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Review Article

Agroecological and Socioeconomic Significance of Different Rice Establishment Methods

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Abstract

Transplanting of rice seedling on the puddle land is the principal system of rice cultivation. Water scarcity and labour shortage imposed a serious threat to the sustainability of rice culture under this popular method. In response to the increased labour scarcity and cost in Asia, many temperate countries switched to machine transplanting and tropical countries adopted wet direct seeding. This switch from puddle transplanting to other system substantially reduced the manual labour requirement in rice culture but contributed a little to the water saving. Recently developed dry direct seeded technology is efficient in reducing both labour and water requirement in rice culture. Wet direct seeding requires puddling of land while puddling is avoided in dry direct seeding. Dry direct seeded rice system contributes a lot to the reduction of greenhouse gas emission and arsenic accumulation. Therefore, considering the agro-climatic situation of the region, the appropriate rice establishment methods should be adopted for sustaining productivity with the minimum use of water and labour and also to protect health and environment.

Keywords: Water Scarcity; Labour Shortage; Transplanting; Dry Direct Seeding; Wet Direct Seeding

Introduction

Rice is the staple food for more than half of the world's population. Rice is grown on 161 million hectares of land with an annual production of about 679 million tons of paddy [1]. About 90% rice of the world is grown in Asia [2]. Rice provides 30-75% of the total calories intake by more than 3 billion Asians [3]. As the population of the world is increasing and the food demand is also increasing. Thus, food production needs to be increased 70% to meet up the global food demand by 2050 [2]. The horizontal expansion of rice area is limited in the near future due to decrease of agricultural land. Thus, the additional rice production should come from the increase of productivity. The major challenges towards achieving the increased production include scarcity of water and labour, increased wage rates and production cost, soil and environmental degradation. This paper focuses the role of different rice establishment method in overcoming these constraints for sustaining rice productivity to ensure food security.

Rice types and ecosystems

Rice belongs to the family poaceae, sub-family Oryzoidaeae, tribe Oryzeae, genus *Oryza*. The genus *Oryza* has 24 species of which only two species, *Oryza sativa* (Asian rice) and *O. glaberrima* (African rice) are the cultivated species and others are wild species. Rice has been cultivated for long period and adapted well under diverse climatic conditions and soils. There are three geographical races under the genus *Oryza sativa* which are considered as subspecies. The three subspecies are *O. sativa* sub sp. indica, *O. sativa* sub sp. japonica, *O. sativa* sub sp. javanica. The Indica types are grown in tropical regions, Japonica types are widely adopted in cooler areas, largely grown in temperate countries. Both indica and japonica are grown in sub-tropical regions.

Rice is grown in a wide range of climate-soil hydrology regimes. Depending on land type, cultivation system and irrigation practice rice culture falls into different ecosystems such as upland, medium land, lowland and deep water [7]. High lands generally remains above flood level after rain but flooding up to 25 cm occurs for some period in medium highlands. Flooding up to 50 cm occur in lowlands while flooding more than 50 cm prevails for long time in the deep water ecosystem. The varietal requirement differs in different ecosystems.

Rice establishment methods

Although there are different rice ecosystems, rice cultivation system is divided into two broad categories, upland rice and lowland rice culture. In upland rice culture, rice is grown on both flat and slopping fields, prepared and seeded under dry land conditions. It fully depends upon rainfall for moisture. Therefore, this system is also known as dry land or rain fed rice culture. The lowland rice culture refers to the rice grown on leveled, bunded and undrained soils with controlled irrigation. This is also known as irrigated rice or flooded rice. Lowland rice culture is mainly the puddle transplanting with conventional irrigation (PTR-CI) method where continuous standing water with high inputs is supplied for maximum output. In case of low land rice culture, the crop is established by direct seeding or transplanting on puddle land. In this system land is flooded and soil preparation is done in wet or submerged soil, referred to as wetland rice culture. Transplanting involves planting of rice seedlings in puddled soil. The dry and wet-seeding methods are jointly referred to as direct seeding because seeds are sown directly in both the methods. In dry seeding seeds are sown on dry cultivated soils by broadcasting, drilling or dibbling. Wet seeding involves sowing of pre-germinated seeds in wet (saturated) puddled soil. Dry seeding traditionally is practiced in rainfed lowland, upland and flood-prone areas while wet seeding is a common practice in irrigated areas and it is further subdivided into aerobic wet seeding, anaerobic wet seeding and water seeding. Seed may be broadcast or sown in rows on dry/moist/puddled soil, whereas only broadcasting is used for seeding on water. Although direct seeding involves both dry and wet seeding but it is wise to separate the direct seeding in two distinct categories as there exist huge differences between the two establishment methods. Therefore, rice establishment methods should be categorized into three principal methods such as transplanting, dry direct seeding and wet direct seeding.

Transplanting

Transplanting of young seedlings in puddled field with continuous flooding is the most popular method of rice cultivation. Transplanting involves raising, uprooting and transplanting of seedlings. This is a resource and cost intensive method since, preparation of seedbed, raising and transplanting of seedlings are labour and time intensive operations. This method is very effective in weed suppression and makes weed management easier. This method also ensures uniform plant stand establishment and reduces main field duration of crop thereby creates opportunity for crop intensification. This method requires no adequate land leveling and can be practiced at variable water levels. Despite all these advantages, this method suffers from different drawbacks. This method requires huge irrigation water (3000-5000 litres of water for producing one kilogram of rough rice) and labourers (consume labourers worth nearly one third of the total cost of rice production). Alternate wetting and drying (AWD) irrigation can be practiced in puddle transplanted system which helps reduce irrigation requirement in rice by 15-30% [5].

During peak period of transplanting, labourers are also become very rare. Puddling also affects soil health because of the dispersion of soil particles and soil becoming compact, which makes tillage operations difficult and increases requirement of energy in succeeding crops, such as wheat. Low wheat yield in the rice – wheat system is mainly due to deterioration of soil structure and the development of subsurface hardpans. The soil health can be maintained by avoiding puddling and adopting unpuddle transplanting method.

Unpuddle transplanting is a new approach of rice establishment in transplanting method which helps improving soil health. In this method strip tillage is done with a VMP (versatile multi-crop planter) to make the furrow in which rice seedling are transplanted in line. Standing weed is destroyed by a knockout application of Glyphosate (Round-up) 3-5 days before ploughing. The field is then flooded with water for 24-36 hours and seedling is transplanted without any puddling. The flooding allows the soil to become soft for easy transplanting in between the rows of the previous crop. The crop residue is retained on the soil surface that reduces the soil erosion and increases the biological activity of soil. This system contributes to saving of irrigation water to some extent. Although weed could be the major constraint to the adoption of the technology at its initial stage, the use of proper management will alleviate the problem easily [9].

System of Rice Intensification (SRI) is an intensive crop management package for puddled transplanting system which has the following aspects: i) transplanting of eight to 14-day old single seedlings within 30 minutes of uprooting, ii) spacing at least 25 cm × 25 cm and may be as high as 50 cm × 50 cm, iii) no standing water is allowed up to reproductive stage, field is kept moist or saturated, iv) Organic fertilizer preferred, v) frequent weeding for 4 times or more. The age of seedling greatly influences on tiller production, grain formation and other yield contributing characters. It is important to maintain moist but aerated soil during the vegetative phase. After panicle initiation, 1-2 cm of floodwater is maintained. Addition of compost at 5 t ha-1 improves soil health and results in maximum tiller production and ultimately leads to higher yield. The water management strategy for SRI technique is that field should not be flooded during vegetative phase and regular water is required to keep soil moist but not saturated. Severe weed infestation is evident in SRI as the soil is kept moist but not submerged. Fifty per cent more labour is required for early and frequent weeding. The land leveling is the pre-requisite for SRI system which farmers cannot afford in most of the cases and thus, it has not been adopted in a wider scale in Bangladesh [5]. Raised bed system is also practiced in many countries where rice seedlings are transplanted in furrows in two lines (20 cm apart) in between two raised beds (45 cm apart) or in two lines (20 cm apart) on the top of the beds. The raised bed system reduces irrigation requirement by 30-40% while weed infestation is a serious problem to this system.

Dry direct seeding method

Dry direct-seeded rice (DDSR) is a traditional practice developed by farmers to suit their agro-ecological conditions [10]. This is common in most of the rain-fed upland or dry-land ecosystem, and some areas of the rain-fed lowland and deep-water ecosystems. Seed is sown on dry (or moist) soil by broadcasting/drilling/dibbling. The seeds can be sown before the start of the wet season, permitting the use of early rains for crop establishment or up to 30 days after the onset of rains for upland rice. After emergence, rice plants grow in upland (aerobic) conditions until harvest (upland rice) or with accumulated standing water in the field for a significant period of the crop life cycle in rain-fed lowlands. Dry sown rice converted to flooded paddy 30-40 days after sowing is sometimes called semidry rice. Rice roots are short and fibrous with dense root hair in dry soil and long and fibrous with long root hairs in wet soil. When dry sown rice fields go flooded, rice plants undergo a dry-to-wet transition and leaves turn yellow temporarily, probably because of physiological shock and/ or induced N deficiency. Stem rot is also serious in dry-seeded rice in soils deficient in K [6].

Very recently dry direct seeding system has been developed where primed or sprouted seeds are sown in dry cultivated land with high input responsive low land rice varieties to get yield similar to that of puddle transplanted system. Sowing can be done manually or by machine (VMP) where substantial labour saving is achieved. In addition to labour saving irrigation requirement can be reduced by 50-60%. A series of field trial at different water short regions like Barind Tract of Bangladesh showed very promising result with dry direct seeded rice [4]. The High Barind Tract in the northwest part of Bangladesh is drought-prone, with the majority of the 1200 – 1400 mean rainfall falling in June to October. Due to lack of irrigation, majority area of this region grows a single crop of transplanted rice in this monsoon season. Switching over from transplanting to direct seeding allow more reliable establishment of rabi crops on residual moisture immediately after the rice harvest. Consequence of delayed start of monsoon results in late transplanting of amon rice as a minimum of 600 mm of cumulative rainfall is needed to complete plowing, puddling and transplanting. Direct seeding can be completed after plowing with only 150 mm of cumulative rainfall [12]. Earlier planted dry direct seeded rice matures 1-2 weeks before transplanted rice, thus reducing risk of terminal drought and allowing earlier planting of a following non-rice crop [13]. DDSR reduces labor and draft power requirements by 16% and 30%, respectively compared with puddled transplanted rice [11].

Wet direct seeding

Wet seeding saves labor cost and drudgery is reduced. The success of wet seeded rice depends on good land preparation and leveling and also on effective weed control [6]. Generally, fields are not properly leveled, leading to poor crop performance because part of the area suffers from water stress and part from excess water. Poor land preparation can result in poor stand establishment in wet-seeded rice. Ponding of water in the field could kill the developing rice seedlings or retard their growth. Seedling establishment may be impeded due to lack of oxygen and accumulation of toxic concentrations of applied herbicides. Wet-direct seeded rice field is usually subjected to heavy weed pressure and causes yield losse due to competition. A poorly prepared field does not provide a suitable medium for optimum plant growth. If the field is not leveled, the seedlings cannot establish quickly in the low spots and weeds will grow abundantly in the high spots. These conditions result in production of stunted plants with low tiller production. The farmers need to dig shallow drainage ditches in their field to drain excess water that remains after puddling or when rain falls soon after seeding to ensure good stand development. Good field drainage and good water control are essential for wet-seeded rice establishment and also for reduction of herbicide phytotoxicity.

Wet direct seeding is done by two methods: (1) surface or aerobic wet seeding and (2) sub-surface or anaerobic wet seeding. Surface or aerobic wet seeding uses pre-germinated seeds (24-h soaking and 24-h incubation) are sown on well-puddled soil surface 1-2 days after puddling. Four different sowing techniques are used in surface seeding: manual broadcasting, broadcasting by motorized duster, spot seeding or dibbling and drum seeding in rows. Pre-germinated seeds (24-h soaking and 24-h incubation) are manually broadcast on the soil surface, 1-2 d after puddling. When seeding is done on soil with standing water, the field is drained immediately after seeding. Sowing of 30-50 kg seed ha^{-1} is optimum but uses 150-200 kg seeds ha^{-1} to guard against poor germination and damage of seed by biotic and abiotic factors. The just-sprouted seeds are sown by motorized seeder. A lower seed rate is applied for high-tillering varieties and higher seed rate for medium tillering types. Seeding is also done by a drum seeded which reduces seed rate (50-75 kg ha^{-1} versus 100-200 kg ha^{-1} for broadcasting), better plant arrangement, which facilitates good aeration and light penetration into the canopy, leading to better plant health and less diseases, optimum plant stand (density), easier fertilizer placement between rows, and effective mechanical weeding by rotary or conical weeder [6].

Seeds are sown below the puddled soil surface to reduce (i) damage by birds and other organisms, (ii) disturbance by heavy rains or flood, (iii) desiccation by water stress or dry weather, and (iv) lodging caused by poor anchorage. Seeds can be broadcast or row seeded using the anaerobic seeder. Four different sowing techniques are used in anaerobic wet seeding: (i) Anaerobic broadcasting, (ii) Anaerobic drum seeding, (iii) Traditional water seeding, and (iv) Modern water seeding [6].

Wet seeding, specifically aerobic wet seeding, is increasingly practiced in irrigated and favourable rainfed lowlands. Most developed countries establish rice by water seeding because of high wages and scarcity of labour. Farmers in developing countries increasingly adopt wet seeding because of migration of farm labour to nonfarm jobs and the consequent labour shortage and high wages for manual transplanting. Farmers resort to wet direct seeding when transplanting is delayed.

Socioeconomic and agro-ecological impact

A low wage rate and assured supply of adequate water are favorable for transplanting. Incentives for dry direct seeding increases when water availability is low and wage rates are high. The response of rising labor costs caused a switch to mechanical transplanting (rice transplanter) in Japan, Korea and Taiwan while a shift to wet direct seeding in Malaysia and Thailand. The major constraints to the adoption of wet direct-seeded crops are high weed competition and lack of land leveling facilities. The yield variability of wet direct seeded rice in the farmer's field is very high mainly because of poor understanding on weed control and water management. The traditional dry direct seeding is mainly done in the upland conditions but it has recently been transformed and made adaptable for the lowland high input responsive system. Dry direct seeding is a technically feasible and economically viable system of rice production which reduces irrigation need by 50-70% and gives similar yield to that of transplanted system. Dry direct seeding saves costs for seedling raising, transplanting and also costs for tillage [8]. Research in Bangladesh reveals that the adoption of DSR in amon season in Bangladesh helps production of good wheat or other crop in the cropping pattern of the locality. On the other hand, adoption of this system in boro (winter) or aus (summer) season could allow cultivation of a rabi crops in between two rice in a piece of land successfully and create scope for crop intensification towards improvement of farm income and livelihood. In addition to social and economic benefits, reduction of greenhouse gas emission and arsenic accumulation in rice contributes a lot to the human health and environment [4].

Conclusion

Puddle transplanting is the principal system of rice cultivation. Water scarcity and labour shortage enacted a serious threat to the sustainability of rice culture under in this method. Many temperate countries switched to machine transplanting while tropical countries adopted wet direct seeding in response to these factors. Both the system reduced the manual labour requirement in rice culture but contributed little to the water saving. However, recently developed dry direct seeded technology could reduce both labour and water requirement in rice culture. In addition this system could contribute a lot to the reduction of greenhouse gas emission and arsenic accumulation. Therefore, the appropriate rice establishment method should be adopted for sustaining productivity with less water and labour and also to protect our health and environment.

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