Studies on the Growth and Yield of Rice under Various Establishment Methods and Water Management Strategies in Tank Irrigated Command Areas

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ABSTRACT

To study the effect of various establishment and water management practices on rice, a field experiment was conducted at Periyar Vaigai Command (PVC) during summer 2019. The experiments comprised of four establishment methods in main plots viz., conventional transplanting (M1), machine transplanting under puddled soil (M2), machine transplanting under unpuddled soil (M3) and sowing with seed drill (M4); four irrigation management practices in sub plots viz., farmers’ irrigation practice (I1), irrigation after formation of hairline crack (I2), irrigation when water level reaches 5 cm below soil surface (I3) and irrigation when water level reaches 10 cm below soil surface (I4). The results of the study revealed that machine transplanting under unpuddled soil recorded 6.5 per cent higher yield compared to conventional manual planting. Among the irrigation management strategies, irrigation after formation of hairline crack recorded 8.1 per cent higher yield compared to farmer’s irrigation practice, which was comparable with irrigation when water level reaches 5 cm below soil surface. Significant interaction was observed with establishment methods and irrigation management practices. This study concluded that machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface will be the suitable management technology to be adopted by the rice growing farmers in tank irrigated command areas.

Keywords: Establishment methods; Irrigation management; Growth; Yield and Water productivity.

INTRODUCTION

Rice is the most important staple food, eaten by more than a half of the world’s population. In Asia, the term Food security can be well related to Rice security as 90% of rice is consumed in this region. Worldwide, water for agriculture is getting increasingly scarce and it is estimated that by 2025, 15–20 million ha of irrigated rice fields may suffer from water scarcity (CGIAR, 2016). In India alone drought will cause as much as 40% yield loss, amounting to 6,500 crores annually. In southern parts of India, mostly rice is grown in command areas under tank irrigation system. Due to delayed onset, early withdrawal and decreased quantity of monsoon rains, releasing of water from dams get delayed and the availability of water in tanks for irrigation also get reduced. The rice crop grown in these command areas suffer terminal stress and the farmers could not achieve higher yield.

Farmers are mostly following manual transplanting under puddled soil condition and puddling alone requires 200 mm of water, which is 16.12% of total water requirement. Puddling causes subsurface hardpan at 15-25 cm, it affected the root growth of the rice, which in turn reduced the nutrient availability (Boparai et al., 1992) and it required more energy for field preparations (Kumar and Ladha, 2011). To overcome these problems, machine transplanting in unpuddled soil condition can be an alternate strategy, which alsoensures optimum plant population. Direct sowing under puddled soil is also an effective technology to reduce labour requirement rather than transplanting, because transplanting required about 300 to 350 man hr ha-1 (Goel et al., 2008) but the TNAU drum seeder required only 16 man hr ha-1 to sow the seeds for a hectare of land (Chandrasekhrarao et al., 2013). Moreover, labour scarcity in agricultural
Continuous flooding is the common practice followed by the farmers and it consumes large quantity of water. Adopting appropriate irrigation management strategies will save huge quantity of water and helps to bring more area under cultivation. It also avoid complete crop failures under water deficit situations. Irrigation after the disappearance of ponded water will improve soil aeration and enhance the water use efficiency. Safe alternate wetting and drying can be recommended as a water saving technology that demands irrigation when water depth falls to a threshold depth of below the soil surface by using the field water tube. Several studies revealed that safe AWD significantly reduced the water input without penalty in rice grain yield (Samoy et al., 2008). It is highly essential to evolve the most suited irrigation management strategy under various establishment methods of rice cultivation that could be recommended to the rice growing farmers in command areas. Hence, a field experiment was conducted to evaluate the growth and yield of rice under various establishment methods and irrigation management strategies to sustain rice production.

MATERIAL AND METHODS

The field experiment was conducted during summer 2019 at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India. The experimental field comes under Periyar Vaigai Command area and is located at 9°54’ N latitude and 78°54’ E longitude at an altitude of 147 m above MSL. Soil texture was sandy clay loam. pH of the soil was 7.2, organic matter of the soil was 0.81%, soil available N was 242.6 kg ha⁻¹, available P was 16.9 kg ha⁻¹ and available K was 432.7 kg ha⁻¹. The experiment was laid out in strip plot design with 16 treatment combinations and three replications. The treatments comprised of four different methods of establishment viz., conventional transplanting (M₁), machine transplanting under puddled soil (M₂), machine transplanting under unpuddled soil (M₃) and sowing with seed drill (M₄), respectively in main plots and four irrigation management methods in sub plots viz., farmers’ irrigation practice (continuous submergence of 5 cm throughout the crop period) (I₁), irrigation after formation of hairline crack (I₂), irrigation when water level reaches 5 cm below soil surface (each irrigation was given to the depth of 2.5 cm) (I₃), irrigation when water level reaches 10 cm below soil surface (each irrigation was given to the depth of 2.5 cm) (I₄). The medium duration fine grain rice variety TKM 13 was used for experimentation. All the nutrient and weed management practices were followed as per TNAU recommendation. All the biometric observations like plant height (cm), tillers m⁻², dry matter production (DMP) (kg ha⁻¹), root length (cm), root dry weight (g plant⁻¹) and root volume (cc plant⁻¹) were observed during physiological maturity and yield attributes viz, number of productive tillers m⁻², number of grains per panicle, panicle length, panicle weight and yield viz, grain yield, straw yield and harvesting index were recorded during harvest of the crop. These data were analysed statistically by following Gomez and Gomez (1984) method. Wherever the treatment differences were found significant (F test), critical differences were worked out at five per cent probability level and the values were furnished. Treatment differences that were not significant denoted as “NS”.

RESULTS AND DISCUSSION

Plant height

Significantly higher plant height was observed with conventional method of transplanting (M₁) and recorded plant height of 108.0 cm compared to conventional manual transplanting (M₁). Hugar et al., (2009) also observed that conventional method of transplanting produced taller plants. Among the irrigation management practices, taller plants were observed with farmers’ method of irrigation (I₁) (109.6 cm) and it was on par with irrigation after formation of hairline crack (I₂). Continuous flooding increased the meristematic cell activity and cell elongation that resulted in increased stem growth rate, ultimately promoted the plant height of rice (Chowdhury et al., 2014). The plant height was significantly decreased with increasing moisture stress (Sariam and Anuar, 2010).

Total number of tillers

Among the establishment methods, machine transplanting under unpuddled soil (M₃) produced distinctly more number of tillers m⁻² (Table 1). However, it was on par with machine transplanting under puddled soil (M₂) (Table 1). Mechanical transplanter could produce optimum depth of planting under unpuddled soil condition and maintained optimum plant population (Kamboj et al., 2013 and Islam et al., 2014), Hossain et al., 2017 stated that buried hill, floating hill or missing hill were not observed with machine transplanting under unpuddled situation, more over the more number of tillers m⁻² under machine transplanting might be due to planting of more number of seedlings per hill, which resulted in increased number of tillers m⁻² and efficient utilization of growth resources (Haque et al., 2016). Lesser number of tillers m⁻² (298) was observed in sowing with seed drill, it might be due to poor establishment and population maintenance (Table 1).
Table 1. Effect of establishment methods and irrigation management practices on plant growth parameters of rice

| Treatment | Plant height (cm) | Tillers m⁻² | Drymatter production (kg ha⁻¹) | Root length (cm) | Root dry weight (g) | Root volume (cc hill⁻¹) |
|-----------|------------------|-------------|-----------------------------|------------------|---------------------|------------------------|
| Main plot |                  |             |                             |                  |                     |                        |
| M₁        | 108.0            | 362         | 13174                       | 27.1             | 9.49                | 53.5                   |
| M₂        | 101.5            | 410         | 13370                       | 28.5             | 10.05               | 54.1                   |
| M₃        | 102.7            | 419         | 13946                       | 31.7             | 10.61               | 59.3                   |
| M₄        | 94.9             | 298         | 12335                       | 25.8             | 8.69                | 51.3                   |
| SEd       | 2.5              | 8           | 312                         | 0.8              | 0.19                | 1.2                    |
| CD (0.05) | 6.1              | 20          | 765                         | 1.8              | 0.47                | 3.0                    |
| Sub plot  |                  |             |                             |                  |                     |                        |
| I₁        | 109.6            | 366         | 13497                       | 24.6             | 9.94                | 54.7                   |
| I₂        | 105.6            | 422         | 14233                       | 26.5             | 10.21               | 58.8                   |
| I₃        | 102.0            | 411         | 13961                       | 29.8             | 10.09               | 55.0                   |
| I₄        | 90.1             | 290         | 11134                       | 32.3             | 8.62                | 49.7                   |
| SEd       | 1.9              | 8           | 249                         | 0.9              | 0.27                | 2.0                    |
| CD (0.05) | 4.6              | 19          | 610                         | 2.2              | 0.66                | 4.9                    |

Between the irrigation management practices, irrigation after formation of hairline crack (I₂) recorded higher number of tillers of 422m⁻², which was comparable with irrigation when water level reaches 5 cm below soil surface (Table 1). It might be due to better aeration, which enhanced the growth of root and nutrient absorption therefore resulted in more growth and tiller production. The same results were observed by Hameed et al. (2011) and Kunnathadi et al. (2015).

Table 2. Effect of establishment methods and irrigation management practices on yield parameters and yield of rice

| Treatment | Productive tillers m² | Filled grains panicle⁻¹ | Fertility percentage | Grain yield (kg ha⁻¹) | Straw yield (kg ha⁻¹) | Harvesting index |
|-----------|------------------------|-------------------------|---------------------|-----------------------|-----------------------|------------------|
| Main plot |                        |                         |                     |                       |                       |                  |
| M₁        | 290                    | 224                     | 91.7                | 5430                  | 6967                  | 0.438            |
| M₂        | 304                    | 229                     | 92.3                | 5573                  | 7067                  | 0.441            |
| M₃        | 342                    | 249                     | 93.0                | 5807                  | 7256                  | 0.445            |
| M₄        | 252                    | 205                     | 90.8                | 4967                  | 6403                  | 0.437            |
| SEd       | 7                      | 5                       | 1.4                 | 118                   | 142                   | 0.009            |
| CD (0.05) | 16                     | 12                      | NS                  | 289                   | 347                   | NS               |
| Sub plot  |                        |                         |                     |                       |                       |                  |
| I₁        | 309                    | 233                     | 94.2                | 5404                  | 6939                  | 0.438            |
| I₂        | 328                    | 245                     | 92.4                | 5878                  | 7424                  | 0.442            |
| I₃        | 314                    | 235                     | 91.5                | 5658                  | 7269                  | 0.438            |
| I₄        | 238                    | 194                     | 89.8                | 4837                  | 6060                  | 0.444            |
| SEd       | 7                      | 5                       | 2.2                 | 118                   | 164                   | 0.004            |
| CD (0.05) | 17                     | 11                      | NS                  | 290                   | 400                   | NS               |
| M x I     |                        |                         |                     |                       |                       |                  |
| SEd       | 10                     | 6                       | 4.0                 | 174                   | 205                   | 0.013            |
| CD (0.05) | 23                     | 15                      | NS                  | 393                   | 464                   | NS               |
| I x M     |                        |                         |                     |                       |                       |                  |
| SEd       | 10                     | 6                       | 4.3                 | 174                   | 221                   | 0.010            |
| CD (0.05) | 23                     | 14                      | NS                  | 394                   | 505                   | NS               |

Various establishment and irrigation management practices showed significant interaction with each other. Machine transplanting under unpuddled soil condition combined with irrigation after formation of hairline crack (M₁I₂) recorded higher tiller number, which was comparable with Machine transplanting
under unpuddled soil condition combined with irrigation when water level reaches 5 cm below soil surface (M_3).

**Drymatter production**

Machine transplanting under unpuddled soil (M_4) produced 5.5 percent higher drymatter production than conventional transplanting (Table 1). This might be due to proper crop establishment because machine transplanting under unpuddled situation that recorded no floating or buried hill and missing hill (Hossain et al., 2017), this in turn increased the number of tillers, number of leaves, leaf area index. Moreover, puddling created sub surface hardpan at 15-25 cm below soil surface (Kukal and Aggarwal, 2003) that hindered the root growth and ultimately affected the nutrient uptake. However, previously mentioned problem was avoided when transplanting was done under unpuddled soil and it promoted higher root growth and nutrient uptake by plant. In the presence of adequate nutrient availability and larger photosynthesizing surface, the drymatter accumulation preceded at a rapid rate leading to its greater accumulation. The results was in line with the findings of Haque et al.(2016).

**Table 3. Effect of establishment methods and irrigation management practices on total water used and water productivity in rice**

| Treatment | Consumptive Use (mm) | Water productivity(kg m⁻³) |
|-----------|-----------------------|---------------------------|
|           | M₁       | M₂       | M₃       | M₄       | Mean | M₁       | M₂       | M₃       | M₄       | Mean |
| I₁        | 1253     | 1253     | 1292     | 1311     | 1277  | 0.43     | 0.43     | 0.46     | 0.38     | 0.42  |
| I₂        | 1083     | 1083     | 1099     | 1051     | 1071  | 0.54     | 0.56     | 0.65     | 0.50     | 0.56  |
| I₃        | 839      | 839      | 764      | 844      | 822   | 0.68     | 0.68     | 0.77     | 0.63     | 0.69  |
| I₄        | 764      | 764      | 714      | 749      | 748   | 0.63     | 0.68     | 0.74     | 0.54     | 0.65  |
| Mean      | 985      | 985      | 927      | 1001     | 988   | 0.57     | 0.59     | 0.66     | 0.51     |       |

Within the irrigation management practices, higher drymatter production of 14233 kg ha⁻¹ was recorded with irrigation after formation of hairline crack (I₂). It was comparable with irrigation when water level reaches 5 cm below soil surface (I₃) during summer season (Table 1). The increase in DMP of rice with those treatments might be due to production of loose soil with increased aeration, which also facilitated more access to water and transport of nutrients such as nitrate (Gurovich and Oyarce, 2015). This might have helped better plant establishment with higher tiller production, improved leaf area and thick erect leaves.

Machine transplanting under unpuddled soil condition combined with irrigation after formation of hairline crack recorded higher drymatter production (15109 kg ha⁻¹), which was comparable with machine transplanting under unpuddled soil and irrigation when water level reaches 5 cm below soil surface. It was mainly due to improved growth parameters (Hossain et al., 2017).

**Root studies**

Different method of establishment and water management practices influenced the root length; root volume and root dry weight. Machine transplanting under unpuddled soil (M_4) and irrigation when water level drops 10 cm below soil surface (I₄) registered the longer root length of 31.7 and 32.3 cm, respectively (Table 1). Non-availability of surface moisture increased the root length to extract moisture from the deeper layer.

Unpuddled machine transplanting (M_4) improved the root volume and root dry weight (Table 1) was due to better root activity compared to conventional puddled transplanting. Because under puddled condition, soil structure was destroyed, subsurface impervious hardpan was developed and lower depth of puddled soil had high bulk density, which in turn affected root growth in puddled transplanting (Garg et al., 2000), whereas under unpuddled soil, structure was maintained that enhanced the root growth and nutrient availability. The similar results were observed by Huang et al., (2011).

Irrigation after formation of hairline crack (I₂) favoured the root growth in terms of root volume and dry weight. It was on par with irrigation when water level reaches 5 cm below soil surface (I₃) (Table 1). Because in both the treatments the soil was kept with optimum moisture and aerated condition, this helped the plant root to get oxygen and water easily. This might favoured the better root growth in the recent study and Thakur et al., (2010), reported similar findings.

**Yield attributes**

More number of productive tillers (342m⁻²) and grains per panicle (249) were observed with machine transplanting under unpuddled soil (M_4) (Table 2). This might be due to higher number of productive tillers, increased nutrient availability in soil, improved root activity, increased nutrient uptake, maintenance of optimum plant population per unit area, uniform depth of planting
Improved grain and straw yield was observed with irrigation after formation of hairline crack ($l_i$). This was on par with irrigation when water level reaches 5 cm below soil surface ($l_i$) (Table 2). This might be due to increased number of productive tillers $m^{-2}$, number of grain panicle with high fertility percentage. Rotational irrigation (safe alternate wetting and drying) improved soil aeration and improved root growth and development, enhanced availability of nutrient throughout the crop growth that enriched yield attributes, thereby it increased rice yield. Ceesson et al., (2006) reported that the cycles of repeated wetting and drying improved rice growth and yield through increased nutrient availability.

Significant interaction was observed between establishment methods and irrigation management practices on rice grain and straw yield. Machine transplanting under unpuddled soil combined with irrigation after formation of hairline crack ($M_1l_1$) was observed with 13% increase in grain yield compared to conventional transplanting with farmers’ irrigation practice of 5 cm of continuous flooding ($M_2l_1$) during summer 2019 (Table 2). It was comparable with machine transplanting under unpuddled soil combined with irrigation when water level reaches 5 cm below soil surface ($M_3l_1$). This might be due to improved root development, larger canopy, less intra plant competition, improved remobilization of assimilates to grain and higher nutrient availability.

Total water consumed and water productivity

Among the various establishment methods, machine transplanting under unpuddled soil ($M_3$) consumed minimum water (927 mm) and produced higher water productivity (0.66 kg m$^{-3}$) as compared to other methods of establishment. Farmers’ method of irrigation ($I_1$) (5 cm of continuous submergence throughout the crop growing season) consumed more water (1277 mm) and produced lesser water productivity. Water productivity was maximum with irrigation when water level reaches 5 cm below soil surface ($l_i$).

CONCLUSION

From the experimental result, it could be concluded that machine transplanting under unpuddled soil condition improved plant growth parameters viz., plant height, tillers $m^{-2}$, drymatter production, root length, root dry weight and root volume. Among the irrigation management practices, irrigation after formation of hairline crack registered increased growth parameter, which was comparable with irrigation when water level reaches 5 cm below soil surface. Yield parameters viz., productive tillers, filled grains panicle and grain yield, straw yield also higher with machine transplanting under unpuddled soil condition and irrigation after formation of
hairline crack, which was comparable with irrigation when water level reaches 5 cm below soil surface. Higher water productivity was recorded with machine transplanting under unpuddled soil condition combined with irrigation when water level reaches 5 cm below soil surface. Hence, machine transplanting under unpuddled soil condition and scheduling of irrigation when water level reaches 5 cm below soil surface can be recommended to the rice growing farmers in tank irrigated command area to sustain rice production.

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**Ethics statement**

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

**Originality and plagiarism**

Authors should ensure that they have written and submit only entirely original works, and if they have used the work and/or words of others, that this has been appropriately cited. Plagiarism in all its forms constitutes unethical publishing behavior and is unacceptable.

**Consent for publication**

All the authors agreed to publish the content.

**Competing interests**

There were no conflict of interest in the publication of this content.

**AUTHOR CONTRIBUTIONS**

Research grant-AK; Idea-SS; Conceptualization-SS; SS,AK; Experiments-SS,SS,AK; Guidance-SS,AK,BR,TS,RA; Writing-original draft-SS; Writing-reviewing & editing-SS,TS,RA

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