Dry Matter Production and Partitioning in Different Plant Parts of Rice Cultivars under Irrigation Regimes and Systems of Cultivation

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ABSTRACT

Background: Growth and yield characteristics of genotypes depend on genetic and environmental factors. Among the different production factors, varietal selection at any location plays an important role. Proper crop management depends on the growth characteristics of various varieties to get maximum benefit from new genetic material. Among the different water-saving irrigation methods in rice, the most widely adopted is alternate wetting and drying (AWD). Many of the rice cultivars vary in their performance under different systems of cultivation.

Methods: A field experiment was conducted on a clay loam soil at Indian Institute of Rice Research (IIRR) Rajendranagar, Hyderabad, Telangana during the kharif seasons of 2017 and 2018, to study the “productivity and water use efficiency of rice cultivars under different irrigation regimes and systems of cultivation” The treatments consisted of two irrigation regimes Alternate wetting and drying and Saturation as main plot treatments, three establishment methods System of Rice Intensification (SRI), Drum Seeding (DS) and Normal transplanting (NTP) as sub plot treatments and four Cultivars namely DRR Dhan 42, DRR Dhan 43, MTU-1010 and NLR-34449 as sub-sub plot treatments summing up to 24 treatment combinations laid out in split-split plot design with three replications.

Result: At 60, 90 DAS/DAT and harvest significantly dry matter production (DMP) was recorded with DRR Dhan 43 cultivar (607, 4320 and 11548 kg ha\(^{-1}\)) respectively in pooled means of both 2017 and 2018) than other cultivars. Whereas MTU-1010 and NLR-34449 recorded on par dry matter production values at all the crop growth stages during both the years of study. However, DRR Dhan 42 produced the lowest dry matter production compared to other genotypes. DRR Dhan 43 recorded higher dry matter accumulation (g m\(^{-2}\)) in root, stem and leaves at all the crop growth stages, during both the years of the study over other cultivars. Alternative wetting and drying method of irrigation recorded significantly higher DMP at all the growth stages of rice (60, 90 DAS/DAT and at harvest) except at 30 DAS/DAT during both 2017 and 2018 as compared to saturation. SRI recorded significantly higher DMP as compared to normal transplanting; however, it was comparably at par with drum seedling at all the growth stages.

Key words: Cultivars, Dry matter production, Irrigation regimes and Systems of cultivation, Partitioning, Rice.

INTRODUCTION

Rice is one of the most important cereal crops occupying second position in global agriculture and it is widely grown in India due to its wider adaptability. Rice is grown in an area of 44.5 M ha with a production of 115.60 M t and a productivity of 2800 kg ha\(^{-1}\) in India (ASG, 2019). It's grown in an area of 22.18 lakh ha with a production of 126.0 lakh tonnes with an average productivity of 5702 kg ha\(^{-1}\) in Andhra Pradesh (Anonymous, 2017). To safeguard and sustain the food security in India, it is quite important to increase the productivity of rice under limited resources, especially land and water. Hence, the major challenges are to produce more rice per unit amount of natural resource. As per the concepts of water foot print and virtual water to produce one kg of rice 3000 to 5000 litres of water is required (Cantrell and Hettel, 2004). Being a water-intensive crop, cultivation of rice has been a big drain on water resources. Rice is a heavy water consumer but water for rice production is becoming scarce and expensive due to the increased demand for water from the ever growing population and industries (Choudhury et al., 2014). Rainfall patterns in many areas are becoming more unreliable, with extremes of drought and flooding occurring at unexpected time. Traditional planting has been the most important and common method of crop establishment practice under irrigated lowland rice ecosystems in tropical Asia. In irrigated lowland rice which not only consumes more water but also causes wastage of water resulting in degradation of land. In recent years to tackle this problem, many methods of cultivation have been
developed and one among them is System of Rice Intensification (Sridharak, 2015; and Thirupathi, 2017).

Senthilkumar (2015) reported that SRI machine transplanting produced significantly higher dry matter production of rice than the other establishment methods. Hussain et al. (2012) observed that transplanting of one or two seedlings hill−1 recorded significantly higher dry matter production and accumulation compared to 3 seedlings hill−1 in system of rice intensification. Chandrapala et al. (2010) observed that at heading and maturity stages, dry matter accumulation under SRI was 10,479 and 19,139 kg ha−1 respectively, which was found to be higher than that under NTP (10,136 and 18,910 kg ha−1, respectively). Growth and yield characteristics of any cultivar depend on genetic and environmental factors. Among the different production factors, varietal selection at any location plays an important role. Proper crop management depends on the growth characteristics of various varieties to get maximum benefit from new genetic material (Sarith, 2017; and Vijay, 2018). Among the different water-saving irrigation methods in rice, the most widely adopted is alternate wetting and drying (Kishore, 2016). Many of the rice cultivars vary in their performance under different systems of cultivation. Higher dry matter production per unit area is the critical prerequisite for higher yield.

Sathish et al. (2016) reported that among the different irrigation regimes recommended submergence of 2 to 5 cm water level as per crop stage recorded significantly higher dry matter production at all the stages of crop and was on par with AWD irrigation of 5 cm submergence depth with 5 cm drop of water level in the field tube and 3 DADPW at 80 and 110 DAS. Geethalakshmi et al. (2009) confirmed that the maximum dry matter production, higher shoot and root length were recorded under SRI method of irrigation (intermittent irrigation) compared to 5 cm depth at one day after disappearance of water and 5 cm depth at two days after disappearance of water. There was increased total dry matter production in AWD irrigation system (Rajesh and Thanunathan, 2003). The amount of dry matter production partitioning depends on effective photosynthesis and respiration of crop. The total yield of dry matter is the total amount of dry matter produced and less the photosynthates used for respiration. Finally, the manner in which the net dry matter produced is distributed among the different parts of the plant, which determine magnitude of the economic yield (Thirupathi, 2017). There was a progressive and conspicuous increase in root, stem and leaf dry matter accumulation (g m−2) with the advancement of crop growth stage up to 90 DAT.

**MATERIALS AND METHODS**

The field experiment comprises of 24 treatment combinations conducted at Indian Institute of Rice Research (IIRR) formerly Directorate of Rice Research (DRR) farm, Rajendranagar, Hyderabad during the kharif seasons of 2017 and 2018. located at 17°19’ N latitude, 78°23’ E longitude and an altitude of 542.3 m above mean sea level. It represents the Southern Telangana agro-climatic zone of Telangana state. According to Troll’s climatic classification, it falls under semi-arid tropics (SAT). During the crop growth period, a total rainfall of 990.4 mm was received in 50 rainy days in the first year and 375.6 mm in 26 rainy days in the second year. The weekly mean maximum and minimum temperature on an average of 30.4°C, 31.2°C and 19.9°C, 18.2°C were recorded during 2017 and 2018 respectively. The soil samples were collected randomly from the experimental field from 0-30 cm depth and analyzed for their physico-chemical properties by adopting standard procedures. Texturally clay loam with an average of 8.05 soil pH, 0.185 Electrical conductivity (dSm−1), 0.485 Organic carbon (%), 2.25, 27.25 and 508 kg ha−1 available Nitrogen, Phosphorus and Potassium respectively. The treatments consisted of two irrigation regimes Alternate wetting and drying and Saturation as main plot treatments, three establishment systems System of Rice Intensification (SRI) with spacing of 25 cm x 25 cm, Drum Seeding (DS) with spacing of 20 cm x 10 cm and Normal transplanting (NTP) with spacing of 20 cm x 15 cm as sub plot treatments and four Cultivars namely DRR Dhan 42, DRR Dhan 43, MTU-1010 and NLR-34449 as sub-sub plot treatments laid out in split-split plot design with three replications. The area of each gross plot was 7 x 3 m2. Seedlings were transplanted with an average of one seedling per hill in the SRI method of planting. FYM at @ 10 t ha−1 was uniformly applied to all the plots before final puddling and levelling. The recommended dose of phosphorus @ 60 kg P2O5 kg ha−1 as single super phosphate (SSP) was applied to all the treatments uniformly as basal and potassium @ 40 kg K2O ha−1 as muriate of potash (MOP) was applied in two splits, 75 per cent as basal and the remaining 25 per cent at 75 DAS/DAT. Recommended dose of nitrogen (120 kg ha−1) was applied through urea in three splits, 50 per cent as basal, 25 per cent at 50 DAS/DAT and the remaining 25 per cent at 75 DAS/DAT.

**Dry matter production (DMP)**

The regular plant samples (which includes shoot, leaves and root) were collected at different stages of the crop growth viz., 30, 60, 90 DAS/DAT and at harvest and oven dried for 72 hours at 60 ± 5°C. The dry weight of the samples were assessed and expressed in kg ha−1.

**Dry matter partitioning**

Root, stem and leaf dry matter accumulation was determined at 30, 60 and 90 DAT/DAS. Five plants marked for destructive sampling were carefully removed with a shovel, thoroughly washed and separated from the shoot portion with a knife. The root, stem and leaf were dried in a hot air oven at 65°C until a constant weight was obtained and was expressed as g m−2.

**Statistical analysis**

The data obtained on the different growth and yield parameters and yield were analysed statistically by the
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method of analysis of variance as per the procedure outlined for split-split plot design given by Gomez and Gomez (1984). Statistical significance was tested by F value at 0.05 level of probability and the critical difference was worked out where ever the effects were significant.

RESULTS AND DISCUSSION

Increase in average total dry matter production of rice was rather slow up to 30 DAS there after it increased linearly up to 90 DAS and further, it continued to increase until maturity but it was at a diminishing rate in both the years of study (Table 1) there was a Progressive increase in dry matter accumulation (g m⁻²) in different plant parts viz., root, stem and leaves with the advancement of crop growth stage up to 90 DAS/DAT (Table 2 and Fig 1).

Effect of irrigation regimes

Alternative wetting and drying method of irrigation recorded significantly higher DMP at all the growth stages of rice (60, 90 DAS/DAT and at harvest) except at 30 DAS/DAT during both 2017 and 2018 as compared to saturation. The dry matter production in AWD was 601 and 620 kg ha⁻¹ at 60 DAS/DAT, 4209 and 4343 kg ha⁻¹ at 90 DAS/DAT and 11022 and 11373 kg ha⁻¹ at harvest during 2017 and 2018 respectively as compared to saturation was 555 and 559kg ha⁻¹ at 60 DAS/DAT, 3864 and 3932 kg ha⁻¹ at 90 DAS/DAT and 10164 and 10327 kg ha⁻¹ at harvest during 2017 and 2018 respectively (Table 1). It is because of rapid growth by maintenance of adequate wetness with intermittent water to crop that maintained good plant roots and varied metabolic processes that perform higher nutrient mobilization. These results were also in line with the observations made by Lu et al. (2000), Kumar et al. (2013) and Chowdhury et al. (2014).

Between the irrigation regimes, there was a significant difference in root dry weight (g m⁻²) during 2017 and 2018. Comparatively higher root dry weight (g m⁻²) was observed in alternate wetting and drying at 30, 60, 90 days after sowing/days after transplanting and harvest during both the years. There was no significant difference in dry matter accumulation (g m⁻²) of root, stem and leaves among the irrigation regimes during both the years of study (Table 2 and Fig 1). Relatively higher dry matter accumulation (g m⁻²) of root was observed in AWD at 30, 60, 90 DAS and harvest during the both years. It might be due to increased root oxidation activity and root source cytokinins in intermediate irrigation in AWD. This finding was in conformity with the findings of Armstrong and Webb (1985), who observed the possibility of extended growth of rice roots under influence of oxygen.

Effect of systems of cultivation

Among the different systems of rice cultivation, SRI recorded significantly higher DMP as compared to normal transplanting; however it was comparably at par with drum seeding at all the growth stages. Significantly the higher DMP was noticed in SRI at 30, 60, 90 DAS/DAT and at harvest (215, 651, 4564 and 11950 kg ha⁻¹ respectively in 2017 and 2018.

Table 1: Dry matter production of rice as influenced by different irrigation regimes, systems of rice cultivation and cultivars during kharif 2017 and 2018.

| Treatments | 30 DAS/DAT | 60 DAS/DAT | 90 DAS/DAT | At harvest |
|------------|------------|------------|------------|------------|
|            | 2017   | 2018   | Pooled   | 2017   | 2018   | Pooled   | 2017   | 2018   | Pooled   | 2017   | 2018   | Pooled   |
| Irrigation regimes (I) | | | | | | | | | | | | |
| I₁ : AWD | 198    | 198    | 601    | 501    | 611    | 4209    | 4343    | 4276    | 11022   | 11373   | 11198   |
| I₂ : Saturation | 196    | 195    | 555    | 559    | 557    | 3864    | 3932    | 3898    | 10164   | 10327   | 10046   |
| SEm ±    | 2.2    | 3.1    | 14.1   | 19.5   | 16.8   | 117.9   | 135.6   | 126.7   | 290.8   | 315.3   | 303.0   |
| C.D (P = 0.05) | NS    | NS    | NS    | 41     | 58     | 50     | 342     | 407     | 375     | 855     | 986     | 921     |
| Systems of rice cultivation (S) | | | | | | | | | | | | |
| S₁ : SRI | 207    | 225    | 215    | 621    | 682    | 651    | 4348    | 4779    | 4564    | 11385   | 12514   | 11950   |
| S₂ : DS  | 202    | 192    | 197    | 613    | 583    | 598    | 4293    | 4086    | 4190    | 10242   | 10700   | 10971   |
| S₃ : NTP | 184    | 168    | 176    | 560    | 509    | 534    | 3921    | 3565    | 3743    | 9270    | 9337    | 9803    |
| SEm ±    | 5.6    | 6.9    | 5.7    | 17.2   | 20.9   | 17.4   | 120.6   | 146.7   | 122.3   | 315.8   | 384.3   | 320.2   |
| C.D (P = 0.05) | 18    | 22     | 19     | 56     | 68     | 56     | 393     | 479     | 398     | 1029    | 1036    | 1044    |
| Cultivars (C) | | | | | | | | | | | | |
| C₁ : DRR Dhan 42 | 183    | 185    | 184    | 556    | 541    | 548    | 3892    | 4044    | 3968    | 9193    | 9851    | 9522    |
| C₂ : DRR Dhan 43 | 205    | 198    | 201    | 603    | 612    | 607    | 4364    | 4276    | 4320    | 11427   | 11670   | 11548   |
| C₃ : MTU-1010 | 195    | 186    | 190    | 601    | 563    | 582    | 4351    | 3945    | 4148    | 10948   | 11150   | 11049   |
| C₄ : NLR-34449 | 190    | 187    | 188    | 571    | 580    | 575    | 4142    | 4111    | 4126    | 11394   | 10330   | 10862   |
| SEm ±    | 6.0    | 5.2    | 4.5    | 18.2   | 15.7   | 13.7   | 127.5   | 110.4   | 96.1    | 334.0   | 289.3   | 251.6   |
| C.D (P = 0.05) | 17    | 14     | 12     | 51     | 44     | 39     | 362     | 314     | 273     | 949     | 823     | 886     |
| Interactions | NS    | NS    | NS    | NS    | NS    | NS    | NS    | NS    | NS    | NS    | NS    | NS    |

Note: SEm- Standard error of mean, C.D- Critical difference, NS- Non Significant.
pooled means of both 2017 and 2018) as compared to normal transplanting (176, 534, 3743 and 9803 kg ha\(^{-1}\) respectively in pooled means of both 2017 and 2018) and it was at par with drum seeding (197, 598, 4190 and 10971 kg ha\(^{-1}\) respectively in pooled means of both 2017 and 2018) (Table 1). Higher dry matter production of the above treatment may be attributed to better establishment of seedlings and more number of tillers m\(^{-2}\). Significantly lower dry matter was recorded with drum seeding at all the stages except at 30 DAS. Lowest dry matter production in drum seeding method may be attributed to non-uniform plant stand and less number of tillers m\(^{-2}\). This was supported by Anbumani et al. (2004). The higher dry matter production in SRI method was attributed to planting of young seedling at shallow depth in wider spacing and cono-weeding which leads to taller plants, higher leaf area, better root growth, profuse and strong tillers with higher crop growth rate. Increased shoot: root ratio and production of more number of tillers hill\(^{-1}\) under wider spacing were the reasons for increased dry matter production (Rajesh and Thanunathan, 2003). In addition to that cono-weeding increased the soil aeration which enhanced availability of dissolved oxygen in irrigation water thereby increasing shoot: root ratio and LAI and subsequently increasing dry matter production (Uphoff, 2002). The results obtained in this investigation are in conformity with the findings of Hussain et al. (2012), Sridevi and Chellamuthu (2012) and Rajendran et al. (2013).

Root dry weight (g m\(^{-2}\)) was higher with the SRI over drum seeding and normal transplanting during both 2017 and 2018 at all the growth stages. Dry matter accumulation in different plant parts was superior with system of rice intensification over drum seeding and NTP during both the years of study at all the growth stages (Table 2 and Fig.1). Less interplant competition would have enabled the plants to have more physiological activity. In square planting with wider spacing more soil area was available for foraging thus leading to improved root growth in SRI. This is in accordance with the observations of Jayakumar et al. (2005), Priyanka et al. (2013) and Rani and Sukumari (2013).

### Effect of rice Cultivars

Among the different varieties, DRR Dhan 43 cultivar recorded significantly higher dry matter production at 30 DAS/DAT (205, 198 and 201 kg ha\(^{-1}\) during 2017, 2018 and in pooled means, respectively) over other cultivars. However MTU-1010 cultivar was at par with DRR Dhan 43 at 30 DAS/DAT. At 60, 90 DAS/DAT and harvest significantly DMP was recorded with DRR Dhan 43 cultivar (607, 4320 and 11548 kg ha\(^{-1}\) respectively in pooled means of both 2017 and 2018) than other cultivars. However MTU-1010 and NLR-34449 cultivars were recorded on par DMP values with DRR Dhan 43. While DRR Dhan 42 cultivar recorded the lowest DMP compared to other cultivars at all the growth stages during 2017 and 2018. difference in DMP among the cultivars and the lower values of DRR Dhan 42 may be due to genetical

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**Table 2:** Root dry weight of rice as influenced by different irrigation regimes, systems of rice cultivation and cultivars during kharif 2017 and 2018.

| Treatments | Root dry weight (g m\(^{-2}\)) |
|------------|------------------------------|
|            | 30 DAS/DAT | 60 DAS/DAT | 90 DAS/DAT | At harvest |
|            | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| **Irrigation regimes (I)** | | | | | | | | | | | | | |
| \(I_1\): AWD | 62 | 72 | 67 | 250 | 265 | 258 | 652 | 802 | 727 | 862 | 1012 | 938 |
| \(I_2\): Saturation | 49 | 71 | 60 | 203 | 235 | 219 | 553 | 691 | 672 | 783 | 901 | 842 |
| SEm ± | 3.0 | 6.8 | 4.9 | 11.5 | 13.8 | 12.1 | 15.5 | 22.5 | 18.2 | 22.5 | 26.5 | 24.2 |
| C.D (P = 0.05) | 10 | 17 | 14 | 33 | 40 | 36 | 64 | 62 | 53 | 64 | 77 | 67 |
| **Systems of rice cultivation (S)** | | | | | | | | | | | | | |
| \(S_1\): SRI | 88 | 108 | 98 | 319 | 361 | 340 | 686 | 835 | 761 | 896 | 1045 | 971 |
| \(S_2\): DS | 41 | 54 | 47 | 246 | 265 | 255 | 582 | 665 | 624 | 792 | 875 | 834 |
| \(S_3\): NTP | 22 | 52 | 37 | 214 | 224 | 219 | 540 | 640 | 590 | 650 | 750 | 700 |
| SEm ± | 4.9 | 5.2 | 4.0 | 14.3 | 10.7 | 11.8 | 19.9 | 23.8 | 20.5 | 18.9 | 33.8 | 28.5 |
| C.D (P = 0.05) | 16 | 17 | 13 | 47 | 32 | 39 | 56 | 73 | 59 | 52 | 83 | 74 |
| **Cultivars (C)** | | | | | | | | | | | | | |
| \(C_1\): DRR Dhan 42 | 44 | 66 | 55 | 196 | 242 | 219 | 579 | 687 | 630 | 789 | 897 | 843 |
| \(C_2\): DRR Dhan 43 | 60 | 82 | 71 | 247 | 265 | 256 | 609 | 798 | 703 | 819 | 908 | 913 |
| \(C_3\): MTU-1010 | 56 | 73 | 64 | 225 | 243 | 234 | 640 | 736 | 688 | 850 | 946 | 898 |
| \(C_4\): NLR-34449 | 51 | 65 | 58 | 237 | 249 | 243 | 582 | 766 | 674 | 792 | 976 | 884 |
| SEm ± | 7.1 | 6.0 | 6.2 | 6.3 | 5.6 | 6.4 | 22.2 | 32.5 | 26.8 | 22.1 | 27.5 | 24.8 |
| C.D (P = 0.05) | 17 | 16 | 17 | 19 | 22 | 19 | 62 | 78 | 74 | 57 | 68 | 62 |
| Interactions | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Note: SEm- Standard error of mean, C.D- Critical difference, NS- Non Significant.
inherent character of the varieties. Similar findings were also line up with Sharath (2017) and Vijay (2018).

Among the different cultivars, DRR Dhan 43 recorded higher root dry weight at 30 DAS/DAT (60, 82 and 71 g m\(^{-2}\) during 2017, 2018 and in pooled means, respectively) over other cultivars. However, MTU-1010 cultivar was at par with DRR Dhan 43, while NLR-34449 was at par with MTU-1010 at 30 days after sowing/days after transplanting. At 60, 90 DAS/DAT and harvest significantly superior root dry weight was recorded with DRR Dhan 43 (256, 703 and 913 g m\(^{-2}\) respectively in pooled means of both years) than other cultivars. However MTU-1010 and NLR-34449 cultivars recorded on par root dry weight values with DRR Dhan 43. While DRR Dhan 42 cultivar recorded the lowest root dry weight over other cultivars at all the growth stages during 2017 and 2018 (Table 2). Differences in root dry weight among the cultivars and the lower values of DRR Dhan 42 may be due to the genetic inherent character of the cultivars. These results corroborate with the findings of Sharath (2017) and Vijay (2018). Among the cultivars, dry matter accumulation (g m\(^{-2}\)) in root, stem and leaves at all the crop growth stages in both the years of study and in pooled means was statistically non-significant except DRR Dhan 43 where recorded significantly higher dry matter accumulation (g m\(^{-2}\)) during both the years of the study over other cultivars.

CONCLUSION

With regard to irrigation regimes, dry matter production (kg ha\(^{-1}\)) and dry matter partition (g m\(^{-2}\)) in root, stem and leaf were significantly higher in alternate wetting and drying method as compared to saturation at all the growth stages.

Among the different systems of cultivation, significantly higher dry matter production (kg ha\(^{-1}\)), was noticed in system of rice intensification at 30, 60, 90 DAS/DAT and at harvest. Significantly lower DMP was recorded in NTP at all the crop growth stage.

ACKNOWLEDGEMENT

This study was a part of the PhD thesis research of the first author. Funding was provided by the Ministry of Tribal Affairs, Govt. of India, for the financial help in the form of National Fellowship and Scholarship for Higher Education of Students, during my study period (No. 2017-18-NFST-KAR-00149). I am grateful to the Indian Council of Agricultural Research and Acharya N.G. Ranga Agricultural University for providing me with the opportunity to pursue my Ph.D. degree program and research. I acknowledge with great pleasure to the Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad for providing the opportunity to conduct the research successfully. The authors would like to thank Senior Scientific Officer, Agricultural Research Institute, Rajendranagar, Hyderabad for providing weather data.

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