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Research Paper

Effect of induced moisture stress at critical stages on physiological traits and yield of rice (*Oryza sativa* L.)

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ABSTRACT

A field investigation was made at the Tamil Nadu Agricultural University farm in Coimbatore during the late *Kharif* 2019 and late *Rabi* 2019-20 seasons to quantify the impact of induced moisture stress (MS) at critical stages (10, 15, 20 & 25 days from panicle initiation and flowering) on physiological traits and yield of rice. The experiment was laid-out in randomized complete block design (RCBD) with three replications. During both seasons, physiological traits (photosynthetic rate, stomatal conductance, transpiration rate and chlorophyll index) were recorded after the MS period (10, 15, 20 and 25 days) at both critical stages. The experimental results revealed that MS of any period and any stage (panicle initiation and flowering) reduced the values of all physiological traits, grain and straw yields in both seasons. The MS period of 25 days from panicle initiation significantly reduced all physiological parameters, including rice yield.

Key words*:* Rice, moisture stress, panicle initiation, flowering, physiological traits, grain yield.

Rice is the main food grain of India's burgeoning population and is cultivated throughout the country under different agro-climatic and ecological conditions. When compared to other crops, rice requires more water (4,000 to 5,000 litres per kg of grain produced). Among the crops cultivated in India, rice consumes about 80% of the total available irrigation water. Therefore, any savings of water for the rice crop would have a greater influence on the water consumption of crops in the country.

Climate change is likely to have a significant impact on food supply, sustainability, accessibility and changes in water quantity and quality. It is projected that climate change would threaten food security and increase the risks associated with the availability of food among rural populations, particularly in the arid and semi-arid tropics (IPCC, 2021). Lee and Dang (2019) predicted that owing to climate change, there is a possibility of an increase in water demand and subsequently, a decrease in rice production.

Moisture stress is one of the important stresses in plants and if it persists, it harms the growth, development and production (Osakabe *et al*., 2014; Vanaja *et al.,* 2017; Kimani *et al.,* 2022). Moisture stress had a negative impact on several physiological traits in crops (Sharma and Kumar, 2014). Water is the most essential input for rice crops throughout their growth, but the panicle initiation and flowering stages are more critical (Yang *et al.,* 2019) and a deficit in these stages leads to a reduction in growth and yield. However, the influence of moisture stress in these two critical stages (panicle initiation and flowering) on various physiological traits of rice remains unknown. Hence, the present field study was made to investigate the different physiological impacts due to induced moisture stress at these critical stages (panicle initiation and flowering) and their influence on rice yield.

MATERIALS AND METHODS

The field experiment was carried out at Wetland farm of Tamil Nadu Agricultural University, Coimbatore during the late *Kharif* (July to November) 2019 and late *Rabi* (December to March) 2019-20 seasons. The experimental site is located at 11.0 °N latitude, 77.0 °E longitude and 426.7 m from MSL. Mean annual rainfall

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received is 746.5 mm with 47 rainy days at the experimental site. The soil of the experimental site is clay loam in texture with low available nitrogen (213.2–238.4 kg ha^{-1}), high available phosphorus (42.0–47.2 kg ha^{-1}) and potassium (642.8–1046.8 kg ha^{-1}).

The field experiment comprised of nine treatments: T_1 – moisture stress (MS) for 10 days from panicle initiation (PI), T_2 – MS for 15 days from PI, T_3 – MS for 20 days from PI, T_4 – MS for 25 days from PI, T_5 – MS for 10 days from flowering, T_6 – MS for 15 days from flowering, T_7 – MS for 20 days from flowering, T_8 – MS for 25 days from flowering and T_9 – control (SRI method of irrigation). The experiment was laid out in a randomized complete block design (RCBD) with three replications.

At the field level, moisture stress (MS) was induced by completely withdrawing water from the respective treatment plots and ceasing irrigation for the duration specified as per treatment. A 30-cm-high polythene sheet was inserted on all four sides of the plots to prevent water seepage. Irrigation was resumed on the plots after the MS periods of 10, 15, 20 and 25 days for treatments T_1, T_2, T_3 and T_4, respectively, during the PI stage. Similarly, at the flowering stage, irrigation was re-started at 10, 15, 20 and 25 days after moisture stress (DAMS) for treatments T_5, T_6, T_7 and T_8, respectively. Treatment T_9 (control) was given irrigation after visualizing the hair-line cracks in the field as specified in the system of rice intensification (SRI) method. All intercultural operations were carried out in accordance with the crop production guide (CPG, 2019) as specified for the rice crop.

The observations on photosynthetic rate (µmol CO_2 m^{-2} s^{-1}), transpiration rate (mmol H_2O m^{-2} s^{-1}) and stomatal conductance (mol H_2O m^{-2} s^{-1}) were measured using the portable photosynthetic system (PPS). The chlorophyll index was quantified using a SPAD meter.

Observations were made on the third leaf from the top of the rice canopy between 1100 and 1200 hrs. The observation was made at 10, 15, 20 and 25 DAMS in both PI and flowering stages during both the late *Kharif* and late *Rabi* seasons. Grain yield and straw yield were accounted after harvest in the net plots and the harvest index was worked out as per standard procedure. The grains from each net plot (after removing the border and sampling rows) were collected, cleaned, sun-dried to reach the moisture content of 14%. The grain yield was then weighted and expressed in kilograms per hectare. The straw obtained from each net plot area was sun-dried and weighed. The straw yield was expressed in kilograms per hectare. The harvest index was calculated based on the formula.

$$HI = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

A correlation is also established between physiological parameters and yield to ascertain their relationship.

RESULTS AND DISCUSSION

The experimental results during both the late *Kharif* and late *Rabi* seasons indicated that MS during PI and flowering stages had significantly reduced the physiological parameters and the yield of rice. Reinforcing irrigation after MS had improved the values of all the physiological parameters studied in rice.

Photosynthetic rate (Pn, µmol CO_2 m^{-2} s^{-1})

The experimental results inferred that MS had significant influence on photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) at all the times of observation (Table 1). Generally, extending the period of MS, gradually reduced the photosynthetic rate (Pn) in both the stages. Evading from MS had increased the Pn values gradually and significantly. During PI stage of late *Kharif* 2019 season, the treatments T_1, T_2, T_3 and T_4 on 10 DAMS, recorded on par and significantly lower P_n (37.41, 37.56, 37.55 and 37.60 µmol CO_2 m^{-2} s^{-1}, respectively) than other treatments. On 15 DAMS, MS continued treatments (T_2, T_3 and T_4) recorded lower P_n than other treatments (T_5, T_6, T_7, T_8 and T_9) and MS relieved treatment (T_1). Similarly, the treatments T_3 and T_4 on 20 DAMS and the treatment T_4 on 25 DAMS (which were continued with MS) recorded significantly lower P_n compared with other treatments and MS reassured treatments. The treatment T_4 continuously measured the lowest P_n throughout the period (10, 15, 20 and 25 DAMS).

At flowering stage, treatment T_7 recorded lower P_n (28.57 µmol CO_2 m^{-2} s^{-1}) than other MS relieved treatments at PI stage (T_1, T_2, T_3 and T_4) and control barring treatments T_5, T_6 and T_8. The MS imposed treatments such as T_6, T_7 and T_8 on 15 DAMS; and T_7 and T_8 on 20 DAMS continued to record significantly lower P_n over other treatments. Treatment T_8 documented the minimum Pn throughout flowering stage. During late *Rabi* 2019-20 season, the same pattern of results was obtained on photosynthetic rate due to the influence of moisture stress. There was a positive correlation (0.630* and 0.573* at PI stage and 0.410* and 0.442* at flowering stage during late *Kharif* and late *Rabi* seasons, respectively) between P_n and grain yield which indicated the direct relationship among them.

Field results clearly indicated that MS had reduced the P_n and when the stress was relieved (by irrigating the field), the P_n values increased gradually depending on the MS period during both the seasons (late *Kharif* 2019 and late *Rabi* 2019-20). The decrement in P_n due to the MS was mainly due to the reduction of leaf area and further it might have inhibited the functions of photosynthetic machinery (damaging chlorophyll pigments, thylakoid membrane and reduction of PS II activity). The MS may also cause the closure of stomata, thereby reduces the CO_2 availability for photosynthesis. Reduction in P_n under severe water stress (30% field capacity) than mild water stress (50% field capacity) in drought tolerant varieties of wheat crop was documented earlier by Akhkha *et al*. (2011). Similarly, reduction of P_n due to MS in soybean (Mutava *et al*., 2015), maize (Vanaja *et al*., 2017), rice (Yang *et al*., 2019) and wheat (Zhao *et al*., 2020) reported earlier supports the present study results.

Transpiration rate (mmol H_2O m^{-2} s^{-1})

The experimental results on transpiration rate during two seasons (late *Kharif* and late *Rabi*) were presented in Table 2. It inferred that MS had significant influence on the transpiration rate of rice in all the times of observation during both stages (PI and flowering). During both late *Kharif* and late *Rabi* seasons,

Table 1: Effect of moisture stress on photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) in rice

Treatments	Late *Kharif* 2019								Late *Rabi* 2019-20							
	Panicle initiation stage				Flowering stage				Panicle initiation stage				Flowering stage			
	10	15	20	25	10	15	20	25	10	15	20	25	10	15	20	25
T_1	37.41	38.51	40.52	41.85	37.74	35.11	31.66	29.99	30.85	32.76	34.22	35.64	39.56	40.82	35.77	32.82
T_2	37.56	35.29	37.54	41.36	35.82	33.19	29.74	28.07	30.53	29.68	32.48	34.32	39.10	40.36	35.31	32.36
T_3	37.55	35.38	31.67	41.56	35.40	32.77	29.32	27.77	30.55	29.04	27.44	30.46	37.28	38.54	33.50	30.54
T_4	37.60	35.57	31.57	27.52	34.18	31.55	28.10	26.43	30.42	29.31	27.38	24.35	31.52	34.76	29.72	26.76
T_5	44.61	44.07	42.56	42.62	31.61	29.99	25.54	23.87	35.74	35.32	36.92	38.75	31.17	34.41	29.36	26.41
T_6	44.50	43.71	41.81	42.45	31.23	28.60	25.15	23.48	35.42	35.29	36.94	38.77	31.33	28.87	23.83	21.54
T_7	44.64	44.25	42.05	42.58	31.20	28.57	23.12	21.45	35.64	35.27	36.84	38.67	31.19	28.73	19.77	16.82
T_8	44.56	43.43	42.33	42.82	31.62	28.99	22.87	18.87	35.36	35.19	36.71	38.54	31.14	28.68	19.64	14.35
T_9	44.65	43.70	42.41	42.41	37.58	34.95	31.50	29.83	35.95	35.48	37.16	38.99	41.71	42.60	37.56	34.60
SEd	0.21	0.26	0.47	0.51	0.42	0.43	0.43	0.40	0.44	0.53	0.29	0.29	0.17	0.16	0.18	0.27
CD (5%)	0.44	0.55	0.99	1.08	0.91	0.90	0.91	0.85	0.92	1.11	0.62	0.61	0.35	0.35	0.37	0.56

Table 2: Effect of moisture stress on transpiration rate (mmol H_2O m^{-2} s^{-1}) in rice

Treatments	Late *Kharif* 2019								Late *Rabi* 2019-20							
	Panicle initiation stage				Flowering stage				Panicle initiation stage				Flowering stage			
	10	15	20	25	10	15	20	25	10	15	20	25	10	15	20	25
T_1	1.807	2.383	3.570	4.917	5.590	4.960	3.623	3.073	1.049	1.665	2.640	3.851	5.834	4.877	3.335	2.380
T_2	1.773	1.740	2.987	4.147	5.233	4.603	3.593	2.990	1.355	1.162	2.122	3.325	5.146	4.189	2.647	1.749
T_3	1.740	1.820	0.687	2.030	4.497	3.853	3.127	2.523	1.362	1.142	0.602	1.818	3.972	3.015	1.473	0.482
T_4	1.820	1.593	0.527	0.430	3.923	3.293	3.273	2.660	1.379	1.164	0.628	0.176	2.463	1.506	0.114	0.063
T_5	3.757	4.457	5.130	6.167	2.167	1.493	0.783	0.227	4.170	4.652	5.174	5.609	3.247	2.290	0.748	0.471
T_6	3.707	4.407	5.107	6.153	1.943	0.723	0.143	0.147	4.274	4.756	5.273	5.708	3.275	2.118	0.576	0.464
T_7	3.570	4.270	4.970	5.993	2.207	0.987	0.100	0.113	4.089	4.572	5.083	5.518	3.185	2.028	0.094	0.032
T_8	3.807	4.507	5.207	6.237	2.373	1.153	0.113	0.060	4.036	4.519	5.020	5.455	3.193	2.036	0.149	0.024
T_9	3.833	4.533	5.233	6.263	5.657	5.017	4.310	2.833	4.186	4.668	5.182	5.617	6.421	5.897	3.922	3.005
SEd	0.305	0.285	0.330	0.319	0.302	0.302	0.203	0.181	0.165	0.157	0.157	0.148	0.089	0.081	0.083	0.057
CD (5%)	0.647	0.603	0.701	0.676	0.640	0.639	0.431	0.384	0.346	0.328	0.327	0.342	0.187	0.169	0.162	0.137

treatments (T_1, T_2, T_3 and T_4) on 10 DAMS at PI stage recorded significantly lower transpiration rate than non-stressed treatments (T_5, T_6, T_7 and T_8) and control (T_9). Transpiration rate at 15 and 20 DAMS at PI stage also in the same trend indicating that imposing MS reduced the values of transpiration rate during both the seasons (late *Kharif* and late *Rabi*). On 25 DAMS, the treatment T_4 recorded the minimum transpiration rate (0.430 and 0.176 mmol H_2O m^{-2} s^{-1} during late *Kharif* and late *Rabi* seasons, respectively).

At flowering stage, treatments (T_5, T_6, T_7 and T_8) on 10 DAMS recorded significantly lower transpiration rate than MS relieved treatments at PI stage (T_1, T_2, T_3 and T_4) and control (T_9) during both seasons. Other times of observation also, imposing MS had reduced the transpiration rate significantly and after relieving MS, the transpiration rate values increased. The transpiration rate and grain yield in rice crop was positively correlated (0.619* and 0.581* at PI stage and 0.367 and 0.402* at flowering stage during late *Kharif* and late *Rabi* seasons, respectively) and it can be inferred that transpiration rate influences rice grain yield directly.

In general, MS had reduced the transpiration rate of rice and relieving MS, increased it. The reduction in transpiration rate due to MS was mainly due to the decrement of soil-plant hydraulic conductance which could have altered the stomatal regulation and thereby reducing the transpiration rate. Akram *et al*. (2013) also reported that PI stage was the most sensitive for drought stress in respect with reduction of transpiration rate (48.11%) followed by anthesis (28.51%) and grain filling (5.54%) stages in rice. Decline of transpiration rate due to water deficit condition was also reported earlier (Khan *et al*., 2017) in other crops.

Stomatal conductance (gs, mol H_2O m^{-2} s^{-1})

Generally, irrespective of stages (PI and flowering) and seasons (late *Kharif* and late *Rabi*), MS had significantly altered the stomatal conductance in rice crop (Table 3). The stomatal conductance (gs) of rice was significantly altered due to imposing MS at all the measured times in the PI stage. On 10 DAMS, treatment T_4 recorded significantly lower gs value of 1.149 and 1.462 mol H_2O m^{-2} s^{-1} during late *Kharif* and late *Rabi* seasons, respectively than other non-stressed treatments (T_5, T_6, T_7, and T_8) and control (T_9). But T_4 treatment was on par with other MS imposed treatments (T_1, T_2 and T_3) with respect to gs. On 15 DAMS, treatment T_4 accounted lower stomatal conductance (1.084 mol H_2O m^{-2} s^{-1} during late *Kharif* and 1.397 mol H_2O m^{-2} s^{-1} during late *Rabi* seasons) than non-stressed treatments, control and MS relieved treatment (T_1). The treatment T_4 continued to record lower gs values on 20 and 25 DAMS (0.926 and 0.777 mol H_2O m^{-2} s^{-1} during late *Kharif* and 1.239 and 1.090 during late *Rabi*, respectively). However, treatment T_4 was on par with T_3 and T_2 on 15 DAMS and T_3 alone on 20 DAMS.

Table 3: Effect of moisture stress on stomatal conductance (mol CO_2 m^{-2} s^{-1}) in rice

Treatments	Late *Kharif* 2019								Late *Rabi* 2019-20							
	Panicle initiation stage				Flowering stage				Panicle initiation stage				Flowering stage			
	10	15	20	25	10	15	20	25	10	15	20	25	10	15	20	25
T_1	1.179	1.234	1.315	1.368	1.590	1.543	1.447	1.071	1.492	1.547	1.628	1.681	1.903	1.856	1.760	1.383
T_2	1.156	1.091	1.172	1.225	1.552	1.505	1.409	1.033	1.469	1.404	1.485	1.538	1.865	1.818	1.722	1.346
T_3	1.169	1.105	0.947	1.000	1.484	1.437	1.342	0.966	1.482	1.418	1.260	1.313	1.797	1.750	1.655	1.279
T_4	1.149	1.084	0.926	0.777	1.265	1.218	1.123	0.747	1.462	1.397	1.239	1.090	1.578	1.531	1.436	1.060
T_5	1.355	1.389	1.460	1.568	1.354	1.307	1.211	0.835	1.668	1.702	1.773	1.881	1.667	1.620	1.524	1.148
T_6	1.352	1.386	1.457	1.565	1.351	1.254	1.159	0.782	1.665	1.699	1.770	1.878	1.664	1.567	1.472	1.095
T_7	1.359	1.392	1.463	1.573	1.370	1.273	1.096	0.720	1.672	1.705	1.776	1.886	1.683	1.586	1.409	1.033
T_8	1.356	1.389	1.460	1.568	1.356	1.258	1.082	0.409	1.669	1.702	1.773	1.881	1.669	1.571	1.395	0.722
T_9	1.389	1.423	1.494	1.605	1.652	1.605	1.509	1.134	1.702	1.736	1.807	1.918	1.965	1.918	1.822	1.447
SEd	0.020	0.020	0.020	0.019	0.027	0.027	0.027	0.264	0.020	0.020	0.020	0.019	0.027	0.027	0.027	0.264
CD (5%)	0.042	0.042	0.042	0.041	0.056	0.057	0.056	0.561	0.042	0.042	0.042	0.041	0.056	0.057	0.056	0.561

Table 4: Effect of moisture stress on chlorophyll index (%) in rice

Treatments	Late *Kharif* 2019								Late *Rabi* 2019-20							
	Panicle initiation stage				Flowering stage				Panicle initiation stage				Flowering stage			
	10	15	20	25	10	15	20	25	10	15	20	25	10	15	20	25
T_1	34.40	35.63	36.73	38.67	38.33	37.43	32.33	28.83	34.40	34.73	36.10	36.00	32.60	31.27	29.40	26.60
T_2	35.27	32.44	34.27	36.43	37.37	36.43	31.50	28.07	34.43	33.83	32.93	35.00	32.63	31.53	29.63	26.67
T_3	34.93	32.43	29.73	33.40	35.43	34.40	29.13	25.63	34.87	33.67	31.40	30.53	32.67	31.67	29.43	26.60
T_4	35.33	32.77	29.47	27.40	30.40	29.40	24.20	20.70	34.83	33.43	31.07	29.50	32.73	32.00	29.40	26.60
T_5	43.67	43.67	44.67	43.80	34.40	33.73	28.23	24.73	36.70	36.80	36.30	36.23	30.40	30.57	29.47	26.67
T_6	43.87	44.43	44.80	44.07	34.47	32.53	27.37	23.60	36.70	36.70	36.43	36.67	30.50	29.13	28.47	26.33
T_7	43.80	44.63	44.70	44.07	34.40	32.70	26.23	22.73	36.60	36.67	36.57	36.47	30.57	29.30	27.50	25.67
T_8	43.70	44.50	43.63	43.33	34.40	32.33	26.17	21.33	36.77	36.57	36.50	36.17	30.50	29.00	27.60	24.00
T_9	44.40	44.87	44.03	43.83	40.27	38.37	33.23	29.73	36.97	36.83	36.77	36.57	33.00	32.10	29.60	27.00
SEd	0.46	0.39	0.38	0.52	0.30	0.28	0.27	0.26	0.40	0.37	0.51	0.68	0.32	0.56	0.50	0.54
CD (5%)	0.97	0.83	0.81	1.10	0.64	0.60	0.58	0.57	0.85	0.79	1.10	0.45	0.68	1.18	1.07	1.14

At flowering stage, on 10 DAMS, stomatal conductance results expressed that MS imposed treatments (T_5, T_6, T_7 and T_8) recorded significantly lower gs values than continuously irrigated treatment (T_9) and MS relieved treatments at PI stages (T_1, T_2, T_3 and T_4). In other times of observation, MS had reduced the gs values significantly and reassurance of moisture through irrigation causes gradual increase in gs values. The correlation between the gs and grain yield was positive (0.676* at PI stage and 0.487* at flowering stage during late *Kharif* and 0.603* at PI stage and 0.429* at flowering stage during late *Rabi* seasons) and significant.

The reduction of gs due to MS might be because MS could accumulate more ABA in plant leaves that damage the stomatal aperture and also decrease the assimilate partitioning due to reduced level of internal CO_2. Several studies also indicate the reduction of gs in rice crop under drought condition (Khan *et al*., 2017).

Chlorophyll index (%)

The effect of MS at PI and flowering stages on chlorophyll index during both late *Kharif* and late *Rabi* seasons were presented in Table 4. Extending the period of MS had reduced the chlorophyll index values in rice crop generally. On 10 DAMS, at PI stage, treatment T_1 recorded lower chlorophyll index (34.40) compared to other treatments during both seasons. However, T_1 was statistically on par with T_2, T_3 and T_4.

On 15 DAMS, the treatment T_3 recorded significantly lower chlorophyll index (32.43%) during late *Kharif* season and T_4 treatment recorded lower chlorophyll index (33.43%) during late *Rabi* season than other treatments. The MS relieved treatment (T_1) recorded more chlorophyll index values (35.63 and 34.73%, respectively during late *Kharif* and late *Rabi* seasons). Similarly, MS relieved treatments, i.e., T_1 and T_2 on 20 DAMS and T_1, T_2 and T_3 on 25 DAMS recorded significantly more chlorophyll index values than MS continued treatments.

The observation at flowering stage indicated that the MS imposed treatments (T_5, T_6, T_7 and T_8) recorded significantly inferior chlorophyll index values than control on 10 DAMS. Also, the moisture relieved treatments at PI stage (T_1, T_2, T_3 and T_4) slowly increased the chlorophyll index values. Similar trend was observed during the other times of observation. Correlation analysis between chlorophyll index and grain yield resulted a positive and significant values (0.675* and 0.645* at PI stage and 0.492* and 0.501* at flowering stage, respectively during late *Kharif* and late *Rabi* seasons).

Generally, imposing MS at any stage or duration, reduced the chlorophyll index values. Moisture stress would increase the photo-oxidation rate resulted in over production of reactive oxygen species that damage the chloroplast membrane led to more lipid peroxidation and finally, destruction of chloroplast. The MS had

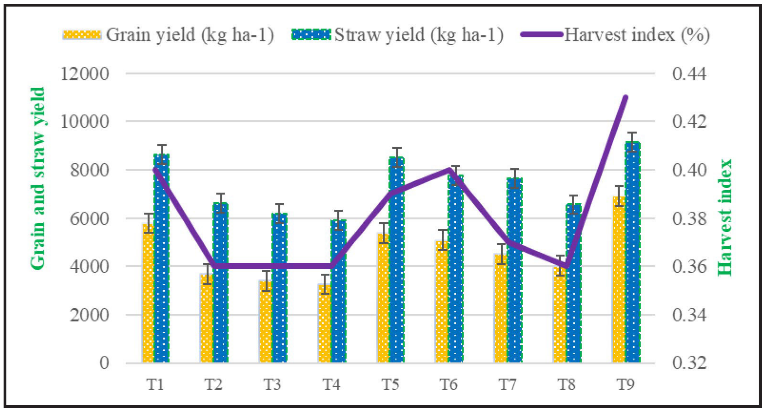

Fig. 1: Effect of moisture stress on yield of rice during late *Kharif* season

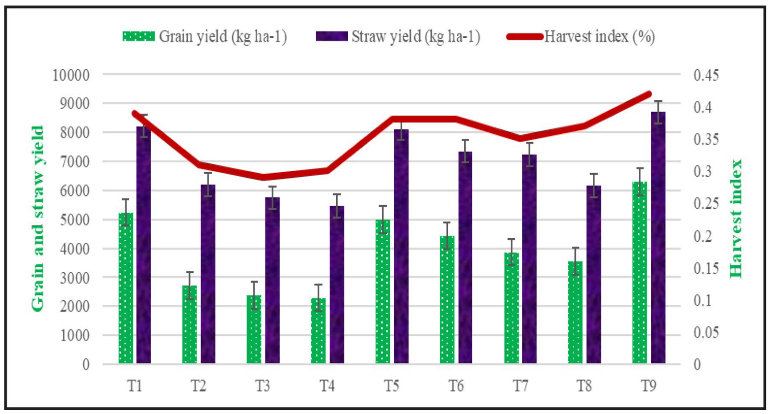

Fig. 2: Effect of moisture stress on yield of rice during late *Rabi* season

reduced the chlorophyll viability and the leaves were converted from green to yellow in different rice genotypes. Chutia *et al*. (2012) revealed that chlorophyll-a and chlorophyll-b and total chlorophyll content were decreased under water stress condition in different rice genotypes. Singh *et al*. (2018) also documented a decreased chlorophyll a and b, SPAD value under reduced soil moisture conditions in different rice genotypes. This is also in line with Xu *et al*. (2020) who studied the moisture stress influence on photosynthetic parameters under drip irrigation system and mulching.

Rice yield

There was a significant variation in grain yield, straw yield and harvest index of rice due to MS during late *Kharif* and late *Rabi* seasons (Fig. 1 and 2).

Uninterrupted supply of moisture through irrigation as per SRI method (T_9) had produced significantly higher grain yield (6915 and 6300 kg ha^{-1} during late *Kharif* and late *Rabi* season, respectively) than all other treatments, followed by T_1. The grain yield penalty was more pronounced due to MS for 25 days at PI stage (52.84% and 63.57% during late *Kharif* and late *Rabi* seasons, respectively), followed by MS for 20 days at PI stage (50.52% and 62.14% during late *Kharif* and late *Rabi* seasons, respectively) compared to control. Reduction of grain yield was more during MS at PI stage than flowering stage with the same stress period. Similar trend was also observed in the straw yield and harvest index (Fig. 1 and 2).

The MS had reduced the physiological parameters as evidenced in the present study and in turn ultimately influenced on the grain yield. Reduction of tiller production, leaf area index and dry matter production due to MS directly influenced on straw yield. Early works had also reported similar kind of results on grain yield (Wang *et al*., 2016) and straw yield (Venkatesan *et al.,* 2005).

CONCLUSIONS

The present field study concluded that the moisture stress of any duration (10, 15, 20 and 25 days) at panicle initiation and flowering stages had significant influence on all physiological parameters (photosynthetic rate, transpiration rate, stomatal conductance and chlorophyll index) of rice during both *Kharif* and *Rabi* seasons. Extended period of moisture stress for 25 days either during panicle initiation stage or during flowering stage recorded much lower physiological traits values. Moisture stress period during panicle initiation stage was more detrimental on rice yield than flowering stage. The correlation between physiological parameters and grain yield was also positive in both the stages (panicle initiation and flowering) and indicated a direct relationship between them.

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