EFFECT OF DROUGHT AT FLOWERING STAGE ON YIELD AND YIELD COMPONENTS OF RAINFED LOWLAND RICE

Prabhasmita Shatpathy*, Arti[1], Surendra Pratap Singh[2], Shishir Kant Singh[3] and Satendra Kumar[4]

Department of Plant Physiology, OUAT, Bhubaneswar, Odisha, India
[1]Department of Crop Physiology, NDUAT, Kumarganj, Faizabad, U.P., India
[2] Central Rice Research Institute, Cuttack, Odisha, India
[3]Department of Agronomy, NDUAT, Kumarganj, Faizabad, U.P., India
[4]Department of Soil Science, SVPUAT,Meerut, U.P., India
Email: pshatpathy@yahoo.com

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Abstract: Drought is a major factor limiting rice production in India. Its occurrence at flowering stage is very common in rainfed lowland rice which leads to a considerable yield reduction or even crop failure some times. The study was therefore, contemplated to determine the effect of drought stress at flowering stage on yield and some yield attributing parameters of four rice varieties viz., IR-42, NDR 8002, BPT 5204 and TCA-48. The experiment was carried out in plastic tubs in a completely randomized design with three replications. Varieties were subjected to three water stress treatments (saturated or 100% available soil moisture regime (ASMR), 50% ASMR, 25% ASMR) at flowering stage by withholding water application. The study revealed that drought reduced significantly the grain yield and yield attributing characters, EBT plant^{-1}, test weight, panicle length, total grains panicle^{-1} and fertile grains panicle^{-1} of all the varieties; but to a greater extent at 25% ASMR. Sterility of varieties under saturated condition varied from 11 to 16%, which increased to the tune of 17 to 32% and 26 to 40% under 50% and 25% ASMR, respectively. Significant drought and varieties interaction effects were exhibited for EBT plant^{-1}, sterile grains panicle^{-1} and fertile grains panicle^{-1}, indicating significant differences of drought levels and genetic differences for these traits. Amongst the varieties, NDR-8002 and TCA-48 were noted to be relatively more drought tolerant than others on the basis of assessment of their yield performance.

Keywords: Rice, Flowering stage, Drought, Yield

INTRODUCTION

Drought is the most important abiotic constraint that reduces yield of rice in rainfed areas (Bernier *et al.*, 2009). It is estimated that 50% of the world's rice production is affected more or less by drought (Bouman *et al.*, 2005). It frequently occurs in those areas, which solely depend on rainfall for irrigation. In eastern India, around 10 million ha area under rice is rainfed lowland. Stable and high yields of rainfed lowland rice are important for food security in many of the subsistence farming system in Asia (Cooper, 1999). In rice, the effect of drought varies with the variety, degree and duration of stress and its coincidence with different growth stages (Kato, 2004). In contrast with other crops, rice is particularly more sensitive to water stress especially at critical growth stages such as panicle initiation, flowering and grain filling (Tao *et al.*, 2006, Yang *et al.*, 2008). Drought at flowering stage is highly detrimental to rice plants. It hampers anthesis and seed setting leading to higher spikelet sterility and lower yield in rice (Ram *et al.*, 1988). It also reduces effective leaf area and photosynthesis, thus plants have to depend on pre-anthesis reserves which may impart tolerance against internal water deficits (Austin *et al.*, 1980). Though plants have naturally evolved several stress adaptive strategies, most of them pertain to survival of plants under stress. However, from the agricultural point of view, any stress adaptive strategy, drought stress in particular, would be useful only if it is associated with superior crop yield under a given stressful environment (Kar *et al.* 2005). Response of different plants to water stress is much complex and various mechanisms are adopted by plants when they encounter drought stress at various growth stages (Levitt, 1980; Jones, 2004). Even behaviour of genotypes within a species is also different. So, one of the strategies to abate drought stress is selection of a genotype expressing comparatively better drought tolerance (Suriyan *et al.*, 2010). It is, therefore necessary to study the performance of genotypes under water stress with the objective of improving crop performance in the drought prone areas of India. Hence, the present endeavour was an attempt to assess the impacts of drought stress at flowering stage on the performance of the rice varieties in terms of the yield and yield components.

MATERIAL AND METHOD

The present study was carried out in plastic tubs at the experimental site of the Department of Crop Physiology, N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) during *Kharif* season of 2011. The experiment consisted four rice varieties (viz. IR-42, NDR 8002, BPT 5204, TCA-48) and three drought treatments (saturated or 100% available soil moisture regime (ASMR), 50%

*Corresponding Author

ASMR, 25% ASMR) which was imposed at flowering stage. The experiment was planned in completely randomized design (Factorial) with three replications. The soil was silt loam type having a pH of 7.8. The native N, P and K contents were 124 kg/ha, 18 kg/ha and 220 kg/ ha respectively. Seeds were directly sown in tubs. Thinning was done in each tub after seedling emergence and only ten healthy and uniform plants were maintained. Plants under saturated condition were irrigated normally. 50% and 25% ASMR was maintained by withholding irrigation in tubs. After 4 days of water withholding in tubs, soil sampling was done periodically and moisture content was computed. When moisture content in soil reached to 14.5% in 50% ASMR and 10.75% in 25% ASMR, drought treatment was terminated by irrigating the tubs. Yield and yield components were recorded at harvest of the crop as follows:

No. of EBT (ear bearing tiller) /plant

EBT were counted on tagged plants and average was taken to express number of EBT/plant.

Panicle length (cm)

Panicle lengths at maturity in each treatment were measured from the base to the apex of panicle with the help of a meter scale.

Total grains/panicle

Grains were carefully separated from panicles of tagged plants and total number of grains per panicle was counted for each treatment.

Fertile and Sterile grains/ panicle

After carefully separating the grains from panicles of tagged plants, total number of fertile and sterile grains per panicle was counted for each treatment.

Sterility percentage

The sterility percentage was calculated as: (total number of sterile grains/ total number of grains) x 100.

Test weight

1000 seeds from each treatment were counted and weighted for assessing test weight in each treatment.

Grain yield (g/plant)

Panicles of tagged plants were separated from plant. Then grains were collected and weighed with the help of electronic balance.

Statistical Analysis

The statistical analysis of experimental data was done by the method described by Panse and Sukhatme (1978) using completely randomized design (CRD) factorial experiment. The comparison of the treatment means made with the help of least significant differences ($P<0.05$).

RESULT

EBT /plant

A close perusal of the data evidently revealed a drastic reduction in EBT/plant of all varieties under both moisture stresses and maximum reduction was observed at 25% ASMR (Table 1). At 50% ASMR, only IR-42 showed significant reduction in EBT/plant over saturated condition, while at 25% ASMR, all varieties exhibited significant reduction. Under both 50% and 25% ASMR, highest EBT were found in NDR-8002. Per cent decrease in EBT at both 50% and 25% ASMR with respect to saturated condition were less in TCA-48 and NDR-8002, while IR-42 had highest reduction. Mean effect of variety showed highest number of EBT in NDR-8002 followed by BPT-5204, IR-42 and TCA-48. Mean effect of stress indicated that reduction in EBT was about double at 25% ASMR as compared to 50% ASMR.

Panicle length

The panicle length reduced significantly due to moisture stress (Table1). Extent of reduction was relatively higher at 25% ASMR as compared to 50% ASMR. Reduction in panicle length at 50% and 25% ASMR over saturated condition varied from 12 (NDR-8002) to 22% (IR-42) and 16 (NDR-8002) to 32% (IR-42), respectively. Thus, it is clear that under both moisture stresses, lowest and highest reduction in panicle length were found in NDR-8002 and IR-42 respectively. Mean effect of variety showed highest panicle length in NDR-8002 followed by TCA-48, while BPT-5204 had lowest. Mean effect of stress indicated 17.1% and 23.1% reduction in panicle length at 50% and 25% ASMR, respectively over saturated condition.

Table 1. Effect of drought at flowering stage on EBT/plant and panicle length of rainfed lowland rice

Varieties	Number of EBT/plant				Panicle length (cm)			
	Saturated condition	50% ASMR	25% ASMR	Mean	Saturated condition	50% ASMR	25% ASMR	Mean
IR-42	6.67	5.34 (19.9)	4.37 (34.5)	5.46	22.3	17.39 (22.0)	15.16 (32.0)	18.28

NDR-8002	7.43	7.00 (5.7)	6.27 (15.6)	6.90	32.1	28.24 (12.0)	26.96 (16.0)	29.10
BPT-5204	5.57	5.03 (9.6)	4.48 (19.6)	5.02	20.4	16.12 (20.9)	14.80 (27.4)	17.10
TCA-48	5.00	4.71 (5.8)	4.43 (11.4)	4.71	26.7	22.4 (16.10)	21.09 (21.0)	23.40
Mean	6.17	5.52 (10.5)	4.89 (20.7)		25.37	21.03 (17.1)	19.50 (23.1)	
SEm	V = 0.13	D = 0.11	V x D = 0.23		V = 0.54	D = 0.47	V x D = 0.94	
CD at 5%	V = 0.38	D = 0.33	V x D = 0.66		V = 1.56D = 1.35		V x D = NS	

(Note: Values in parenthesis indicate per cent decrease due to 50% and 25% ASMR calculated over saturated condition; ASMR- Available Soil Moisture Regime)

Total grains/panicle

Number of total grains per panicle as influenced by drought at flowering stage has been given in Table 2. All the varieties showed marked reduction in total grain number at both 50% and 25% ASMR, however magnitude of reduction was more at 25% ASMR. Per cent reduction in total grains per panicle at 50% ASMR over saturated condition ranged from 8.5 to 17.9% which increased to the tune of 12.7 to 25.5% at 25% ASMR. At both 50% and 25% ASMR, minimum per cent reduction in total grains was observed in NDR-8002 followed by TCA-48, BPT-5204 and IR-42. Mean effect of variety indicated highest grain number in BPT-5204 which was significantly higher than other varieties.

Fertile grains/ Panicle

Like total grains, numbers of fertile grain per panicle were also decreased at 50% and 25% ASMR and maximum decrease was found at 25% ASMR (table 2). All the varieties showed significant reduction in fertile grains at 50% and 25% ASMR over saturated condition. At both 50% and 25% ASMR, maximum fertile grains were found in NDR-8002 which was at par to BPT-5204 and significantly higher than other varieties. Per cent reduction in fertile grains at 50% and 25% ASMR over saturated condition varied from 15.3 (NDR-8002) to 35.9% (IR-42) and 27.9 (NDR-8002) to 42.51% (IR-42), respectively. Mean effect of variety showed highest fertile grain in BPT-5204 which was at par to NDR-8002 and significantly higher than other varieties. Mean effect of stress indicated 25.5% and 36.6% reduction in fertile grains at 50% and 25% ASMR, respectively over control.

Table 2. Effect of drought at flowering stage on total grains and fertile grains/panicle of rainfed lowland rice

Varieties	Number of total grains/panicle				Number of fertile grains/panicle			
	Saturated condition	50% ASMR	25% ASMR	Mean	Saturated condition	50% ASMR	25% ASMR	Mean
IR-42	94.75	77.72 (17.9)	70.61 (25.5)	81.03	82.43	52.78 (35.9)	42.51 (48.4)	59.24
NDR-8002	139.00	127.23 (8.5)	121.36 (12.7)	129.20	124.26	105.22 (15.3)	89.56 (27.9)	106.35
BPT-5204	160.00	133.51 (16.6)	126.12 (21.2)	139.88	141.76	96.93 (31.6)	83.62 (41.0)	107.44
TCA-48	120.5	105.00 (12.9)	99.13 (17.7)	108.21	100.35	79.28 (21.0)	69.09 (31.1)	82.91
Mean	128.56	110.86 (13.8)	104.30 (18.9)		112.20	83.55 (25.5)	71.19 (36.6)	
SEm	V = 2.85	D = 2.47	V x D = 4.95		V = 2.14	D = 1.85	V x D = 3.71	
CD at 5%	V = 8.26	D = 7.15	V x D = NS		V = 6.19	D = 5.36	V x D = 10.72	

(Note: Values in parenthesis indicate per cent decrease due to 50% and 25% ASMR calculated over saturated condition; ASMR- Available Soil Moisture Regime)

Sterile grains/ Panicle

All varieties recorded significant increase in sterile grains per panicle at 50% and 25% ASMR over saturated condition (Table 3). At both 50% and 25% ASMR, BPT-5204 recorded significantly higher number of sterile grains than rest of the varieties. Lowest numbers of sterile grains were observed in NDR-8002 and IR-42 at 50% and 25% ASMR, respectively. Mean effect of varieties indicated highest number of sterile grains in BT-5204 followed by TCA-48, NDR-8002 and IR-42. Mean effect of stress showed 40.6% and 51% increase in sterile grains per panicle at 50% and 25% ASMR, respectively over saturated condition.

Sterility percentage

A tremendous increase in sterility percentage of all varieties was found due to moisture stresses at flowering stage (Table 3). Sterility of varieties under saturated condition varied from 10.6 to 16.3%, while at 50% and 25% ASMR, it varied from 17.3 to 32.1% and 26.2 to 39.8%, respectively. Under both 50% and 25% ASMR, lowest sterility % was observed in NDR-8002 and highest in IR-42. Mean effect of variety showed highest sterility % in IR-42 followed by BPT-5204, TCA-48 and NDR-8002.

Table 3. Effect of drought at flowering stage on sterile grains /panicle and sterility % of rainfed lowland rice

Varieties	Number of sterile grains/ panicle				Sterility (%)			
	Saturated condition	50% ASMR	25% ASMR	Mean	Saturated condition	50% ASMR	25% ASMR	Mean
IR-42	12.31	24.94 (50.6)	28.10 (56.2)	21.78	13.00	32.1	39.8	28.3
NDR-8002	14.73	22.01 (33.1)	31.80 (53.7)	22.84	10.6	17.3	26.2	18.0
BPT-5204	18.24	36.58 (50.1)	42.50 (57.1)	32.44	11.4	27.4	33.7	24.2
TCA-48	19.64	25.73 (23.7)	30.04 (34.6)	25.14	16.29	24.5	30.3	23.7
Mean	16.23	27.31 (40.6)	33.11 (51.0)		12.82	25.3	32.5	
SEm	V = 0.63	D = 0. 54	V x D = 1.09		-	-	-	
CD at 5%	V = 1.82	D = 1.58	V x D = 3.16		-	-	-	

(Note: Values in parenthesis indicate per cent decrease due to 50% and 25% ASMR calculated over saturated condition; ASMR- Available Soil Moisture Regime)

Table 4. Effect of drought at flowering stage on test weight (1000 grains) and grain yield of rainfed lowland rice

Varieties	Test weight (g)				Grain yield (g $plant^{-1}$)			
	Saturated condition	50% ASMR	25% ASMR	Mean	Saturated condition	50% ASMR	25% ASMR	Mean
IR-42	27.76	24.61 (11.3)	23.84 (14.11)	25.40	16.41	11.32 (31.0)	8.50 (48.2)	12.07
NDR-8002	33.31	31.98 (4.0)	31.31 (6.5)	32.20	23.01	19.09 (17.0)	15.60 (32.2)	19.23
BPT-5204	23.21	21.95 (5.4)	20.26 (12.7)	21.80	20.01	14.80 (26.0)	11.40 (43.0)	15.40
TCA-48	30.82	28.81 (6.5)	28.13 (8.7)	29.25	19.36	15.10 (22.0)	12.00 (38.8)	15.48
Mean	28.77	26.83 (6.7)	25.88 (10.0)		19.70	15.08 (23.4)	11.87 (39.7)	
SEm	V = 0.65	D = 0. 56	V x D = 1.12		V = 0.38	D = 0. 32	V x D = 0.65	
CD at 5%	V = 1.88	D = 1.63	V x D = NS		V = 1.09	D = 0. 94	V x D = NS	

(Note: Values in parenthesis indicate per cent decrease due to 50% and 25% ASMR calculated over saturated condition; ASMR- Available Soil Moisture Regime)

Test weight

Test weight as influenced by moisture stress at flowering stage has been given in Table 4. All varieties showed a marked decrease in test weight at 50% and 25% ASMR with respect to saturated condition. Per cent reduction in test weight at 50% ASMR over saturated condition varied from lowest 4 (NDR-8002) to highest 11.3% (IR-42), while at 25% ASMR, it varied from lowest 6.5 (NDR-8002) to highest 14.1% (IR-42). Mean effect of variety showed highest test weight in NDR-8002 followed by TCA-48, IR-42 and BPT-5204.

Grain yield/plant

Moisture stress at flowering stage caused a severe reduction in grain yield of all varieties (Table 4). Per cent reduction in grain yield at 50% ASMR over saturated condition ranged from 17 to 31% which increased to the tune of 32.2 to 48.2% at 25% ASMR. Under both moisture stresses, minimum per cent reduction in grain yield was found in NDR-8002 followed by TCA-48, while IR-42 had highest reduction. Mean effect of varieties showed highest grain yield in NDR-8002 followed TCA-48, BPT-5204 and IR-42. Mean effect of stress exhibited 23.4% and 39.7% reduction in grain yield at 50% and 25% ASMR, respectively over saturated condition.

DISCUSSION

Yield of any crop is dependent on the combination of genetic makeup, physiological processes and yield attributes and any degree of imbalance in the said parameters may hamper the crop yield. Moreover, availability of sufficient water supply is inevitable to ensure maximum crop harvest in rice being a water loving crop (Basu *et al.* 2010). In the present experiment, the effect of moisture stress at flowering stage was clearly reflected in great reduction in almost all the yield traits measured. EBT/plant, panicle length, total grains per panicle, fertile grains per panicle, test weight and grain yield were markedly reduced under moisture stresses, however reduction in above traits were more at 25% ASMR in comparison to 50% ASMR. Since, grain yield is the product of EBT number, panicle length, fertile grains per plant and individual grain weight, hence reduction in all these components under moisture stresses accounted for decrease in grain yield. Similar to our findings reduction in grains per panicle, per cent filled grain and 1000 grain weight have been observed due to water stress in rice (IRRI, 1984). Yambao and Ingram (1988) also reported that water stress near flowering can reduce the number of fertile spikelet drastically. Our results also support the work of Sarvestani *et al.* (2008) who observed reduction in total biomass, harvest index, filled grain, unfilled grain and 1000 grain weight under water stress in rice cultivars. He also reported that water stress at flowering stage had a greater grain yield reduction than other times.

Flowering stage was more sensitive to water stress for 1000- grain weight, fertile grains per panicle and sterile grains per panicle leading to substantial decrease in these parameters. Water stress at flowering stage caused a significant reduction in grain size and grain weight which may be due to hindered translocation of assimilates towards grain filling resulting in decreased paddy yield due to hampered stomatal and hydraulic conductance. Pantuwan *et al.* (2002) and Cattivelli *et al.* (2008) also have reported hampered paddy yield because of drought stress at critical growth stages.

It was also observed that sterility % of different varieties increased with increase in moisture stress level. Similar to our results, Lafitte (2002) reported that drought stress around flowering time causes dramatic yield reduction due to spikelet sterility. According to O'Toole and Numuco (1983) decreased panicle exertion is a causal factor of spikelet sterility in water stressed rice.

The well watered plants had, more yield (g/plant), a higher fertility percentage and higher yields as compared to those subjected to water deficit. Similar results were reported by Yeo *et al*. (1996) who observed that water deficit reduces yield in *Oryza sativa*. Bouman and Toung (2001) also had similar results and concluded that rice crops are susceptible to drought which causes large yield losses in many countries. Yield depends on accumulation of dry matter and on its partitioning (Baruah *et al*., 2006). Grain yield of rice may be limited by the supply of assimilates to the developing grain (source limitation) or by the capacity of the reproductive organ to accept assimilates (sink capacity) (Sikuku *et al*., 2010). Low yield under drought treatments may be due to less number of ear bearing tillers per plant, reduction in total grain number per panicle, increase in sterile grains and a greatly decreased proportion of fertile grains and reduction in 1000- grain weight.

Our findings are in harmony with those of Yang *et al.*, (2001), Venuprasad *et al.*, (2008) and Wang *et al.*, (2010), who have stressed upon taking into account of different yield parameters during screening of rice varieties or while developing new rice varieties for drought prone areas. Similarly, Suriyan *et al.* (2010) has observed the ill effects of drought stress and reported that water deficit stress at the reproductive stage of four indica rice (*Oryza sativa* L.) genotypes adversely affected grain size, weight and ultimately paddy yield of all the varieties under study.

CONCLUSION

The results of present experiment clearly demonstrate that drought at flowering stage causes a severe reduction in grain yield and yield components of rice. Genetic differences were found among varieties for EBT plant^{-1}, sterile grains panicle^{-1} and fertile grains panicle^{-1}. NDR-8002 and TCA-48 recorded relatively lower reduction in grain yield and almost all yield contributing characters measured. These varieties have adaptive features for flowering stage drought tolerance and may be cultivated in drought prone areas and used as tolerant lines under breeding programs.

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