control the problem of *Phalaris minor* [46]. Pandey *et al*. [49] reported higher grain yield (3440 kg/ha) and B:C ratio (2.38) for zero tilled wheat as compared to conventionally grown wheat with a grain yield of 3224 kg/ha and B:C ratio of 1.81 in Kailali district of Nepal. Since residue retention is a common practice in zero tillage system, so the organic matter content of the soil is also increased and soil compaction is reduced due to enhancement of biological activities in soil. The constrains of adapting zero tillage in wheat under RW system of developing countries are the small size of land holdings of small and marginal farmers and the involvement of lumpy technology (i.e. non-divisible piece of machinery) [5, 6] involving high procurement cost.

4.2 Bed planted wheat

In this method of wheat crop establishment, which is synonymous to furrow irrigated raised bed (FIRB), the land is cultivated traditionally and ridges/raised beds and furrows are prepared by using a raised bed planting machine where seeds are planted in rows and irrigation water is applied in furrows. In rice-wheat cropping system, raised beds are newly prepared for wheat and then in the next season rice is grown on the same bed under zero tillage with required repairing of the beds [50]. The most beneficial aspect of this method as mentioned in case of rice is the border effect imparted to maximum number of plants. Bed planted wheat also showed better performance with significantly highest number of tillers per running meter compared to others establishment methods viz. broadcasting and criss cross sowing, in the middle gangetic plain regions during both the experimental years [51]. Mollah *et al*. [50] reported a yield increase of 21% and water saving of 41–46% with a 70 cm wide bed with two rows over conventional method in wheat. However,

Treatment	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	Jalandhar	Patiala	Jalandhar	Patiala
Rotovator	41.19	44.52	63.02	68.1
Happy Seeder	43.63	49.53	66.75	75.8
Farmers practice	42.47	46.02	64.98	70.4

Source: Singh et al.*, 2013.*

Table 3.
A study showing influence of sowing methods on grain and straw yield of wheat.

the requirement of labour for bed preparation and favorable soil texture are some constraints in the adoption of this method.

4.3 Strip tilled wheat

In strip till planting, seed and fertilizers are placed simultaneously in a single operation by tilling the planting strips with a width of 4–6 cm [52] and depth of 2–7 cm. Unlike zero tillage, the row zone is completely pulverized with standing crop residues in the field. This method facilitates early establishment of wheat crop, reduces soil erosion from surface and efficient utilization of resources such as labour, fuel, soil etc. The fuel consumption in strip tillage was reduced by 57% and 38%, respectively as compared to conventional tillage and minimum tillage [52]. Usage of strip tillage produces high crop yields with lower production costs and provides better soil erosion control compared to conventional tillage [53]. Hossain *et al*. [32] reported higher yield of wheat in this method as compared to conventional method in all the three experimenting years. This method is recommended for medium land with irrigation facilities. However, higher cost of the strip till machine poses a constraint for the adoption of this method.

5. Conclusion

Newly developed techniques are precision establishment techniques, use of need based crop establishment technology conserves the scarce resources and reduces the crop establishment cost of rice-wheat system These techniques are machine based which help in mechanization and optimization of resources. Thus, these techniques should be promoted to obtain higher net return, sustainable intensification, maintenance of soil health and reduction in environmental pollution.

6. Future thrust

Weed management is a major challenge in these crop establishment methods as new complexes of weed flora are being observed by the farmers. Therefore, efficient weed management practices should be researched for wider adaptability of these techniques.

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