Annals of Arid Zone 31(3) 191-194 1992

Influence of the Duration of Favourable Moisture Between Droughts on Wheat

A N Lahiri, B K Garg, S Kathju, S P Vyas, P C Mali and Uday Burman
Division of Arable Cropping System, Central Arid Zone Research Institute, Jodhpur – 342 003 India

Abstract Diverse effects of 3,6, 9 and 12 days of favourable moisture between two drought cycles on wheat (*Triticum aestivum* L. cv. Kalyan sona) have been reported here. The first cycle of drought imposed for a period of 10 days on separate sets of plants at 51, 54,57 and 60 days after sowing (DAS) caused comparable reductions in plant water potential (ψ plant), relative turgidity (RT%) and grain yield. All these plants were simultaneously subjected to a second cycle of drought at 73 DAS for a uniform period of 9 days. Observations on ψ plant, RT, stomatal resistance and also contents of free amino acids, free proline and soluble protein, at the end of the second drought cycle and 48 h after irrigation, indicated that the adverse effects of water stress were more severe in plants which were given shorter (3 and or 6 days) compared to longer (9 and 12 days) periods of adequate soil moisture between two droughts. Changes in the activities of amylase, nitrate reductase, malate dehydrogenase and glucose-6-phosphate dehydrogenase generally revealed a similar trend. Notwithstanding a larger decline in grain yield under two, as compared to one cycle of drought, the grain yield was also depressed more under shorter (3 and 6 days) as compared to longer (9 and 12 days) period of adequate water supply between the stress events. Evidences provided here show that, among other factors, the period of favourable moisture between droughts has a significant influence on metabolism and crop performance.

Key words Drought cycles, Favourable Moisture period, Metabolism, Performance, *Triticum aestivum*

Field crops may often be subjected to repeated droughts. Certain studies (Levitt 1972, Singh *et al.*1973) suggest that the initial drought hardens the crops enabling them to withstand the subsequent water stress better. However, others (Sionit *et al.* 1980, Garg *et al.* 1984) did not support this contention. It has also been found (Vyas *et al.* 1990) that early drought upto a certain intensity, may help the plants to partly overcome the adverse effects of the subsequent water stress but greater initial stress under two droughts may cause a cumulative damage. The effects of two cycles of droughts on plants may also depend on the developmental stage at which stress is experienced (Sionit *et al.* 1980, Garg *et al.* 1984). But in none of these investigations the importance of favourable moisture period between the two droughts, has received any special attention. An attempt has been made here to generate some information in this area.

Materials and Methods

Wheat (*Triticum aestivum* L. cv. Kalyansona) were grown in pots (2 plants in each) with 10 kg of loamy sand soil supplemented with 80 kg ha^{-1} each of N and P_2O_5. Water was withheld from separate sets of 30 pots at 51, 54, 57 and 60 DAS for a period of 10 days and these were irrigated 61,64,67 and 70 DAS, respectively. Thirty undroughted pots watered frequently, served as controls. Sets of 10 pots from each of the treatment were frequently watered till maturity to ascertain the influence of a single cycle of drought on the grain yield. In the remaining 20 pots under each of the treatments except the control plants, irrigation was suspended at 73 DAS for a uniform period of 9 days to subject them to a 2nd cycle of drought. Thus different sets of plants were allowed 12,9, 6 and 3 days of favourable soil moisture ('wet' period) between two droughts. After the 2nd drought plants from all treatments were frequently watered till harvest (28 days after the termination of the 2nd drought).

Dry matter and grain yield of plants which experienced two cycles of drought, with variable wet periods were recorded from ten replicates (pots).

Plant water potential (ψ plant) was measured by a Pressure Chamber (PMS Instrument Company, USA) just before watering in the 1st and 2nd cycle of drought and also 2 days after the termination of the 2nd drought. The relative turgidity (RT %) of fully expanded uppermost leaf (Slayter and McIlroy 1961) and the stomatal resistance (LI-1600 Steady State Porometer) of the adaxial surface of leaves were also measured at the same time. Uppermost two fully expanded leaves of plants of each treatment were analysed (Garg *et al.* 1984) for changes in the levels of free amino acids, free proline and soluble protein. Activities of nitrate reductase (Jaworski 1971), amylase (Shain & Mayer 1968), malate dehydrogenase (MDH) (Davies & Kunn 1957) and glucose 6 phosphate dehydrogenase (G-6-PDH) (Kirkman 1962) were estimated an hour before the termination of the second drought and 48h after rewatering.

Results and Discussion

Data presented in Table 1 indicate that the plant water status, as well as the yield was adversely affected due to droughts at 51, 54, 57 and 60 DAS as compared to the control. The maximum stress experienced by plants in different cases were comparable notwithstanding slight differences in age. Although yield was significantly reduced due to drought in all cases as compared to the control but differences among treatments were not significant. It may be mentioned here that Ψ plant and RT % of the control as well as the prestressed plants after the last irrigation prior to the on-set of the 2nd drought cycle, were comparable and these ranged between -1.2 to -1.3 MPa and 80.1 to 86.9% respectively.

The data under Table 2 indicate that at the point of maximum water stress, in the 2nd cycle of drought, plant water status was more favourable in plants which were allowed 'wet' periods of 9 and 12 days between the drought events as compared to those allowed shorter periods of 3 and 6 days. After 48h of the termination of the 2nd cycle of drought ψ plant and RT% of all the treatments became more or less comparable to the control, but these indices under longer 'wet' period (9 and 12 days) between the droughts still remain marginally higher than plants under shorter wet period (3 and 6 days). Stress induced increase in stomatal resistance was also least under 12 days of favourable moisture, but remained significantly higher than the control. The stomatal resistance increased further under 6 and 9 days intervals where the values were comparable. However, the stomatal resistance increased to a higher value when the favourable period of moisture was only 3 days. On rewatering a fast normalization was noted in all cases.

Examination of the levels of certain metabolites (Table 2) at the point of maximum stress development in the 2nd drought cycle indicate that the accumulations of free proline and free amino acids as well as, the reductions in the levels of soluble protein were less in plants which were allowed 9 and 12 days of favourable moisture interlude between two droughts as compared to those under 3 and 6 days. These trends were perceptible even after 48h of irrigation particularly in levels of soluble protein and free proline. A better metabolic status of plants, which were allowed a longer period of favourable moisture between two drought events

Table 1 *Water Status at the point of maximum stress and grain yield (g plant^{-1}) of plants subjected only to the 1st cycle of drought at different DAS, and in the control.*

Observations	Control	Drought at indicated DAS				LSD	
		51	54	57	60	5%	1%
ψplant (-MPa)	1.0 – 1.2	2.2	2.2	2.3	2.2	–	–
RT (%)	83.2 – 81.6	65.4	65.2	65.1	65.3	–	–
Grain yield	3.58	1.73	1.75	1.77	1.87	0.41	0.53

Table 2 *Influence of favourable moisture period between two droughts on plant water status, metabolic parameters at the point of maximum stress (S) and 48h after rewatering (R) of 2nd stress cycle and on dry matter and grain yield*

Parameter		Favourable moisture period (days)					LSD
		Control	3	6	9	12	(5 %)
ψ plant	S	−1.2	−2.0	−2.0	−1.9	−1.7	0.22
(MPa)	R	−1.4	−1.6	−1.5	−1.4	−1.4	NS
RT	S	81.3	68.2	71.2	75.1	77.8	3.6
(%)	R	80.0	79.8	82.2	82.3	81.3	NS
Stomatal	S	4.83	47.40	24.40	25.50	12.70	3.32
resistance (SCm^{-1})	R	2.70	3.19	1.73	2.23	2.43	NS
Soluble protein	S	237.2	142.2	156.9	203.2	193.2	10.9
($mg\ g^{-1}$ dw)	R	201.4	141.1	152.5	199.9	183.1	12.8
Free proline	S	0.56	2.94	1.52	0.68	0.98	0.20
($mg\ g^{-1}$ dw)	R	0.29	0.75	0.84	0.37	0.25	0.18
Free amino acids	S	5.91	11.50	10.87	5.38	6.95	1.16
($mg\ g^{-1}$ dw)	R	5.48	4.61	5.03	5.22	4.01	NS
Amylase (mg Starch	S	53.6	143.2	134.0	130.7	92.7	12.4
hydrolysed $g^{-1} dw\ h^{-1}$)	R	54.6	62.2	46.9	35.1	–	8.4
Nitrate reductase	S	330.1	139.7	152.8	232.4	174.6	18.3
($\mu g\ NO_2\ g^{-1}\ dw\ h^{-1}$)	R	304.6	224.1	247.8	265.1	252.5	23.8
MDH	S	14.03	7.05	7.56	7.48	8.94	0.91
(Δ OD $min^{-1}\ g^{-1}$ dw)x10^5	R	7.82	5.85	5.59	7.32	7.23	1.14
G-6-PDH	S	6.89	4.09	5.09	5.21	5.67	1.04
(Δ OD $min^{-1}\ g^{-1}$ dw)x10^3	R	6.08	4.99	5.72	6.43	5.87	0.84
Grain yield ($g\ plant^{-1}$)	–	3.58	0.65	0.86	1.40	1.53	0.36
Dry matter shoot ($g\ plant^{-1}$)	–	5.10	2.70	2.77	2.84	3.09	0.68

seems to be a definite pointer to the importance of the 'wet' period interlude between the two cycles of water stress. Singh *et al*. (1973) observed in barley that a previous exposure to water stress led to an increased potential for proline accumulation during the subsequent stress. But our earlier study on wheat (Garg *et al*. 1984) did not support this observation. However, the results of the present investigation suggest that among other factors, the time lag between the two cycles of drought may also influence the level of proline accumulation, just as it may alter the levels of other metabolites.

Observations on activities of leaf enzymes further support this contention (Table 2). Amylase activity increased progressively over the control at the point of maximum stress in the second drought cycle by 72.9, 143.8, 150.0 and 167.2% when the period of favourable moisture was 12,9,6 and 3 days respectively. After 48 h of recovery, the level of activity declined below the control under 9 days of favourable period between the two droughts. Similarly the nitrate reductase activity also declined under the second drought but the decrease was less under a long (9 and 12 days) than short (3 and 6 days) well watered period. At recovery, the activity under all the treatments showed a sharp increase confirming to the established pattern (Sinha & Nicholas 1981) but the extent of activity as such, remained relatively higher under the longer period of favourable moisture.

Observations recorded here indicate that the activity of MDH, a key respiratory enzyme of the TCA cycle, declined under 3,6,9 and 12 days of favourable moisture to 49.8,45.1, 46.7and 36.3 % respectively as compared to the control. Post drought rehabilitation of the activity of this enzyme was faster under longer as compared to shorter interval of favourable moisture. Again, it has been reported (Todd 1972) that the activity of G-6-PDH, a key enzyme of hexose monophosphate shunt, declines under severe water stress. A similar trend was noticed here. However, it was interestingly found that its decline at the point of maximum water stress in the second drought cycle was only 17.8% with respect to the control at 12 days of favourable moisture interval while it was 40.7% under 3 days. At recovery, this pattern was not substantially altered.

Table 2 further indicates that the grain yield significantly declined under stress in all cases. However, the yields of plants under 9 and 12 days of 'wet' period between the two cycles of drought were significantly higher than those under 3 and 6 days. Despite the progressive improvement with increasing duration of the favourable 'wet' period, the differences between 3 and 6 days interval, as well as, between 9 and 12 days were not significant. It is again noteworthy that the decline in the yield in the 2nd cycle, as compared to that of the 1st cycle (Table 1) was more under 3 and 6 days of favourable moisture while it was less under 9 and 12 days. But the higher yield under one cycle as compared to two cycles of drought generally suggest a cumulative adverse effect of drought events as noted by certain other workers (Sionit *et al*. 1980, Vyas *et al*. 1987). Again, dry matter production declined under stress but the observed increases with longer 'wet' periods were not large enough to be significant.

Diverse measurements recorded here clearly suggest that the period of favourable moisture between two droughts significantly influence various plant processes. Therefore, changes in performance of plants suffering from two cycles of drought depend not only on intensity and rate of development of stress, stage of growth, species and cultivar but also on the period of adequate water supply between the stress events which regulates the water status and metabolism of plants during the second cycle of drought. However, a field verification of the study is required.

Acknowledgements

Thanks are due to Mr PK Bhardwaj and Mr OP Char for technical help.

References

Davies DD & Kunn E 1957 Isolation and properties of Malic dehydrogenase from Ox heart mitochondria. *Biochemical Journal* **66** 307-316

Garg BK, Vyas SP, Kathju S & Lahiri AN 1984 Influence of repeated water stress on wheat. *Proceedings of the Indian Academy of Science* (Plant Science) **13** 477-484

Jaworski E 1971 Nitrate reductase assay in intact plant tissues. Biochemical and *Biophysical Research Communications* **43** 1274-1279

Kirkman HN 1962 Glucose-6-phosphate dehydrogenase from human Erythrocytes. Further purification and characterization. *Journal of Biological Chemistry* **327** 2364-2370

Levitt J 1972 *Responses of Plants to Environmental Stresses* Academic Press, New York. p. 697

Shain Y & Mayer AM 1968 Activiation of Enzymes during germination " Amylopectin 1, 6-Glucosidase in peas. *Physiologia Plantarum* **21** 765- 776

Singh TN, Paleg LG & Aspinall D 1973 Stress metabolism III. Variations in response to water deficit in the barely plant. *Australian Journal of Biological Science* **26** 65-76

Sinha SK & Nicholas DJ 1981 Nitrate Reductase In : The *Physiology and Biochemistry of Drought Resistance in* Plants (Eds. LG paleg and D Aspinall) Academic Press, New York, 145-169

Sionit N, Teare ID & Kramer PJ 1980 Effects of repeated application of water stress on water status and growth of wheat. *Physiologia Plantarum* **50** 11-15

Slatyer RO & McIlroy IC 1961 Practical *Microclimatology with Special Reference to the Water Factor in Soil Plant Atmosphere Relationship* UNESCO, Paris

Todd, GW 1972 Water deficits and enzymatic activity In : Water Deficits and Plant Growth. Vol. III (Ed TT Kozlowski Academic Press, New York 177-216

Vyas SP, Garg BK, Kathju S & Lahiri AN 1987 Influence of soil fertility on sesame (*Sesamum indicum* L) under repeated water stress. *Annals of Arid Zone* **26** 256-266

Vyas SP, Garg BK, Kathju S & Lahiri AN 1990 Improvement of drought tolerance in sesame (*Sesamum indicum* L) through early water stress. In : *Proceedings of International Congress of Plant Physiology* Volume 2 (Eds. SK Sinha, PB Sane, SC Bhargava and PK Aggarwal) Society for plant Physiology and Biochemistry, New Delhi. 880-884

(Received June 1992 Accepted August 1992)