

# A Review on Effect of Establishment Methods on Growth, Yield and Yield Attributes of Rice and on Succeeding Crops after Rice

Arjun Bastola

Lecturer, Bright Mid-Western Agriculture and Forestry Campus, Agriculture and Forestry University, NEPAL

Corresponding Author: arjunbastola143@gmail.com

## ABSTRACT

Rice is cultivated mainly by the transplanting in the puddled soil in the Asian region and in the Nepal. Puddling breakdown the soil structure and it requires more labor for transplanting, more water for field preparation and it emits more methane gas, which contributes global warming. To overcome these drawbacks, direct seeding of rice (DSR) is being popular among the farmers for the cultivation of rice. DSR had more water and labor use efficiencies and the maturity of the rice is also earlier as compared to transplanting methods. There is also increase in the intensification of crops, reduction in the global warming and the yield of succeeding crops after rice is also increased due to less soil destruction in the dry direct seeding of rice. The growth, yield and yield attributes of rice are also similar and better in DSR. So, DSR could be recommended for the cultivation of rice to increase labor and water use efficiencies, reduced global warming, increase the yield of succeeding crops and finally increase the profitability of the farmers.

**Keywords-** Climate change, Direct seeded rice, Rice yield, Tillage, Water use efficiency, Yield attributes of rice

## I. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's most important food crops and has been grown for more than 6000 years in South Asia. It is the world's third crop on the basis of volume of production (503.2 million tons) after wheat and maize (FAOSTAT, 2017). It is estimated that more than 90% rice is grown and consumed within Asia region (Fairhurst and Dobermann, 2002). Rice in Nepal accounts for 1.49 million ha with the total production of 5.61 million tons and average productivity of 3.76 t ha<sup>-1</sup> (MOALD, 2020).

Puddling is the most usual and traditional practice for the establishment of rice in South-East Asian region and in the Nepal also many farmers are practicing the puddling of soil for the cultivation of rice. Puddling is commonly operated in wetland, which involves the breakdown of the structure of soil and dispersion of the soil by plowing and harrowing in the state of saturation. Ghildyl (1978) defined puddling as stirring of water and soil, rendering it impervious to water.

Direct seeded rice (DSR) refers to the cultivation of rice by sowing the seeds in no till or conventional till

field rather than growing rice seedling in the nursery and transplanting them to the main field after 25-30 days. Direct seeding of rice is gaining popularity in Asian countries (Kumar and Ladha, 2011; Balasubramanian and Hill, 2002). The major drivers of DSR from transplanted rice are water and labor scarcity.

## II. ESTABLISHMENT METHODS

### *Transplanting of rice in puddled field*

Puddling involves saturating and flooding the soil; plowing the supersaturated soil and plowing or harrowing at progressively lowers water content. Puddling involves two phases: increasing the soil moisture and mechanical manipulation on soil. Increase in soil moisture content leads to softening, swelling and weakening of soil aggregates. At field capacity cohesion between aggregates increases, reaches a peak and decreases. When such a soil is plowed or harrowed, the aggregates are destroyed as a consequence.

The benefits of the puddling limits only to the rice. The other crops involved in cropping system are badly affected, mainly the wheat. Puddling is not only labor and capital intensive and more time requiring but also caused complete destruction of soil structure with increased bulk density ultimately reducing root penetration of non-rice crop and growth and development are badly affected (Bajpai and Tripathi, 2000; Oussible et al., 1992). Due to the puddling growth of root is reduced which cause reduction in the uptake of water and water stress is experienced by the plant. This cause compaction of soil and more number of tillage is required and for succeeding crop more energy is required which increase the cost of cultivation. The hydraulic conductivity and infiltration loss is also low reducing groundwater availability (Bajpai and Tripathi, 2000).

It facilitates transplanting of seedling and weeds control and restrain the water and nutrient loss (Singh et al., 2000). Due to formation of the reduced layer, the water cannot be lost through percolation (De Datta, 1981) which in addition reduces the loss of nutrients through leaching. Weed management is much easier due to lower germination of weeds in puddled field and also due to the number of harrowing before planting which costs lower for production (Pandey and Velasco, 2002). According to De Datta (1981), puddling has many benefits on rice: reduced draft requirements for tillage, better control of

weeds, transplanting will be easy, more water conservation, and availability of nutrient will be increased.

#### **Direct seeding of rice**

DSR is commonly classified as 1) Direct seeding in dry soil, 2) Direct seeding in wet soil and 3) Water seeding. Among these techniques, there is either difference in tillage operation or crop establishment or both. The area facing labor shortage is commonly practicing wet direct seeding. Dry direct seeding is commonly practiced in the area prone to water shortage like rainfed lowland and upland. In dry direct seeding dry seeds are broadcasted in the field. The sprouted seeds are broadcasted in the puddled field in wet direct seeding. Water seeding is done mostly in weed prone areas. In this technique broadcasting of pre-germinated seeds are done in the puddled or unpuddled field with standing water.

### **III. ADVANTAGES OF DSR**

#### **High water use efficiencies:**

Rice establishment through transplanting uses highest water. Rice has similar water productivity as wheat (Zwart and Bastiaanssen, 2004). Whatever water is applied is not utilized by the plant to increase the productivity or not used in evapotranspiration in transplanting. Seasonal water input for typical puddled transplanted soil ranges from 660 to 5280 mm depending on climatic condition, hydrological condition, growing condition and type of soil (Tuong and Bouman, 2003). Among the limiting factor prime factor identified is water resource which has been mainly required throughout the life cycle of plant. Requirement of water is high in puddled transplanted rice (TPR) which rises by 30% over DSR (Devkota et al., 2015). Pandey and Velasco (1999) stated that huge water and labor requirement for TPR have reduced profit margins of conventional rice farming. This was the major cause of shifting traditional TPR to DSR. Based on type of DSR water conservation by DSR vary from 12 to 35% when shift from TPR. Balasubramanian and Hill (2002) have reported that mean water productivity (kg grain m<sup>-3</sup>) of irrigation was 1.01 for wet seeded rice, 1.52 for dry direct seeded, and 0.69 for transplanted with grain productivity of 4.3 -4.6 tha<sup>-1</sup>.

As the agriculture share of water is reducing in the alarming rate there is need to change water using behavior through intervention of the existing technology for higher water use efficiencies. The per capita water availability of Nepal was 21,623 m<sup>3</sup> in 1950 which would be reduced to 4820 m<sup>3</sup> by 2020 and 3467 m<sup>3</sup> by 2050 (Gardner-Outlaw and Engelman, 1997). As the rainfall is uneven the groundwater withdrawal has been at its high peak. The drastic reduction in the availability of water and inefficient use of water resources has created the urgency of alternative of rice production technology. DSR is found to be best alternative for efficient water use. Both Wet-DSR and Dry-DSR have high water use efficiency over conventional-TPR (Weerakoon et al.,

2011). DSR has higher potential in Asian countries as having advantage of saving of labor and water resources as well.

#### **High labor use efficiency:**

The agricultural labor availability is reducing as the active population is shifting to non-agricultural economic intervention. This not only reduces the labor availability but also enhances the wage rate. Puddled TPR requires higher number of energy and labor than DSR (Pandey and Velasco, 2002). Labor saving ranges from 0 to 46% in DSR (Kumar and Ladha, 2011). DSR in Bihar requires 75 persons ha<sup>-1</sup> as compared to labor requirement in transplanted rice which is 152 persons ha<sup>-1</sup> (Singh and Malhi, 2006). Thus peak labor scarcity at the time of field preparation and transplanting of rice seedlings and at the same time high labor wage is forcing the rice farmers to move from puddled transplanting to direct seeding.

#### **Increased crop intensification and early maturity:**

DSR favors crop intensification. DSR facilitating double cropping of rice is reported in Iloilo, Philippines (Pandey and Velasco, 2002). Further the short duration varieties and new herbicides have also facilitated double cropping and even triple cropping. DSR provides early maturity to crop and is less labor intensive (Bhusan et al., 2007; Jehangir et al., 2005) and has less methane emissions (Pandey and Velasco, 1999) than TPR. Encountering with terminal drought is reduced as a result of early maturity due to earlier planting and lack of transplanting injury (Tuong et al., 2000).

#### **Allows higher productivity of the subsequent crops:**

Puddled field preparation mostly favors to rice but the subsequent crops in the system are hampered adversely. In most of the DSR operated area, the production of Wheat was found to be greater than under puddled TPR in India (Gangwar et al., 2009; Tomar et al., 2005). The yield other subsequent crops of rice like mustard, soyabean, chickpea and mungbean were also badly affected due to poor establishment after puddled TPR. Puddled TPR is mostly responsible to change the soil structure due to complete destruction of the soil aggregates and macro pores which cause hard pan development at superficial level. Due to this root development is highly affected and yields are mostly affected.

#### **Reduced global warming potential:**

Nitrous oxide (N<sub>2</sub>O), methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) has paramount role for global warming. Rice play an important role in global warming potential (GWP) through production of methane rather than other two. Carbon is reduced to methane in the soil having less than -150 mv of redox potential in anaerobic soil condition mostly favored under puddled and submerged field and nitrogen is reduced to N<sub>2</sub>O in aerobic condition of soil with the redox potential of above 250 mv. It has been observed that one methods of reducing one of the greenhouse gases induces the production of the other responsible gases. But DSR is responsible for lesser GWP than CT-TPR (Kumar and Ladha, 2011) due to lesser

production of CH<sub>4</sub> (Pathak et al., 2009; Singh et al., 2009).

#### IV. GROWTH, YIELD ATTRIBUTES AND YIELD

##### *Effect of establishment methods on crop growth*

Crop growth is the irreversible increase in total dry matter in plant. Crop growth is observed as increase in plant height, leaf number, differentiation of plant parts, stem diameter etc. Derpsch (2007) pointed out that that growth, development and grain yield from crop is not determined by the tillage conditions only because the growth development and yield is determined by many factors like cropping system practices, climatic and soil factors, type of equipment used for land preparation and seed sowing, use of pesticides for insect and disease control, etc. Many research conducted in the conservation and conventional tillage had inconsistent result in the crop production apparently based on crop rotation, soil type, and local climatic conditions (Angas et al., 2006; Martin-Rueda et al., 2007). Many researchers have observed significantly taller plants in DSR than conventional transplanted rice (Singh et al., 2004; Ali et al., 2012; Laary et al., 2012). While Awan et al. (2007) observed good plant growth in transplanted rice due to anaerobic condition which increased nutrient availability and efficient nutrient uptake. Generally, transplanted rice produced lower tillers, leaf area index and dry matter as compared to DSR (Ginigaddara and Ranamukhaarachchi, 2009; Dingkuhn et al., 1990; Schnier et al., 1990). The plant population per square meter was higher in DSR due to continuous sowing within the seeding row (Patil et al., 2007).

##### *Effect of establishment methods on yield attributes of rice*

Economic expression of the crop plants with majorly attributes such as panicle number per square meter, total count of grain per panicle and thousand grain weight is termed as yield. Akhagari and Kaviani (2011) has reported that thousand grain weight, tillers count, effective tillers count and panicle length were not significantly influenced by establishment method resulting similar yield in TPR (4.96 t ha<sup>-1</sup>) and DSR (4.62 t ha<sup>-1</sup>). Higher sterility percentage was observed in DSR (12.62%) than TPR (7.92%) by 37.2% but count of grains per panicle was recorded more for TPR (121.72) than DSR (102.82).

Naresh et al. (2013) also observed that the thousand grain weight was not affected by establishment technique but the effective tillers were significantly higher in DSR (372.25 m<sup>-2</sup>) as compared to puddled TPR (272.89 m<sup>-2</sup>). Sterility was also higher in DSR (Naresh et al., 2013; Akhagari and Kaviani, 2011; Sah et al., 2007) which ranged from 22 to 16%.

Naresh et al. (2013) observed total tillers and effective tiller count, average grains count per panicle and sterility percentage was significantly dissimilar between

TPR and DSR. DSR had more effective tillers count by 26.7% and total number of tillers per square meter by 27.8% compared to TPR. Similarly Sah et al. (2007) also observed that effective tillers per square meter in both years i.e. 2003/4 was significantly higher for DSR (248 m<sup>-2</sup>) as compared to TPR (174 m<sup>-2</sup>) and in the year 2004/5 DSR (313 m<sup>-2</sup>) as compared to TPR (247 m<sup>-2</sup>) which ranges from 26.72% to 42.53% higher. Naresh et al. (2013) observed grain per panicle was higher in TPR by 20.5% as compared to DSR. Contradictory result to Naresh et al. (2013) and Akhagari and Kaviani, (2011), Sah et al. (2007) observed greater thousand grain weight in DSR than TPR in both years of experiment. But count of grains per panicle was seen to have lower in DSR (102 in 2003; 95 in 2004) than TPR (155 in 2003; 113 in 2004).

##### *Effect of establishment methods on yield of rice*

Variable effects were observed in crop yield due to zero tillage. Holland (2004) and Govaerts et al. (2007) observed increased yield by enhancing the fertility of soil through water and soil conservation and organic carbon sequestration whereas in some cases zero tillage was believed to have negative effect on the yield of crops by changing soil biological and physiochemical conditions, such as lowering the temperatures of soil in high latitude areas and seasons with lowering the temperature and higher incidence of diseases and insect attack (Boomsma et al., 2010; Deubel et al., 2011). Kumar and Ladha (2011) reported that in Nepal, Phillipines and Thailand yield of Dry DSR was non-significant to Pu-TPR whereas in India yields were significantly lower in Dry DSR compared to Pu-TPR by 9.2%. It was due to the difference in the soil ability to provide nutrient, water availability and nematodes.

Grain yield in DSR is found to be low as compared to TPR although having the advantage of both cost and labor saving (Naklang et al., 1996; Farooq et al., 2006; Bastola et al., 2020). Several researchers however reported minimum and no-till DSR systems can have similar grain yield to TPR (Mabbayad and Buencosa, 1967; Sharma et al., 1988; Gupta et al., 2002; Bhattacharaya et al., 2006; Qureshi et al., 2006). Some other reports had at par or even more grain yields in DSR if the crop is grown with better crop management technique (Ho and Romli, 1998; Ko and Kang, 2000; Sharma and Ghosh, 2000; Oyediran and Heinrichs, 2001; Bastola et al., 2020). Drought stress throughout reproductive and vegetative stages of DSR resulted in yield losses by 20 and 31%, respectively while under TPR it was 27 and 43% (Maqsood, 1998). Awan et al., (2007) and Bhushan et al., (2007) also reported DSR was more stress tolerant than TPR and yield is more under drought stress. In Parsa district of Nepal, DSR showed 22.55 to 25.12% higher yield as compared to TPR in three years of experiment (Sah et al., 2007). At Jiaying agriculture Research institute of china significantly more grain yield was found in transplanted conditions (9.11 t

ha<sup>-1</sup>) as than to direct seeding (8.86 t ha<sup>-1</sup>) during 2006 to 2009 (Chen et al., 2012).

#### **Effect of establishment methods on yield of succeeding crops**

Naresh et al. (2013) recorded that in puddled-TPR of rice followed by zero till (ZT)-drill seeding of wheat the grain yield of wheat was obtained 5.05, 5.1 and 5.07 t ha<sup>-1</sup> in the year 2008-09, 2009-10 and 2010-11 respectively and similarly in the puddled-TPR of rice followed by conventional tillage and broadcasting of wheat the grain yield of wheat was obtained 4.85, 4.75 and 4.95 t ha<sup>-1</sup> in the year 2008-09, 2009-10 and 2010-11 respectively. But in the ZT-drill seeding of rice followed by ZT-drill seeding of wheat the grain yield of wheat was obtained 5.25, 5.4 and 5.45 t ha<sup>-1</sup> in the year 2008-09, 2009-10 and 2010-11 respectively and in the reduced tillage-drill seeding of rice followed by ZT-drill seeding of wheat the grain yield of wheat was obtained 5.4, 5.45 and 5.35 t ha<sup>-1</sup> in the year 2008-09, 2009-10 and 2010-11 respectively. But Timsina et al. (2010) reported the significantly higher grain yield in ZT-DSR (6.68 t ha<sup>-1</sup>) than in CT-DSR (5.79 t ha<sup>-1</sup>) and TPR (5.57 t ha<sup>-1</sup>). Sharma et al. (1988) reported that rice yield was 4.17 t ha<sup>-1</sup> in wet DSR, 3.72 t ha<sup>-1</sup> in puddled TPR and lowest (3.62 t ha<sup>-1</sup>) in dry-DSR. The highest yield of succeeding wheat (5.38 t ha<sup>-1</sup>) was obtained under TPR plot and the lowest (5.13 t ha<sup>-1</sup>) under wet-DSR. The total system productivity was 9.30 t ha<sup>-1</sup> in wet-DSR, 9.10 t ha<sup>-1</sup> in TPR and 8.99 t ha<sup>-1</sup> in dry-DSR. Similarly higher yield was recorded in TPR (5.69 t ha<sup>-1</sup>) than ZT-DSR (4.25 t ha<sup>-1</sup>) and CT – DSR (4.15 t ha<sup>-1</sup>) while slightly higher yield of succeeding crop wheat (1.94%) was obtained under ZT-DSR followed by ZT-wheat than TPR followed by ZT-wheat (Naresh et al., 2013). Grain yield of mechanical TPR was higher under no till (7.30 t ha<sup>-1</sup>) than under conventional puddled conditions (6.60 t ha<sup>-1</sup>). Further the succeeding yield of wheat was comparable in both systems (Dev et al., 2013). Grain yield of rice under either residue retention (3.20 t ha<sup>-1</sup>) or removal (3.24 t ha<sup>-1</sup>) on ZT-DSR were significantly lower than the conventional TPR (4.18 t ha<sup>-1</sup>) while similar yield of wheat was recorded under puddled TPR and ZT-DSR with residue plot and significantly lower under ZT-DSR without residue (Jat et al., 2014).

## **V. CONCLUSION**

Transplanting of rice in the puddled soil is the most common method for the cultivation of rice in the south-east Asian region but due to many drawbacks of this method direct seeding of rice is getting popular among the farmers because of less labor and water requirement and reduced global warming. Similarly the growth, yield and yield attributes of rice in direct seeding is similar and even better than transplanted rice so direct seeding method could be recommended for the cultivation of rice to get better profit.

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