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Efficacy of RWC, LWP, Proline, LDR and Transpiration Rate as Indices for Selection against Water Deficit in SRI and Conventional Methods of Rice Planting

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An Investigation was carried out during dry season (DS) of 2007 to study the effect of water deficit and its alleviation using Plant Growth Regulators (PGRs) / Bio-fertilizers / Chemicals in two different planting methods *viz*., System of Rice Intensification ('SRI') and traditional planted rice ('TPR') using ADT 43 variety. The result showed that the stressed plants of SRI (M_2) maintained high values of RWC (84.50 %), LWP (-1.70 MPa), Proline (7.96 µmoles g^{-1}), LDR (0.177 s cm^{-1}) and Transpiration rate (39.34 µg H_2O cm^{-2} s^{-1}) than that of the TPR (M_4) method of planting (RWC: 83.64 %; LWP: -1.86 MPa; Proline: 8.22 µmoles g^{-1}; LDR: 0.188 s cm^{-1} and Transpiration rate: 33.99 µg H_2O cm^{-2} s^{-1}) at flowering stage. Foliar spray of PPFM (S_5) excelled rest of the treatments. For the stressed category, interactive effect of $M_2 \times S_5$ was the best performer of RWC (88.70 %), LWP (-1.43 MPa), Proline (9.89 µmoles g^{-1}), LDR (0.161s cm^{-1}) and transpiration rate (44.36 µg H_2O cm^{-2} s^{-1}) at flowering stage. Mean grain yield reduction of 22.3 and 31.6 per cent as noticed in the water stress treatment of SRI and conventional transplanting methods could be narrowed down to 6.5 and 12.3 per cent respectively with supplementation stress ameliorants.

Key words: Planting methods, Water stress, Ameliorants, RWC, LWP, Proline, LDR Transpiration rate.

Plant responds to diverse environment signals in order to survive stresses such as drought (Pastori and Foyer, 2002). A crucial gate way for averting water stress effects is to maintain favorable internal water balance for realizing sustainable crop productivity under water limited environment. Various physiological parameters have been associated with drought (as drought induced response) and drought tolerance. In order to fully understand the physiological functions of the plants, it is imperative to study the variations in plant water status and concomitant physiological processes of the plants. Therefore, attempts have been made to elucidate the information on plant water relations under water stress scenario and possible role of the selected ameliorative measures in mitigating the ill-effects of the stress in both SRI and TPR methods of planting.

Materials and Methods

The experiment was laid out in a split plot design using ADT 43 variety replicated thrice at the Tamil Nadu Agricultural University, Coimbatore during DS, 2007. The experiment was conducted on a clay loam soil in a lowland rice area at wet land, Central Farm of TNAU (11^0 N, 77^0 E; 426.72 m altitude). In the present study, both SRI and TPR methods of rice cultivation were practiced. In TPR, 20 days old seedlings were transplanted at 15 cm x 10 cm spacing. In SRI, 14 days old seedlings were transplanted at 25 cm x 25 cm spacing. Size of each plots measured 4 m x 5 m. The experimental plots were laid out with double channels (buffer channels) around all the plots to prevent sub-soil lateral water flow. The main plot includes: "SRI" planting + Recommended Irrigation Schedule (M_1), "SRI" planting + Modified Irrigation Schedule (M_2), TPR planting + Recommended Irrigation Schedule (M_3) and TPR planting + Modified Irrigation Schedule (M_4). For the SRI and TPR methods of planting, the recommended irrigation plots were irrigated to 2 and 5 cm depth one day after disappearance of ponded water, respectively. In the former case, this was pursued up to flowering. Thereafter, irrigation was given to 5 cm depth till seven days before harvest.

For the modified irrigation schedule M_2 and M_4 plots, the water stress was imposed in two phases viz., first one during panicle initiation (50 to 65 days after sowing (DAS) and second one during flowering stage (80 to 95 DAS) by withholding irrigation in the specified stages during DS.The stress was imposed one day after disappearance of ponded water during panicle initiation and flowering stages. Whenever rain fall was received during the stress period, the rain water was immediately drained off from the respective plots without percolation.

After the termination of the stress period, the stressed plots were re-irrigated to the required depth immediately in both SRI and TPR methods of planting. In both non-stressed and stressed plots, irrigation was suspended seven days before the expected time of harvest.

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The sub-plot treatments *viz.,* Control (S_1), 0.5 ppm Brassinolide (BR; S_2), 100 ppm Salicylic Acid (SA; S_3), 1% Potassium chloride (KCl; S_4) and spray of Pink Pigmented Facultative Methylotroph (PPFM; S_5) Bacterial Isolate load of 10^6 @ 10 ml per litter were imposed at panicle initiation and flowering stages one day after the imposition of the stress. Observations on the selected physiological traits were made at flowering and harvest stage by adopting the standard procedures. For recording physiological traits like Relative Water Content (RWC) (Weatherly, 1950), Leaf Water Potential (LWP) (Scholander *et al*., 1965), Proline (Bates *et al.*, 1973) standard procedure were followed. Leaf Diffusive Resistance (LDR) and transpiration rate were measured in fully expanded flag leaf using the Steady State Porometer (Model LI-1600 of LI-COR, Lincoln, Nebraska, USA). Grain yield per hectare was calculated from the mean plot yield.

Results and Discussion

The result of the present study showed that the stressed plants of SRI (M_2) maintained high values of RWC (84.50 %), LWP (-1.70 MPa), Proline (7.96 µmoles g^{-1}), LDR (0.177 s cm^{-1}) and Transpiration rate (39.34 µg H_2O cm^{-2} s^{-1}) than that of the TPR (M_4) method of planting (RWC: 83.64 %; LWP : -1.86 MPa; Proline: 8.22 µmoles g^{-1}; LDR: 0.188 s cm^{-1} and Transpiration rate: 33.99 µg H_2O cm^{-2} s^{-1}) at flowering stage. Foliar spray of PPFM (S_5) excelled rest of the treatments. For the stressed category, interactive effect of $M_2 \times S_5$ was the best performer of RWC (88.70 %), LWP (-1.43 MPa) Proline (9.89 µmoles g^{-1}), LDR (0.161s cm^{-1}) and Transpiration rate (44.36 µg H_2O cm^{-2} s^{-1}) at flowering stage (Table 1).

Higher grain yield (6665 kg ha^{-1}) was registered with non-stressed SRI (M_1) which was 19.6, 10.3 and 33.0 per cent more than M_2, M_3 and M_4 respectively. But, the yield reduction noticed under water stress scenario could be substantially decreased with the supplementation of PPFM biofertilizer in both SRI and TPR methods of planting (Table 1).

In order to fully understand the physiological functions of plants, it is imperative to study the variations in plant water relations. Towards this, the results generated in the present study on the effect of planting methods and ameliorants *vs* plant water relations are discussed below with relevant literatures carried out in the related areas.

Relative Water Content (RWC) of leaves is often considered as a measure of plant water status, reflecting metabolic activity in tissues. Interestingly, in the present investigation, the stressed plants of SRI maintained higher values of RWC than that of the TPR plants. The chosen amelioratorsespecially BR, KCl and PPFM maintained higher RWC in the leaf cells in both the system of planting under stress. Thus, maintenance of higher plant water status (in terms of higher values of RWC) played a pivotal role in stabilizing various plant processes and yield (Kumar and Kujur, 2003).

The Leaf Water Potential (LWP) is a dependable indicator of plant water status especially under limited water supplying environment. Fukai *et al.* (1999) emphasized the ability of rice plants to maintain higher LWP to stabilize rice yield in rainfed areas. This is in accordance with the present investigation of stressed plants of SRI practice possessing higher values for LWP which helped for stabilizing the grain yield.Among the three ameliorators, PPFM played a vital role in maintaining favourable water balance which was more evidently seen in the case of the stressed plants of SRI

Table 1. Effect of planting methods, water stress and ameliorants on plant water relations and grain yield of rice (ADT 43) during dry season 2007

Treatment	RWC (%)	LWP (MPa)	Proline (µmoles g^{-1})	LDR (s cm^{-1})	Transpiration rate (µg H_2O cm^{-2} s^{-1})	Grain yield (kg ha^{-1})
M_1	89.50	-0.94	2.78	0.147	46.64	6665
M_2	84.50	-1.70	7.96	0.177	39.34	5574
M_3	87.72	-1.05	2.62	0.151	42.08	6045
M_4	83.64	-1.86	8.22	0.188	33.99	5011
SED	1.44	0.02	0.09	0.002	0.250	36.5
CD at 5%	2.94	0.04	0.19	0.005	0.613	89.3
S_1	81.60	-1.61	4.30	0.180	34.58	5261
S_2	88.20	-1.32	5.61	0.162	42.72	6024
S_3	83.93	-1.51	4.64	0.173	37.47	5613
S_4	88.33	-1.31	6.01	0.161	43.06	6163
S_5	89.65	-1.20	6.41	0.153	44.74	6309
SED	1.73	0.03	0.12	0.003	0.477	69
CD at 5%	3.55	0.06	0.29	0.007	0.972	140
M_1S_1	87.20	-1.11	2.17	0.175	42.08	6219
M_1S_2	91.10	-0.85	3.00	0.144	49.63	6805
M_1S_3	87.50	-1.00	2.56	0.156	43.67	6493
M_1S_4	90.20	-0.91	3.01	0.138	47.60	6884
M_1S_5	91.50	-0.81	3.14	0.120	50.23	6923
M_2S_1	78.20	-1.97	6.58	0.190	33.54	4572
M_2S_2	85.60	-1.65	7.62	0.177	40.08	5756
M_2S_3	82.10	-1.91	6.73	0.185	36.11	5201
M_2S_4	87.90	-1.55	8.96	0.171	42.63	6050
M_2S_5	88.70	-1.43	9.89	0.161	44.36	6192
M_3S_1	83.90	-1.22	1.93	0.162	35.02	5977
M_3S_2	90.10	-0.95	3.06	0.144	45.55	6379
M_3S_3	85.40	-1.17	2.02	0.159	40.03	6049
M_3S_4	88.70	-1.00	2.98	0.148	44.08	6344
M_3S_5	90.50	-0.92	3.11	0.141	45.71	6476
M_4S_1	77.10	-2.14	6.52	0.191	27.69	4175
M_4S_2	86.00	-1.82	8.74	0.182	35.60	5154
M_4S_3	80.70	-1.95	7.25	0.193	30.07	4707
M_4S_4	86.50	-1.76	9.08	0.187	37.92	5373
M_4S_5	87.90	-1.62	9.51	0.189	38.66	5645
Mean	86.34	-1.39	4.76	0.146	40.51	5874
M at S						
SED	3.22	0.05	0.21	0.006	0.890	128
CD at 5%	6.58	0.10	0.42	0.012	1.841	266
S at M						
SED	3.29	0.05	0.22	0.006	0.954	137
CD at 5%	6.96	0.11	0.47	0.013	1.944	280

Main plots	Sub plots
M_1- SRI with conventional irrigation	S_1-Control
M_2 - SRI with stress at PI & FF	S_2-0.5 ppm BR
M_3 - TPR with conventional irrigation	S_3-100 ppm SA
M_4 - TPR with stress at PI & FF	S_4- 1 % KCl
	S_5- 10^6 PPFM Bacterial isolate

practice and recorded higher values of LWP than that of the plants under TPR method of planting. This might be due to the mechanism of favourable root activity by PPFM supplementation, which needs to be elaborated further in future studies.

Proline acts as a compatible solute and a protective agent for cytoplasmic enzymes and structures. Increased accumulation of proline in the SRI practice could be possible because of restricted water supply than the TPR method of planting. The rice genotypes exhibiting high proline accumulation had a marked effect on the ability to maintain water status consequently delayed tissue death and leaf senescence in rice under water stress (Uyprasert *et al*., 2004). The role of ameliorators such as PPFM > KCl > BR was significant in increasing the content of proline in the stressed plants. Aruna Tyagi *et al*. (1999), these bioregulators could increase the hydrolysis of macro-molecules into the simpler ones like mono and disaccharides and amino acids especially proline etc. and consequently higher osmolyte concentration resulting in favourable osmoregulation process during water stress conditions.

Leaf Diffusive Resistance (LDR) got increased due to the imposition of water stress in both the planting methods (M_2 and M_4) during DS. Similar result of increased LDR under SRI planting was evident with the findings of Quingquan (2002).Plants supplemented with the bioregulators were also able to curtail the water loss by offering more diffusive resistance at stomatal level under water stress situations in both the methods of planting.

Transpiration, the major process involving water loss from the plants, was higher under non-stressed conditions. The SRI practice resulted in moderate reduction in transpiration than the TPR planting under water deficit situations. The observed reduction in transpiration rate under stress was associated with increased LDR (Mishra and Pradhan, 1972). Further, close analysis of the data showed a reduction of only 2.0 per cent with the stressed plants of SRI as against 12.1 per cent for the stressed plants of TPR system at FF stage during DS. Due to the application of bioregulators, the reduction in the transpiratory loss of water from the plants was generally minimal with the stressed plants of SRI system than the TPR method of planting. Specifically, the favourable role of PPFM and KCl was found to be phenomenal under water deficit conditions with reference to SRI practice.

Thus, the present investigation indicated that adequate supply of water led to higher values of LWP and the stomatal conductance and cooler leaves. The reverse was also true for the stressed plants. Low rate of transpiration and reduced stomatal conductance are considered advantageous under drought as they are associated with conservation of leaf moisture and maintenance of higher LWP under water stress (Selvi *et al.,* 2001). Nevertheless, use of PPFM as well as potassium mitigated the ill-effects of stress and exhibited more avoidance mechanism of drought stress in maintaining favourable LWP (by way of osmoregulation), cooler temperature and enhanced physiological processes such as hydration of colloids and viscosity of protoplasm leading to elevation in leaf water potential as observed by Ali (1985).

From the experiment, it is inferred that the stressed plants of SRI maintained higher values for the parameters of plant water relation than that of the TPR method, which ultimately translated into the grain yield. The chosen amelioratives generally maintained higher values of RWC, LWP, Proline, LDR and Transpiration rate, in the leaf cells in both the systems of planting. Towards this, a special reference could be made to the use of 10^6 bacterial isolate of PPFM, viz., *Methylobacterium* sp. (10 ml lit^{-1}.) to mitigate the ill-effects of water stress.

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