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Effect of drought on growth, leaf rolling, plant-water status and yield of rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted at Raipur during the dry season of 1999 and 2000 to study the effect of drought at panicle initiation stage on growth, leaf rolling, plant-water status and yield of rice. Drought significantly decreased the plant height and leaf area index. Significant varietal variations were observed in terms of capacity to maintain water status, leaf rolling and yield stability under drought. 'Kranti' maintained higher leaf relative water content up to the end of drought spell and was related with yield stability. The studies showed that leaf rolling under drought is governed by leaf water status. The result also indicated that varieties with bigger plant size suffered more due to drought compared to smaller plant size.

Key words : Rice, Yield stability, Drought, Relative water content, Leaf rolling

Drought is commonly considered the most severe limitation to the productivity of rice in rainfed rice-growing area. In Chhattisgarh, rice is grown in about 3.9 million ha, of which 80% is rainfed. In rainfed crop, drought may occur at any stage of crop growth in general and reproductive stage in particular leading to partial or total crop failure. Under such conditions, identification of drought tolerant varieties and the traits responsible for drought tolerance become very important to sustain the productivity in the region. Two approaches can be followed to improve the drought tolerance in rice, i.e. to select varieties directly for yield under drought conditions or select indirectly using physiological or morphological traits associated with drought tolerance or combination of both of these strategies. The studies on selection for yield under drought conditions in the dry season (rain-free period) are relevant to test the yield stability of the varieties. Among the selection based on secondary traits, leaf relative water status (Sullivan, 1971) and leaf rolling can be used as a selection criteria. The present studies examine the performance of 7 rice varieties under

drought conditions at panicle initiation stage in terms of yield stability and ability to maintain growth and leaf water status.

MATERIALS AND METHODS

A field experiment was conducted at Raipur during dry season of 1999 and 2000. The average annual rainfall of this region is 1,300 mm, most of which is received from third week of June to third week of September and a very little rainfall from January to second week of June. The experimental soil was clay in texture containing 0.077% available N, 9.4 mg/kg available phosphorus and 0.698 cmol/kg available potassium with pH 7.5. The experiment was conducted in split plot design keeping water regime (irrigated and drought) in main plots and 7 varieties in subplots replicated thrice. The varieties were staggered in the nursery to match the phenological stages during the drought spell. A distance of 2 m was provided between replications and plots to prevent the water movement between plots during drought spell. Drought was imposed for 2 weeks by withdrawing the irrigation in drought plots. There was no rain during the drought spells in both the years. The average volumetric soil moisture was 17% and 21% at the end of drought spell during 1999 and 2000 respectively. Drought plots were re-irrigated after 2 weeks of drought. In irrigated plots, water was maintained at 5 ± 2 cm throughout the growth period. Plant height, dry matter production, LAI and tiller number were recorded before releasing the drought spell from irrigated and drought plots. Leaf rolling was recorded by using 1-5 scale, 1 being flat and 5 tightly rolled. The rating was done on the last day of the drought spell at 1400 hr.

RESULTS AND DISCUSSION

Effect of drought

Drought caused significant effect on plant height, leaf area index, unfilled grains, test weight and grain yield of rice (Tables 1 and 2). The dry matter and tillering were, however, not affected by drought. Irrigated crop recorded markedly higher values of plant height, LAI, test weight and grain yield while it had lower percentage of unfilled grains. The results revealed that among the growth attributes, plant height and LAI were relatively more sensitive to drought than tillering. Over the seasons, the grain yield reduced by 40.8% due to drought when compared with irrigated crop.

Varietal performance

Varieties differed significantly in terms of growth and yield attributes and grain yield in both the seasons except tillering in 2000 (Tables 1 and 2). Varieties 'IR 42342' and 'IR 20' were taller than other varieties. However, variety 'R 405A 4' recorded identical plant height to these 2 varieties in 1999 but had dwarfer plants to these varieties in the next season (2000). 'Kranti' produced the dwarfest plants among all the varieties. Varieties 'IR 42342', 'IR 20' and 'R 405A 4' had relatively higher dry matter accumulation than other varieties. 'Kranti' in 1999 and 'Shyamla' in 2000 recorded the lowest dry matter.

Varieties showed differential behaviour to drought in terms of LAI. Drought caused marked reduction in LAI over irrigated

crop in all the varieties except 'Shymala' in both the seasons and 'Mahamaya' in 1999 (Table 4). Varieties also behaved differently to drought in 2 seasons. In 1999, 'IR 42342' being on par with 'R 405 A 4' recorded higher LAI over other varieties under irrigated conditions while in 2000, 'R 405 A 4' was on par with all other varieties except 'Kranti' which recorded the lowest LAI. Under drought conditions, LAI among the varieties was not perceptible in 2 seasons, except in 1999 where 'Kranti' had markedly lower LAI than 'Shymala', 'IR 42342' and 'R 405 A 4'. These findings

Table 1. Growth attributes of rice varieties under irrigated and drought conditions

Treatment	Plant height (cm)		Dry matter (g/m²)		Leaf area index		Number of tillers/m²	
	1999	2000	1999	2000	1999	2000	1999	2000
Water regime								
Irrigated	76.7	72.5	417.2	521.8	2.56	3.55	324.8	362.9
Drought	64.4	62.4	369.8	391.0	1.92	2.34	280.2	320.6
CD (P=0.05)	4.5	4.0	NS	NS	0.26	1.11	NS	NS
Variety								
'IR 20'	76.7	76.5	409.0	516.8	2.18	3.32	334.2	391.0
'Kranti'	61.3	59.6	329.7	398.2	1.99	2.41	320.5	319.4
'R 405 A 4'	79.8	69.8	443.9	507.3	2.45	3.27	304.3	320.1
'Shyamla'	62.0	59.0	366.7	306.3	2.23	2.86	266.2	355.5
'IR 42342'	78.7	74.5	440.1	509.8	2.62	2.95	278.2	343.1
'Mahamaya'	66.7	65.4	387.9	462.2	2.04	2.71	253.8	318.7
'R 650-1817'	68.7	67.4	377.0	494.2	2.19	3.10	360.2	344.4
CD (P=0.05)	5.5	4.0	60.9	61.9	0.29	0.45	50.7	NS

Table 2. Grain yield and its components in rice varieties under irrigated and drought conditions

Treatment	Unfilled grains (%)		Test weight (g)		Grain yield (t/ha)		Pooled
	1999	2000	1999	2000	1999	2000	
Water regime							
Irrigated	35.2	33.0	21.66	22.22	5.27	4.88	5.07
Drought	64.6	61.9	17.58	20.07	2.46	2.48	2.47
CD (P=0.05)	20.8	18.7	4.03	1.31	0.73	0.14	0.31
Variety							
'IR 20'	49.8	43.8	14.98	16.15	3.47	4.05	3.76
'Kranti'	48.5	44.1	20.93	23.75	3.32	3.46	3.39
'R 405 A 4'	60.3	48.6	17.31	20.38	2.92	3.76	3.34
'Shyamla'	51.9	42.2	21.05	21.46	2.67	2.85	2.76
'IR 42342'	46.4	61.9	20.55	21.43	4.71	3.00	3.85
'Mahamaya'	37.4	44.2	23.31	24.31	5.88	4.20	5.04
'R 650-1817'	55.0	47.2	19.23	20.12	4.07	4.46	4.26
CD (P=0.05)	10.2	8.1	1.23	1.20	0.72	0.83	0.66

suggested that varieties with bigger plant canopy suffered more due to drought because limited moisture cannot maintain the turgidity of larger canopy. This has also been substantiated by the findings that leaf rolling due to drought was lower in 'Shyamla' and 'Kranti' than 'IR 42342' and R 405 A 4' (Table 3). At the end of the drought spell, the leaf relative water content (RWC) was higher in the former 2 varieties compared to the latter 2 varieties and 'IR 20' indicating that small plant size varieties maintained higher RWC during drought. A higher reduction of leaf RWC in bigger plant canopies could be associated with higher water loss from its canopy. Pantuwan *et al.* (2001) also observed that large plants were disadvantaged because they use more water and experienced higher water deficit than did smaller plants. The results further indicated that leaf rolling under drought is governed by leaf RWC. O'Toole and Moya (1978) also reported that genotypes maintaining higher leaf water potential tend to maintain low rolling. Variety 'R 650-1817' being on par with 'IR 20' and 'Kranti' recorded more number of tillers than other varieties in 1999.

Varieties also differed under irrigated and drought conditions in terms of grain filling in 2000 (Table 4). Under irrigated conditions, variety 'IR 42342' being on par with 'R 405 A 4', 'Shyamla' and 'R 650-1817' recorded higher percentage of non-filled grains than other varieties. Under drought conditions also, 'IR 42342', recorded the maximum non-filled grains, being markedly inferior to 'Shyamala' and 'R 405 A 4'. In general, the grain filling was poor in 'IR 42342' under both the conditions and in 'IR 20' under drought conditions. 'Mahamaya' produced bolder seeds than other varieties in both the seasons, except 'Kranti' in 2000, where both were on par. 'IR 20' had the lowest test weight in both the seasons.

Over the seasons, 'Mayamaya' recorded significantly higher yield over all other varieties (Table 2). This could be ascribed to higher grain filling and test weight of this variety. 'Shyamla' was the lowest yielding variety but was on par with 'R 405 A 4' and 'Kranti'. The interaction effect in 1999 (Table 4) revealed that 'Mahamaya' being

Table 3. Grain yield and its components in rice varieties under irrigated and drought conditions

Variety	Leaf rolling score		Relative water content (%)	
	1999	2000	1999	2000
'IR 20'	3.70 ab	3.61 c	65.21 de	67.21 b
'Kranti'	2.11 c	2.03 e	78.25 a	82.88 a
'R 405 A 4'	4.63 a	4.66 b	63.38 e	65.10 b
'Shyamla'	1.82 c	1.97 e	75.25 ab	80.16 a
'IR 42342'	4.00 ab	4.97 a	65.36 de	63.21 b
'Mahamaya'	2.99 bc	3.28 d	72.22 bc	78.66 a
'R 650-1817'	3.68 ab	3.30 d	69.11 cd	79.66 a

Means followed by a common letter are not significantly different at the 5% level by DMRT

Table 4. Interaction effect of water regime x variety on growth and yield attributes and yield of rice

Water regime	Variety						
	'IR 20'	'Kranti'	'R 405 A 4'	'Shyamla'	'IR 42342'	'Mahamaya'	'R 650-1817
				Leaf area index (1999)			
Irrigated	2.54	2.40	2.87	2.35	3.18	2.14	2.49
Drought	1.83	1.59	2.04	2.11	2.06	1.94	1.89
CD (P=0.05)							
Between water regimes at the same variety	0.42						
Between varieties at the same water regime	0.45						
				Leaf area index (2000)			
Irrigated	3.93	2.73	4.26	3.13	3.57	3.30	3.94
Drought	2.70	2.10	2.29	2.59	2.33	2.12	2.26
CD (P=0.05)							
Between water regimes at the same variety	0.63						
Between varieties at the same water regime	1.18						
				Unfilled grains (%) (2000)			
Irrigated	21.3	24.6	43.3	38.6	47.9	22.6	32.9
Drought	66.3	63.7	54.0	45.8	75.9	65.8	61.6
CD (P=0.05)							
Between water regimes at the same variety	11.4						
Between varieties at the same water regime	20.1						
				Grain yield (t/ha) (1999)			
Irrigated	5.25	4.27	4.68	3.54	6.35	7.57	5.21
Drought	1.69	2.37	1.17	1.80	3.07	4.19	2.92
CD (P=0.05)							
Between water regimes at the same variety	1.01						
Between varieties at the same water regime	1.40						

on par with 'IR 42342' under irrigated conditions and also on par with 'R 650-1817' under drought conditions produced higher yield over other varieties. The magnitude of reduction in grain yield due to drought was lower (43.9-44.6%) in 'R 650-1817' 'Kranti' and 'Mayamaya', while it was the highest (67.8%) in 'IR 20'. The higher reduction in yield of 'IR 20' was related with poor grain filling and lower test weight under drought conditions, consequently resulting in low yield stability of the variety.

The higher yield stability of 'Kranti' under drought was related with low leaf rolling and higher leaf relative water content (Table 3). The maintenance of high RWC under drought can be due to higher water uptake from the soil or low water loss from the canopy. The results showed that the capacity to maintain high internal plant water status during drought is the key to yield stability. These results are in agreement with those of Jongdee (1998).

The results further indicated that varieties with smaller canopy perform relatively better under drought conditions.

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