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ROLE OF SECONDARY TRAITS IN IMPROVING THE DROUGHT TOLERANCE DURING FLOWERING STAGE IN RICE

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SUMMARY

Studies were conducted to examine the role of different secondary traits in improving the flowering stage drought tolerance in rice. Six varieties were exposed to drought for three weeks during flowering stage. The tolerant varieties maintained leaf temperature lower than air temperature under drought. The maintenance of lower leaf temperature was related with higher transpiration rates with the help of higher root to shoot ratio. It was found that maintenance of higher plant water status under drought plays a central role in stabilizing the various plant processes and yield. A strong relationship between leaf water potential with delay in flowering and membrane stability was observed under drought. Drought delay flowering in all varieties, and a larger delay in flowering was related with higher spikelet sterility and lower gain yield. It is concluded that flowering delay due to drought is an strong indicator of drought susceptibility. The less delay in flowering, high leaf water status, higher root to shoot ratio, low leaf temperature and higher membrane stability under drought contributes significantly to flowering stage drought tolerance in rice.

Key words : **Drought tolerance, flowering stage, rice, secondary traits.**

INTRODUCTION

Over half of the world's rice is grown in rainfed fields where drought, often decreases yield. However the progress towards yield improvement in rainfed areas has been slow as compared to irrigated rice ecosystem (Mackill *et al.* 1996). Water shortage can develop any time during crop growth, however, drought around flowering stage is a recurrent phenomena in rainfed regions. Water shortage during flowering and grain filling stages reduces yield drastically (Boonjung and Fukai 1996). Indirect selection using morpho-physiological characteristics can improve the drought tolerance in rice. Several putative traits have been identified for drought tolerance in rice, however, the usefulness of these traits has not been fully evaluated in relation to yield advantages/stability under flowering stage drought.

Genotypic variation in maintaining internal plant water status at flowering was associated with grain yield under drought (Pantuwan *et al.* 2001). The maintenance of plant water status, more than plant functions, controls crop performance under drought (Blum 2002). The mechanism controlling internal plant water status may involve water uptake/or water conservation by the plant and also internal plant water conductance during drought. Plant water status can differ significantly among cultivars exposed to the same period of water exclusion (O'Toole and Moya 1978). In rice, these differences are related to variation in stomatal control of transpiration (Dingkuhn

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et al. 1989), water extraction (Lilley and Fukai, 1994) and variation in canopy size at the onset of stress (Mitchell *et al.* 1998). Membrane stability was associated with drought tolerance in rice (Tyagi *et al.* 1999). Delay in flowering under drought was linked with drought susceptibility (Pantuwan *et al.* 2001). Higher root to shoot ratio and canopy cooling was also associated with drought tolerance in various crops. Photosynthetic stability under drought was described as an important index of drought tolerance (Smith and Hurd 1979). The current study examines the role of different secondary traits in improving the flowering stage drought tolerance in rice.

MATERIALS AND METHODS

The studies were conducted at Instructional Farm of Indira Gandhi Agricultural University, Raipur during wet season 2000 and repeated in 2001. The plastic PVC pipes of one-meter length and twenty cm diameter were used for studies. The PVC pipes were buried in the ground up to 80 cms. The experiment was conducted with six varieties (Mahamaya, Kranti, Indira A-9, R-405-A-4, R-827-287, Shyamla) in five replicates using RCBD (factorial) design. These varieties were selected from medium maturity group. Total duration of varieties included in the studies ranges from 128 to 135 days under irrigated conditions. Drought was imposed one week before flowering for three weeks. Panicle initiation stage was used as a basis to calculate the expected date of flowering. Rainout shelters were used to protect the plants from rains during drought spell. The net photosynthetic rate, leaf temperature, ambient temperature, stomatal conductance and transpiration were measured with the help of a portable photosynthesis system (Model-6400, Li-Cor, U.S.A.) for two days continuously after two weeks of imposing drought. Photosynthesis rate and associated characteristics were measured during 09.30 and 10.30 hrs. Leaf water potential was measured using a pressure chamber (Model-1003, PMS Instrument company, U.S.A.) for two days continuously from 11.00 to 11.30 hrs after two weeks of imposing drought. The mean of two days (after two weeks of drought) was calculated for above measurements and analyzed statistically. Delay in flowering was estimated by comparing the flowering in irrigated pipes. Flowering was recorded when 50% of plants shows flowering (anthers of the terminal spikelets protrude and shed pollen) on the mother tiller. After completing (before re-irrigation) the drought spell of three weeks root and shoot samples were collected for estimation of root to shoot ratio. For estimation of membrane stability, leaf disc (0.5 g) were thoroughly washed in running tap water and double distilled water. After washing leaves were placed in double distilled water at 40°C for 30 minutes. After that the electric conductivity (C_1) of the sample was recorded by conductivity bridge (Elico India, Model CM-180). Subsequently the samples were placed in boiling water bath (100°C) for 10 minutes and electrical conductivity was recorded as above (C_2). The membrane stability index (MSI) was measured after two weeks of drought spell and was calculated as follows :

$$MSI = [1 - (C_1/C_2)] * 100$$

The stastistical analysis and relationships were performed as per the method described by the Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Two weeks of drought spell significantly reduced the leaf water potential. The reduction in leaf water potential was highest in R-405-A-4 (-2.53 Mpa) and lowest in Kranti (-1.55 Mpa). The maintenance of higher leaf water status was linked with root to shoot ratio. The root to shoot ratio increased in Kranti, while a decrease was observed in R-405-A-4 under drought conditions. The higher partitioning of dry matter into roots helps in water extraction from deeper soil layers in drying soil and maintains higher water potential. The leaf water potential is recognized as an index for whole plant water status and maintenance of high leaf water potential and is considered to be associated with dehydration avoidance mechanism (Levitt 1980). The high leaf water potential in Kranti was responsible for photosynthetic stability under drought compared to other varieties (Table 1). It was found that stomatal conductance also controls the photosynthetic rate in drying soil. The transpiration rate significantly decreased due to drought. Mahamaya and Kranti maintained higher transpiration rates under drought compared to other varieties, which indicates that increased root to shoot ratio under drought keeps the aerial plant parts well supplied with water in these varieties.

The results on days to flower and yield components are presented in Table 2. In all varieties the flowring was

Table 1. Effects of drought on photosynthesis, stomatal conductance and transpiration under irrigated and drought conditions.

Water Regime (W)	Varieties (V)	Photosynthesis rate ($\mu mol\ m^{-2}\ s^{-1}$)	Stomatal conductance ($mol\ m^{-2}\ s^{-1}$)	Transpiration ($mmol\ m^{-2}\ s^{-1}$)
Irrigated	Indira A-9	22.84	0.78	9.67
	Kranti	17.69	0.68	7.85
	Mahamaya	21.25	0.89	8.88
	R-405-A-4	23.72	0.93	11.11
	R-827-287	17.11	0.66	7.58
	Shyamla	16.63	0.63	5.64
I-Mean		19.87	0.76	8.45
Drought	Indira A-9	1.95	0.09	1.02
	Kranti	9.63	0.28	2.11
	Mahamaya	9.88	0.29	2.68
	R-405-A-4	3.69	0.11	1.35
	R-827-287	5.21	0.18	1.62
	Shyamla	4.88	0.13	1.25
D-mean		5.87	0.18	1.67
CD (5%)	W	0.71	0.07	0.97
	V	0.86	0.06	0.66
	(V x W)	2.15	0.21	1.85

Table 2. Time to flowering and yield characteristics under irrigated and drought conditions.

Water Regime (W)	Varieties (V)	Flowering (Days)	Grain yield hill $^{-1}$ (g)	Spikelet Sterility (%)	Test weight (gram)
Irrigated	Indira A-9	98	14.56	28.98	17.12
	Kranti	91	16.29	26.68	21.95
	Mahamaya	96	18.25	22.58	24.78
	R-405-A-4	102	20.12	31.58	19.25
	R-827-287	99	12.24	23.33	12.85
	Shyamla	96	11.05	28.22	19.69
I-Mean		97	15.41	26.89	19.27
Drought	Indira A-9	107	3.80	69.25	15.68
	Kranti	93	9.87	38.22	21.21
	Mahamaya	98	9.98	41.28	22.89
	R-405-A-4	108	5.68	64.58	17.02
	R-827-287	103	4.98	54.28	11.25
	Shyamla	101	4.66	49.66	17.25
D-mean		101	6.49	52.87	17.55
CD (5%)	W	3.96	2.68	8.25	NS
	V	2.86	1.92	5.38	1.21
	(V x W)	3.83	2.72	NS	NS

delayed due to drought. Such delay in flowering was highest (9 days) in Indira A-9 and lowest in Kranti and Mahamaya (2 days). The leaf-air temperature differed among varieties. Under irrigated conditions, leaf temperature was lower than air temperature, however drought increased the leaf temperature. The leaf temperature of Kranti and Mahamaya was lower than air temperature, while other varieties increased the leaf temperature under drought conditions (Fig. 3). The maintenance of leaf temperature lower than air temperature shows that higher transpiration in these varieties helped in canopy cooling. Jackson (1982) also reported that canopy temperature is a function of leaf transpiration rate. The membrane stability was recorded lower in Indira-A-9 and R-405-A-4 after two weeks of drought, shows that low leaf water status cannot support the membrane stability. Higher leaf water status of Kranti and Mahamaya was associated with higher membrane stability.

The study clearly indicate that maintenance of higher plant water status under drought plays a central role in stabilizing the various plant processes and yield. A strong relationship between leaf water potential under drought was observed with delay in flowering (r = -0.79**) and membrane stability (r = 0.89**). The maintenance of higher leaf water poential under drought was achieved by higher root to shoot ratio (Fig 1 & 4). The varieties with larger delay in their flowering under drought recorded

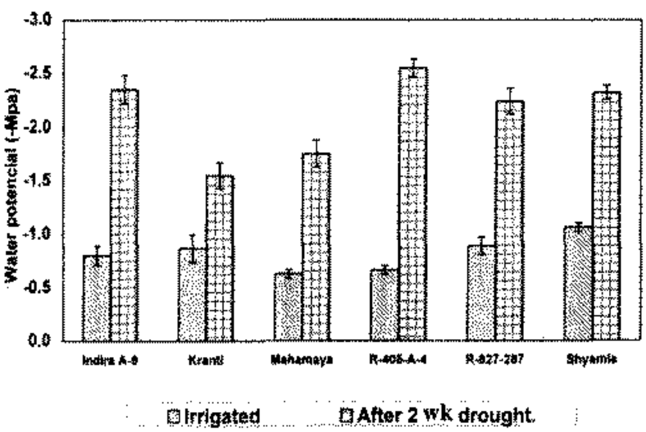

Fig. 1. Water potential under irrigated and drought conditions

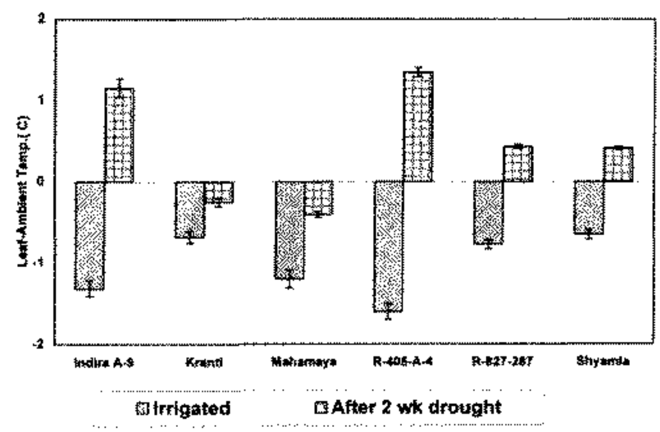

Fig. 3. Leaf-ambient temperature under irrigated and drought conditions

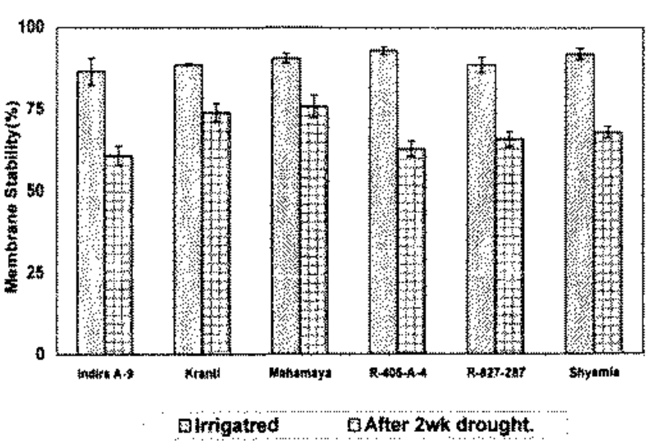

Fig. 2. Membrane stability under irrigated and drought conditions

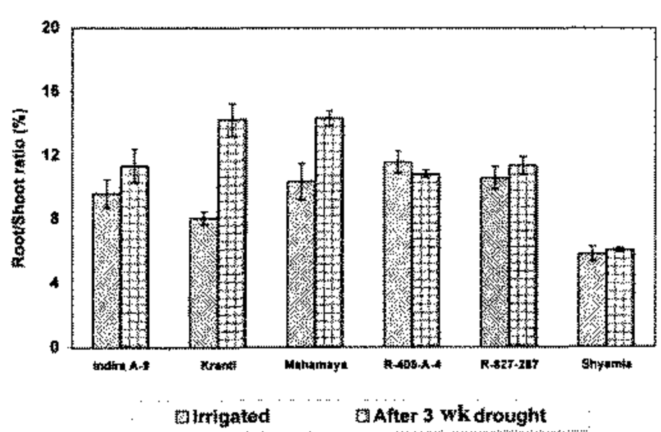

Fig. 4. Root/Shoot ratio under irrigated and drought conditions

Error bars indicate ± SE of means

higher spikelet sterility and lower grain yield because they flowered when soil moisture was lower. A strong relationship between delay in flowering with spikelet sterility (r = 0.94**) and grain yield (r = -0.83**) was observed under drought conditions. It can be concluded that delay in flowering due to drought is a result of low plant water status and higher delay in flowering can be related to drought susceptibility. Pantuwan *et al.* (2001) also reported that delay in flowering is a strong indication of drought susceptibility in rice. The less delay in flowering, high leaf water status, higher root to shoot ratio, photosynthetic stability, lower leaf temperature and higher membrane stability under drought contributes significantly to flowering stage drought tolerance in rice. These traits can be used as indirect selection criteria to improve the grain yield stability of rice under drought.

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