

INFLUENCE OF SOIL FERTILITY ON SESAME (*SESAMUM INDICUM* L.) UNDER REPEATED WATER STRESS

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ABSTRACT

Effects of one, two and three consecutive cycles of drought at the critical stage were studied in sesame crop grown under improved soil fertility (IF) and low soil fertility (LF) conditions. The dry matter production and seed yield of plants under one or two cycles of drought were significantly more under IF than under LF conditions notwithstanding the fact that ψ_{plant} RT % and diffusive resistance indicated relatively more water stress in the former than in the latter condition. This advantage was, however, lost under three cycles of drought. IF-plants under one or two cycles of drought had higher absolute nitrogen content which declined in the third cycle. Improved soil fertility generally increased both oil content of seeds and oil yield per plant. Droughts marginally increased the oil content of seeds but reduced the oil yield per plant.

INTRODUCTION

Adequate soil fertility significantly alleviates the adverse effects of a single cycle of drought in determinate crops, such as, pearl millet (Lahiri et al., 1973) and in indeterminate legumes, such as, clusterbean, moth bean and mung bean (Lahiri, 1980; Lahiri and Kackar, 1985). A similar finding has also been made in wheat subjected to two consecutive droughts at different developmental stages (Garg et al., 1984).

Little information in this regard is, however, available on sesame, an indeterminate oil-seed crop, which is grown extensively in drought prone areas having generally low soil nitrogen. It has been reported (Vyas et al., 1983) that this crop is most sensitive to water stress when the grand period of growth coincides with the onset of flowering. In view of these, an attempt has been made here to evaluate the effects of one, two or three successive cycles of drought at the aforesaid critical stage in plants raised under low (LF) and improved (IF) soil fertility conditions. Special emphasis in this regard has been laid on alterations in growth and yield, nitrogen uptake, nitrate reductase activity and composition of seeds.

MATERIAL AND METHODS

Sesame (*Sesamum indicum* L. cv T-13) plants were grown in pots (2 plants per pot) each containing 8 kg loamy sand soil (7.1% clay, 5.6% silt, 63.1% fine sand and

24.1% coarse sand, having 0.15% organic carbon, 12 kg/ha of available phosphorus as P_2O_5 and 220 kg/ha of available potassium as K_2O , without (low fertility-LF) or with (improved fertility-IF) 60 kg N/ha (as urea), 40 kg P_2O_5 /ha (as dicalcium phosphate) and 20 kg K_2O /ha (as muriate of potash). Plants under both these fertility conditions were subjected to (a) a single cycle of water stress during 40 to 45 d. a. s. (rewatered on 45th day after taking observations and samples for analyses), (b) two successive stress cycles at 40 to 45 days and 46 to 50 d. a. s. (watered on 45th and 50th day) and (c) three successive stress cycles at 40 to 45 d. a. s., 46 to 50 d.a.s. and 51 to 56 d. a. s. (watered on 45th, 50th and 56th day). Plants were maintained close to field capacity prior to and after the aforesaid stress periods. The control plants were maintained close to field capacity throughout the growing period.

Observations on dry matter production and seed yield were recorded at harvest (100 days after sowing). Plant water status was evaluated about an hour before and 24 hours after the termination of the 1st, 2nd and 3rd drought cycles, from relative turgidity (RT%) and plant water potential (ψ_{plant} , Pressure chamber manufactured by M/s PMS Instrument Co., USA). The diffusive resistance of the abaxial side of leaves (LI-1600 Steady State Porometer) was also measured at the same time. Activity of nitrate reductase was determined after Jaworski (1971) in fully expanded uppermost two leaves in the control, and at the point of maximum stress development and also 24 hours after rewatering in the stressed plants. The tissue nitrogen concentration and the nitrogen uptake was determined at harvest. Seeds obtained from different treatments were analysed for oil, crude protein and total soluble carbohydrates (Vyas et al., 1985). The data on dry matter production and seed yield were based on six replicates while all other measurements were based on three replicates.

RESULTS AND DISCUSSION

Figure 1 illustrates the drifts in ψ_{plant} , RT% and diffusive resistance of LF and IF plants during the three cycles of drought at the points of maximum stress development, rewatering and also of control. The magnitude of stress experienced by the plants under IF condition was higher than that of LF condition in all the three drought cycles. The intensity of stress, in terms of decline in ψ_{plant} , and relative turgidity and also increase in diffusive resistance, was relatively higher in the 3rd cycle as compared to the 1st and 2nd cycles, particularly in the IF-plants. There was an unambiguous parallelism in the stress mediated changes in plant water status and diffusive resistance in plants grown under both the fertility conditions. It has been suggested (Jones and Turner, 1980; Turner and Jones, 1980) that the solute accumulation in cells under mild stress enables them to maintain their positive turgor when subjected to more severe subsequent drought. The present observations did not, however, indicate any merit of the preliminary stress in the improved turgor maintenance during the 2nd or the 3rd drought cycles. This could possibly be due to the rapid

development of initial stress and absence of sufficient time lag between the two stress events. Under conditions of fast development of initial stress, Sionit et al. (1980) also did not observe any turgor maintenance during the subsequent drought.

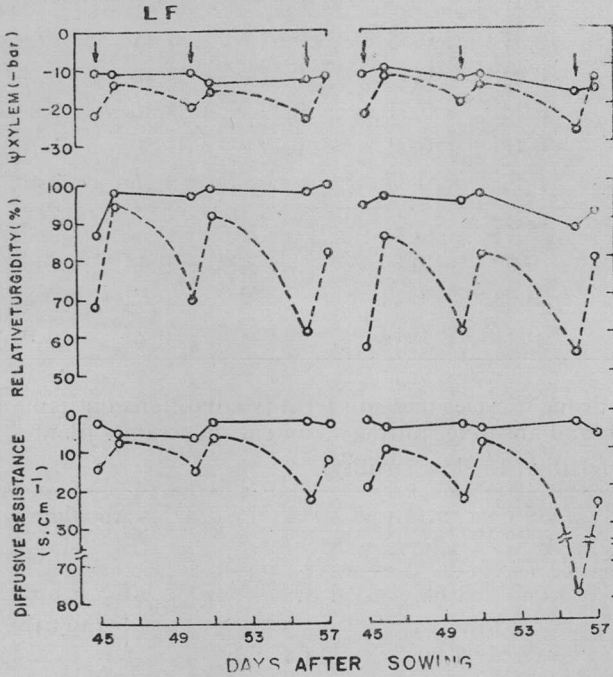


Fig. 1. Effects of repeated drought cycles on ψ_{plant} , relative turgidity and diffusive resistance of sesame plants grown under low (LF) and improved (IF) fertility conditions, o—o control, o— —o droughted.

The marginal means in Table 1 indicate a progressive decline in dry matter production and seed yield with the increasing number of drought cycles. Again, these were significantly higher under IF as compared to LF condition. Although drought, as such, reduced both dry matter production and seed yield with respect to the control, the cell values reveal that plants performed significantly better under IF condition as compared to LF condition under both one and two cycles of drought. However, under three successive drought cycles this advantage was lost. A similar improvement of growth and yield with improved soil fertility has also been found in wheat (Garg et al., 1984) under two successive droughts at different stages of growth.

The tissue nitrogen concentration progressively increased with the increase in the number of drought cycles (Table 2). Water stress, as such, is known to increase nitrogen concentration (Verma, 1976; Eck and Musick 1979; Vyas et al., 1985). Fertility improvement consistently led to a higher nitrogen concentration in the tissue in the control as well as in droughted plants.

Table 1. Effects of drought cycles and soil fertility conditions on seed yield and dry matter production of sesame plants (IF-improved fertility; LF-low fertility)

Drought treatments	Seed yield (g/plant)			Dry matter (g/plant)		
	IF	LF	Mean	IF	LF	Mean
Control	0.71	0.55	0.63	4.45	3.65	4.05
One cycle	0.61	0.43	0.52	3.40	2.40	2.90
Two cycles	0.56	0.31	0.43	3.30	1.85	2.57
Three cycles	0.18	0.21	0.19	1.50	1.70	1.60
Mean	0.51	0.37	—	3.26	2.40	—
LSD	5%	1%		5%	1%	
Fertility(F)	0.05	0.07		0.44	0.60	
Drought(D)	0.08	0.11		0.62	0.85	
FxD	0.11	0.14		0.77	1.03	

Table 2. Effects of drought cycles and soil fertility conditions on tissue nitrogen concentration and absolute nitrogen content in sesame plant at harvest (IF-improved fertility; LF-low fertility)

Drought treatments	N concentration(%)			Absolute N (mg/plant)		
	IF	LF	Mean	IF	LF	Mean
Control	2.06	1.68	1.87	90.7	60.7	75.7
One cycle	2.18 (22.6)	1.90 (14.7)	2.04	74.4 (49.0)	45.6 (63.1)	60.0
Two cycles	2.22 (11.0)	2.00	2.11	70.9 (85.6)	38.2	54.5
Three cycles	2.57 (15.7)	2.22	2.39	38.6 (4.9)	36.8	37.7
Mean	2.26 (12.9)	1.95	—	68.7 (51.7)	45.3	—
LSD	5%	1%		5%	1%	
Fertility (F)	0.06	0.08		8.7	11.9	
Drought (D)	0.09	0.12		12.3	16.7	
FxD	0.12	0.17		ns	ns	

Figures in parentheses indicate per cent increase in IF condition over LF condition.

The absolute nitrogen content per plant was 63.1 and 85.6 per cent higher in IF plants than in LF plants in the first and second cycles of drought, respectively. However, this increase drastically reduced to only 4.9% in the third cycle. This indicated that a low and comparable absolute nitrogen in IF and LF plants towards the end precluded the manifestation of performance superiority of IF plants under the three cycles of drought. It is likely that a favourable uptake and reserve of nitrogen of

IF at predrought stage helped them to overcome the adverse effects of the first cycle of drought. Under two cycles of drought, it is highly unlikely that the brief favourable soil moisture interlude between the first and second cycle could improve the uptake. Therefore, one feels inclined to conclude that a carry over effect of the initial high nutrient status of plants under IF helped to maintain growth and yield despite two successive stress cycles. Under three consecutive droughts, a diminished tissue nutrient pool and the reduced period as well as the reduced rate of uptake due to fast approaching crop maturity did not permit restoration of tissue nutrient status and hence the comparable growth and yield of IF and LF plants.

Interestingly a higher nitrogen status of control plants under IF condition, generally increased the activity of the nitrate reductase (an adaptive enzyme) as compared to that of the plants under LF condition (Table 3). However, at the lowest point of tissue water status under first, second and third cycles of drought, the activity of this enzyme in LF and IF plants was comparable, due to its high sensitivity to water stress (Huffakar et al., 1970; Plaut, 1974). Within 24 hours of rewatering the activity of the enzyme increased both in IF and LF plants and it was more in the former as compared to the latter. The post-drought restoration of nitrate reductase activity, atleast in the first and the second cycle of drought, improved the performance and yield of IF plants through improved nitrogen utilisation. However, in the third cycle this mechanism did not bring about any favourable effects as the plants at that time were fast approaching maturity.

Table 3. Leaf Nitrate-reductase-activity ($\mu\text{g NO}_2$ formed g^{-1} day wt h^{-1}) after repeated drought cycles in sesame plants grown under improved fertility(IF) and low fertility (LF) conditions

Treatment	One cycle		Two cycles		Three cycles	
	IF	LF	IF	LF	IF	LF
Control	172.3 \pm 6.5	152.1 \pm 6.8	139.9 \pm 6.2	124.7 \pm 4.5	110.0 \pm 5.4	54.2 \pm 4.4
Droughted	13.0 \pm 3.9	12.0 \pm 1.6	13.9 \pm 3.1	16.9 \pm 2.6	0.0	0.0
Rewatered	32.9 \pm 2.9	24.7 \pm 2.1	91.5 \pm 6.6	41.6 \pm 2.6	42.7 \pm 4.4	35.7 \pm 4.5

Relatively few attempts have been made to study the consequences of repeated droughts on the seed composition of oil seed crops. Vyas et al. (1983, 1985) observed that single cycle of water stress of varying intensities in sesame decreased the estimated protein and carbohydrates and increased the oil content of seeds. A similar trend has been also observed in the present study. The marginal means (Table 4) indicate that IF condition generally improved the per cent oil content of seeds, (and thus improved the oil yield per plant) over LF condition. Metawally et al. (1984) also found an increase in the oil yield of sesame with increasing nitrogen levels grown under different levels of irrigation. Aulakh et al. (1980), however, found that in *Brassica*, application of nitrogen did not influence the oil content of seeds but

Table 4. Influence of drought cycles and soil fertility conditions on seed composition and oil yield of sesame plants (IF-improved fertility; LF-low fertility)

Drought treatments	Crude protein (%)			Carbohydrate (%)			Oil (%)			Oil yield (mg/plant)		
	IF	LF	Mean	IF	LF	Mean	IF	LF	Mean	IF	LF	Mean
Control	20.8	18.8	19.8	17.0	13.1	15.1	51.6	49.5	50.5	366	272	319
One cycle	20.0	17.2	18.6	14.0	11.6	12.8	54.2	52.2	53.2	331	224	277
Two cycles	19.2	16.1	17.6	14.9	11.8	12.9	54.0	52.8	53.4	302	163	232
Three cycles	16.0	15.4	15.7	13.6	10.0	11.8	54.4	53.1	53.7	103	111	107
Mean	19.0	16.9	—	14.9	11.6	—	53.6	51.9	—	275	192	—
LSD	5%	1%	—	5%	1%	—	5%	1%	—	5%	1%	—
Fertility(F)	1.97	ns	—	1.48	2.05	—	0.94	1.30	—	15.1	20.9	—
Drought(D)	2.78	ns	—	2.10	2.91	—	1.35	1.87	—	21.3	29.6	—
FxD	ns	ns	—	ns	ns	—	ns	ns	—	ns	ns	—

improved the oil yield per unit of land. The marginal means in the aforesaid table further indicate that the oil concentration in seeds significantly increased under single cycle of drought but there was hardly any difference in the concentrations found under one, two or three successive cycles of droughts. But the oil yield per plant progressively and significantly declined with increasing number of drought cycles. This decline, therefore, seems to be arising from the drought mediated seed yield rather than any large effect on oil concentration of the seeds. The absence of any significant interaction between drought \times fertility with respect to oil concentration and oil yield per plant interestingly suggests that magnitude of effects of drought treatments were more or less identical under both the fertility treatments.

The marginal means for the concentrations of crude protein and carbohydrates indicate a significant increase in their levels under IF as compared to LF. But it is interesting to note that crude protein significantly declined only under three cycles of drought as compared to the control while carbohydrate concentration was significantly reduced even under a single drought cycle and the reduction was comparable under one, two or three cycles of drought. It is concluded that fertility induced advantages under drought conditions at the critical stage of sesame may be obtained upto a threshold of two successive cycles of water stress.

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