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Assimilate partitioning pattern in aerobic rice as influenced by drip biogation

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Dry matter partitioning plays an important role in economic yield of crop plants. In this present study, it was carried out using two genotypes such as TNRH 180 (pipeline hybrid) and a variety PMK (R) 3 with 100, 125 and 150 % Pan Evaporation (PE) water levels of surface and subsurface drip irrigation as well as conventional irrigation at different stages of crop growth. The variety PMK (R) 3 under lesser moisture regime (100% PE) demonstrated significantly enhanced dry matter remobilization compared to hybrid. The advanced contribution of dry matter from stems and leaves for better grainfilling were observed in both genotypes in the case of higher moisture supply situation (150% PE) as compared with conventional surface drip irrigation. But, interestingly, subsurface drip irrigation at 125% PE moisture level established current photosynthesis contribution to grainfilling which was much more marked in the pipeline hybrid culture and also on the favourable condition exhibited by hybrid culture. Dry matter contribution was more at post-flowering stage, while on variety, it exhibited from stems and leaves.

Keywords: Drymatter partitioning; surface drip; subsurface drip; seaweed extract; humic acid; biogation

Introduction

Aerobic culture is an emerging technology designed to enhance water use efficiency in rice production (Tuong *et al.*, 2005; Matsuo and Mochizuki, 2009) by growing the plants in non-puddled and non-flooded fertile soils (Atlin *et al*., 2006; Haryanto *et al*., 2008; Matsunami *et al*., 2009). The aerobic culture could save water without any yield penalty compared with flooded culture but with some risks of poor performance (Kato *et al.*, 2009). In drip irrigation, water is provided most efficiently at right time and practically near the root zone of the crop. Generally, between 15 to 60 per cent of the fraction of the soil alone is wetted. It enables precise application of water and nutrients at precise zone avoiding soil erosion and drain of water by deep percolation (Herman, 1982).

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Towards this, Vanitha (2008) established that drip fertigation scheduled at 125% PE with 100% Recommended Dose of NPK Fertilizer resulted not only in water saving but also with increased values for water productivity. The productivity of cereals depends not only on the accumulation of dry matter, but also on the effective partitioning to the plant parts of economic importance and this is a key to yield stability particularly under drought stress (Kumar *et al*., 2006).

Remobilization of reserves to grain is critical for grain yield if the plants are subjected to water stress during grain filling (Palta *et al*., 1994; Ehdaie and Waines, 1996). Among cereals, pre-anthesis assimilates help in yield stability during terminal drought (Blum *et al.*, 1983). In wheat, pre-anthesis assimilate reserves from stem and sheaths contribute 25 - 33 per cent of the final grain weight (Hans, 1993; Gebbing and Schnyder, 1999). In cereals, grains are the most important sinks for carbon and nitrogen after anthesis. In rice, available carbon assimilates for grain production are determined by carbon assimilation during the grain filling period ('current photosynthesis') plus assimilate reserves stored in the straw (Cook and Yoshida, 1972). Pre-anthesis storage may contribute 20-40 per cent of the final crop yield depending on cultivar, reflecting its importance for attaining higher grain yields (Yoshida, 1972; Murata and Matsushima, 1975). The early senescence induced by a moderate water-deficit during grainfilling can enhance the remobilization of stored assimilates and accelerate grain filling of rice (Yang *et al.*, 2001). In the present investigation, an attempt has been made to examine the variation in the production of drymatter before and after flowering and its partitioning to reproductive organs in different chosen treatments especially during Dry Season (DS), 2009 and 2010 with the objectives of quantifying the production and redistribution of dry matter in grain filling and how this varied among different treatments and genotypes.

Materials and methods

Experimental detail: Investigations were carried out during dry season of 2009 and 2010 in the Wetlands of Tamil Nadu Agricultural University, Coimbatore, India located at 11^0 N latitude, 77^0 E longitude and at an altitude of 426.72 m above Mean Sea Level. The soil of the experimental field was deep clay loam with soil contained 30.1% clay, 25.4% silt, 30.2% fine sand and 9.3% coarse sand. During DS (2009), the contents of available nitrogen (N), phosphorus (P) and potassium (K) were 289, 20, 354 kg ha^{-1} respectively with the pH of 7.9. The treatments consisted of three irrigation methods (conventional irrigation, surface and subsurface drip irrigation) with three water levels of 100, 125 and 150% PE. Each treatment had three replications in a factorial randomized block design.

During DS (2010), the contents of available N, P and K were 332, 24 and 387 kg ha^{-1} respectively with the pH of 8.2. The treatments consisted of three irrigation methods (conventional irrigation, surface and subsurface drip irrigation at 125% PE level) along with 75 and 100% Recommended Dose of Fertilizer (RDF) (Vanitha, 2008). Seaweed extract (*Ascophyllum nodosum*) and humic acid were biogated @ 500 mL ha^{-1} through drip irrigation after mixing in the fertilizer tank and let out to the respective treatments during tillering, panicle initiation and flowering stages two days after fertigation. For conventional irrigation seaweed extract and humic acid were applied as a foliar spray @ 500 mL ha^{-1} in the respective treatments during tillering, panicle initiation and flowering stages. Each treatment had three replications in a split plot design.

Agronomic practices: The experimental plots were dry-ploughed and harrowed. Raised flat beds were formed and laid out with double channels around all the plots to prevent subsoil lateral water flow. Before sowing, the wet seeds were treated with the biofungicide, *Pseudomonas flouresence* followed by *Azophosmet*, biofertilizer each at the rate of 200 g 10 kg^{-1} of seeds. Sprouted and treated seeds were dry-sown by hand dibbled at 3 cm depth in rows of 20 cm apart at seeding rate of 30 kg ha^{-1} using rice variety PMK (R) 3 and TNRH 180 (pipeline hybrid) spaced at 20 x 10 cm.

Weekly fertigation schedule indicating the nutrient requirement at different phenological stages as adopted by Vanitha (2011) were given at the recommended doses of NPK (150:50:50 kg ha^{-1}) in the form of water soluble fertilizers starting 21 days after sowing. In the case of conventional irrigation method recommended package of practices were followed. For both conventional irrigation and drip system plots, recommended doses of $FeSO_4$ (50 kg ha^{-1}) and $ZnSO_4$ (25 kg ha^{-1}) were applied as the basal dressings before sowing in all the treatments. Gypsum was also applied basally @ 500 kg ha^{-1} before sowing. Installation of drip system, from sub-main, in-line laterals were laid at a spacing of 0.8 m with 4 lph emitters spaced at 0.6 m such that one lateral could cover four rows of 20 cm each. In case of subsurface drip irrigation, the laterals were buried to a depth of 10 cm in the soil. In case of conventional irrigation treatment, irrigation was scheduled at 1.25 IW/CPE ratio to 3.0 cm depth throughout the crop growth.

Sampling and data collection: For estimating total dry matter accumulation, the entire plant was pulled out with the root system intact at different stages and separated into the leaf, culm, root and panicle portions. They were weighed separately after drying the plants at 80 ± 2^{o}C for 48 hours and expressed in g m^{-2}. The total dry matter accumulation was arrived at by summing up the dry weights of leaf, culm, root and panicles and the values expressed as g m^{-2}.

Apparent contributions to grain filling from different sources were estimated as follows (Kumar *et al*., 2006):

DMcp = TDMmt – TDMfl (1)
DMs = SDMfl – SDMmt (2)
DMl = LDMfl - (LDMmt + DDMfl to mt) (3)

Where: TDM is the total shoot drymatter, SDM the stem dry matter, LDM the green leaf drymatter, DDM the dead leaf drymatter, mt the maturity, fl the flowering, DMcp the apparent contribution of current photosynthesis after anthesis to grainfilling, DMs the apparent contribution of drymatter partitioning from stems to grainfilling, DMl is the apparent contribution of drymatter partitioning from leaves to grainfilling.

Measured values of grain yield were then compared with estimates from

Current photosynthesis (DMcp) (4)
Current + stem contribution (DMcp + DMs) (5)
Current + stem + leaf contribution (DMcp + DMs + DMl) (6)

Any remaining discrepancy between measured and apparent contribution was taken as drymatter redistribution from roots.

Statistical analysis: The data collected were subjected to statistical analyses in the respective design using ANOVA Package (AGRES version 7.01) following the method of Gomez and Gomez (1984).

Results and discussions

The results on apparent contribution of different sources of assimilate to grain yield for DS (2009) and DS (2010) are presented in Fig. 1 and 2 respectively.

Contribution from plant part dry matter to grain filling: During DS (2009), there was clear cut variation for the reallocation of drymatter to grainfilling processes from the genotypes and irrigation treatments (Fig. 1). It is shown that redistribution of drymatter from stem and leaves was greater in the variety than the hybrid. Similarly, contribution of drymatter remobilization from stem and leaves to build up grain yield was observed under water deficit

(100% PE) situations in both the genotypes. This finding was comparable with the hypothesis that water-deficit condition promoted remobilization of assimilates to panicles for increased grain yield under stress. In wheat, Yang *et al*. (2001) reported that 75 - 92 per cent of pre-anthesis ^{14}C stored in the straw was reallocated to grains under water-stress, 50 - 80 per cent higher than the amount remobilized under well watered conditions. This was also consistent with the present finding that drymatter remobilization was enhanced under water-deficit situations.

Variations were also observed between genotypes to the extent of drymatter partitioning to grain under favourable conditions (125% PE), with hybrid culture TNRH 180 filling their grains mainly from post-flowering drymatter production, while PMK (R) 3 variety showed more drymatter partitioning from stem and leaves. This is in conformity with the findings of Kumar *et al*. (2006). In the case of excess water supply (150% PE), the contribution of drymatter from stem and leaves in grainfilling was more significant for both the genotypes especially under surface drip system. While under subsurface system, current photosynthetic contribution to grainfilling was more marked in the hybrid.

Genotypic differences in dry matter partitioning: Variation was also evident between genotypes in the extent of drymatter allocation to grain yield under different irrigation treatments, with hybrid culture TNRH 180 generally filled their grains mainly from post-flowering drymatter ('current photosynthesis'), while the variety, PMK (R) 3 exhibited more drymatter partitioning from stem and leaves.

Besides, drymatter partitioning into green leaves at maturity differed between genotypes. The hybrid culture, TNRH 180 possessed higher green leaf drymatter at harvest, but produced higher grain yield. This is in agreement with the findings of Kumar *et al*. (2006) suggesting that retaining larger green leaf area through maturity might retard remobilization from leaves, while accelerated leaf senescence could assist in more nonstructural carbohydrate remaining in the straw, leading to a lower HI. Such scenario was clearly seen with excess moisture supply situation in the hybrid compared to the variety.

Poor grainfilling as observed under excess moisture supply in the hybrid, resulting in lower HI, was generally considered to be closely associated with its stronger stay-green or delayed senescence until ripening stage in the hybrid in comparison with the conventional variety (Wang *et al*., 1998; Chen, 2001; Gu and Tang, 2001).

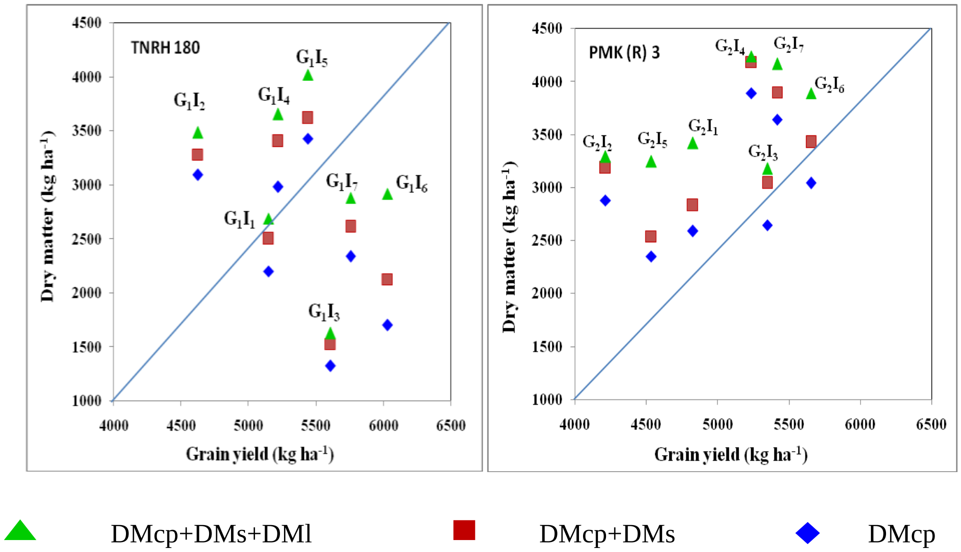
Variations were also observed between genotypes in partitioning to panicles under deficit and moderate water supply situations. Hybrid culture, TNRH 180 partitioned higher drymatter to panicles in the given two scenarios compared to PMK (R) 3, resulting in higher grain yields. This is in accordance with the findings of Kumar *et al*. (2006).

Thus, from the present study clearly indicated that plant senescence due to water stress significantly could increase remobilization of drymatter in rice as observed by Yang *et al*. (2003). They reported that controlled water deficiency especially during grainfilling enhanced whole plant senescence and such hastened senescence could facilitate remobilization of carbon reserves, accelerated grainfilling and increased the grain yield even under drought. Regarding DS (2010), methods of irrigation and biogation treatments exhibited phenomenal variations for the contributions of drymatter remobilization from stem and leaves.

Irrigation methods vs. dry matter partitioning: Little contribution from current photosynthesis and greater share of drymatter reallocation from stem and leaves to the panicles were seen for both conventional irrigation practice and surface drip system. For the subsurface drip system, equal share of drymatter allocation from current photosynthesis and retranslocation of drymatter from stem and leaves was apparent for building up the grain yield (Fig. 2).

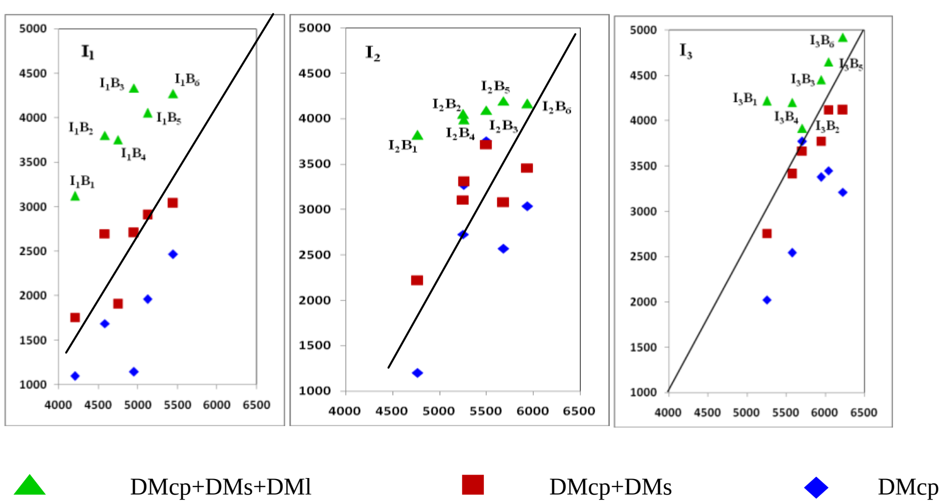
Dry matter contribution due to biogation: Considering the biogation treatments, drymatter retranslocation of current photosynthesis contributed substantially for both humic acid and seaweed extract application. In contrast, share of stem and leaves was phenomenal for the unbiogated control treatment (Fig. 2).

In conclusion, drip fertigation is an emerging technology for rice production under water crisis environment. From the present study, subsurface drip irrigation at 125% PE with recommended level of fertilizer with seaweed extract biogated plants achieved with better drymatter partioning leads to higher grain yield.



G_1:	TNRH 180	G_2:	PMK (R) 3	I_1:	Conventional irrigation
I_2:	Surface drip @ 100% PE	I_3:	Surface drip @ 125% PE	I_4:	Surface drip @ 150% PE
I_5:	Subsurface drip @ 100% PE	I_6:	Subsurface drip @ 125% PE	I_7:	Subsurface drip @ 150% PE

Fig. 1. Apparent contribution of different sources of dry matter for grain yield under different drip irrigation treatments (DS, 2009)



I_1:	Conventional irrigation	I_2:	Surface drip @ 125% PE	I_3:	Subsurface drip @ 125% PE
I_2:	75% RDF	I_3:	75% RDF + Humic Acid	I_4:	75% RDF + Seaweed Extract
I_5:	100% RDF	I_6:	100% RDF + Humic Acid	I_7:	100% RDF + Seaweed Extract

Fig. 2. Apparent contribution of different sources of dry matter for grain yield under different drip biogation treatments (DS, 2010)

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