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SALINITY-FERTILITY INTERACTION ON GROWTH, PHOTOSYNTHESIS AND NITRATE REDUCTASE ACTIVITY IN SESAME

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SUMMARY

Interactive effects of soil salinity (0, 3, 6 and 9 dSm^{-1} approximately) and soil fertility (LF-N_0P_0 and IF-$N_{60}P_{40}$) were studied on net photosynthesis, leaf diffusive resistance, nitrate reductase activity, mineral composition and on growth and yield of sesame (*Sesamum indicum* L.) with a view to alleviate the adverse effects of salt stress through improvement of soil nutritional status. Although a progressive decline with increasing salinity was recorded in all the observed parameters but seed yield and dry matter production were significantly higher in plants raised at improved soil fertility (IF) as compared with low fertility (LF) plants at all levels of salinity. The magnitude of the detrimental effects of salt stress was also less in IF than LF plants. The improved nutritional status induced a higher photosynthetic efficiency coupled with higher chlorophyll concentration and more favourable concentrations of N, P and K as well as wider K:Na ratios in the fertilized plants despite salt stress. The activity of nitrate reductase was adversely affected by increased salinity but it was consistently higher in IF as compared to LF plants at all salinity levels. These changes possibly contributed to the better performance of improved fertility plants both under control as well as salinity stress conditions. The results indicate the importance of fertilizer application under salt stress for achieving sustainable yields.

Key words: **Fertility, mineral composition, nitrate reductase, photosynthesis, salinity, sesame**

INTRODUCTION

Salt stress is one of the major environmental constraints which limit crop productivity, particularly in arid and semi-arid regions where low soil fertility is also an important growth limiting factor. Supply of nutrients through fertilizer application under salinity has been reported to significantly overcome the detrimental effects of salts in different crops (Ravikovitch and Yoles 1971, Bernstein *et al.* 1974, Garg *et al.* 1982, 1993, Feigin 1985). This phenomenon seems to be crop specific and known to be mediated through elimination of nutritional deficiencies (Bernstein *et al.* 1974, Garg and Vyas 1997). It has been further observed that improved metabolic efficiency and enhanced activities of enzymes of nitrogen metabolism under improved soil fertility conditions also contribute towards improved plant performance despite salt stress (Garg *et al.* 1993, 2001). Sesame, a prominent oil seeds crop of drylands is also prone to salinity conditions. This study was prompted by the lack of information on the physiology of salt tolerance of sesame and particularly on the alleviation of salinity effects through improvement of soil fertility, in view of the poor nutritional status of arid zone soils.

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MATERIALS AND METHODS

The present investigation was carried out in the net house at the Central Research Farm of the Central Arid Zone Research Institute at Jodhpur. Plants of sesame (*Sesamum indicum* L. cv. T-13) were grown in glazed pots containing 40 kg loamy sand soil (Typic Camborthids) having 7.1, 5.6, 63.1 and 24.1 per cent of clay, silt, fine sand and coarse sand, respectively. The soil had 0.28 per cent organic carbon and 0.023 per cent total nitrogen, 80 kg ha^{-1} available nitrogen, 12 kg ha^{-1} available phosphorus and 120 kg ha^{-1} available potassium. Plants were grown at four levels of soil salinity (0, 3, 6 and 9 dS m^{-1}) under low (LF-no fertilizer application to farm soil) and improved (IF-60 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}) soil fertility conditions. Two plants were maintained in each pot and there were 20 replicates (pots) under each of the 8 treatments.

The salinity treatments were created by salinising the farm soil to 3, 6 and 9 dS m^{-1} levels separately before filling of pots by adding a mixture of salts to soil based on the average salt composition of local ground waters of equivalent salinity (60 per cent NaCl, 15 per cent Na_2SO_4, 10 per cent each of $NaHCO_3$, $CaCl_2$ and $MgCl_2$ and 5 per cent $MgSO_4$). The actual measured ECe values were 3.07, 6.12 and 9.08 dSm^{-1} while farm soil had ECe value of 0.14 dS m^{-1}. Plants were maintained close to field capacity by frequent watering with tap water throughout the growing period.

At the vegetative (30 days after sowing) and flowering (50 DAS) stages two uppermost fully expanded leaves from six plants (3 pots) were removed for biochemical analyses and these pots were discarded. Leaf samples from each of the three replicates were used separately for the estimation of nitrate reductase activity (Jaworski 1971) . At the same time concentration of total chlorophyll (Arnon 1949), was also analyzed in triplicate, in the same set of leaves.

Rates of net photosynthesis were measured in the uppermost fully expanded leaves of intact plants using LI-6200 portable photosynthetic system at vegetative and flowering stages. Simultaneously observations were also recorded on leaf diffusive resistance using LI-6200 system. All these measurements were made on clear and sunny day between 11.00 to 12.00 a.m. For this purpose, 4 plants were randomly selected from each treatment at both the growth stages.

Plant performance was assessed from seed yield and dry matter production (above ground biomass) at harvest and data were based on 10 replicates for each treatment. Nitrogen, phosphorus, potassium and sodium concentrations were analysed, in triplicate (Jackson 1973) from representative shoot samples at harvest. The significance of the data was adjudged through analysis of variance adopting factorial design.

RESULTS AND DISCUSSION

Increasing salinity progressively and significantly decreased seed yield and dry matter production (DMP) under both the fertility conditions (Table 1). However, the reduction in seed yield as well as DMP was consistently less under improved fertility (IF) as compared to low fertility (LF) condition at all levels of salinity. For instance, seed yield decreased by 50.6% under LF and only 43.7% under IF conditions at 9.1 dS m^{-1} salinity as compared to respective control plants. Similarly reduction of DMP was 45.3% in LF and 37.8% in IF plants at the same salinity in comparison with control. The results indicate that improvement in soil fertility partly alleviated the detrimental effects of salt stress. This points to a nutritionally induced tolerance to salt stress as has been observed in wheat (Garg *et al*. 1990), Indian mustard (Garg *et al.* 1993) and a number of other crops (Bernstein *et al*. 1974, Grattan and Grieve 1994). However, there is no previous study on the beneficial effects of improved nutrition on salt tolerance in sesame.

Fertility-induced salt tolerance and improvement in growth probably arises from the maintenance of higher concentrations of nitrogen, phosphorus and potassium and a lower concentration of sodium in the shoot tissue of IF plants as compared to LF plants at all levels of salinity (Fig.1). On an average fertilzer application enhanced N concentration by 29.1%, P concentration by 13.3% and K concentration of 18.2% while reduced Na concentration to the extent of 14.9%. The percentage

Table 1. Influence of soil salinity on seed yield and shoot dry matter production of sesame grown under low (LF) and improved (IF) soil fertility conditions.

Salinity level (d Sm^{-1})	Seed yield (g $plant^{-1}$)			Shoot dry matter (g $plant^{-1}$)		
	LF	IF	Mean	LF	IF	Mean
0.14	4.09	4.95	4.52	8.16	9.78	8.97
3.07	3.25	4.03	3.64	7.02	8.56	7.79
6.12	2.86	3.66	3.26	5.87	7.37	6.62
9.08	2.02	2.78	2.40	4.46	6.08	5.27
Mean	3.06	3.85	-	6.38	7.95	-
LSD(0.05)	Salinity 0.43	Fertility 0.31	S x F 0.62	Salinity 0.60	Fertility 0.42	S x F 0.85

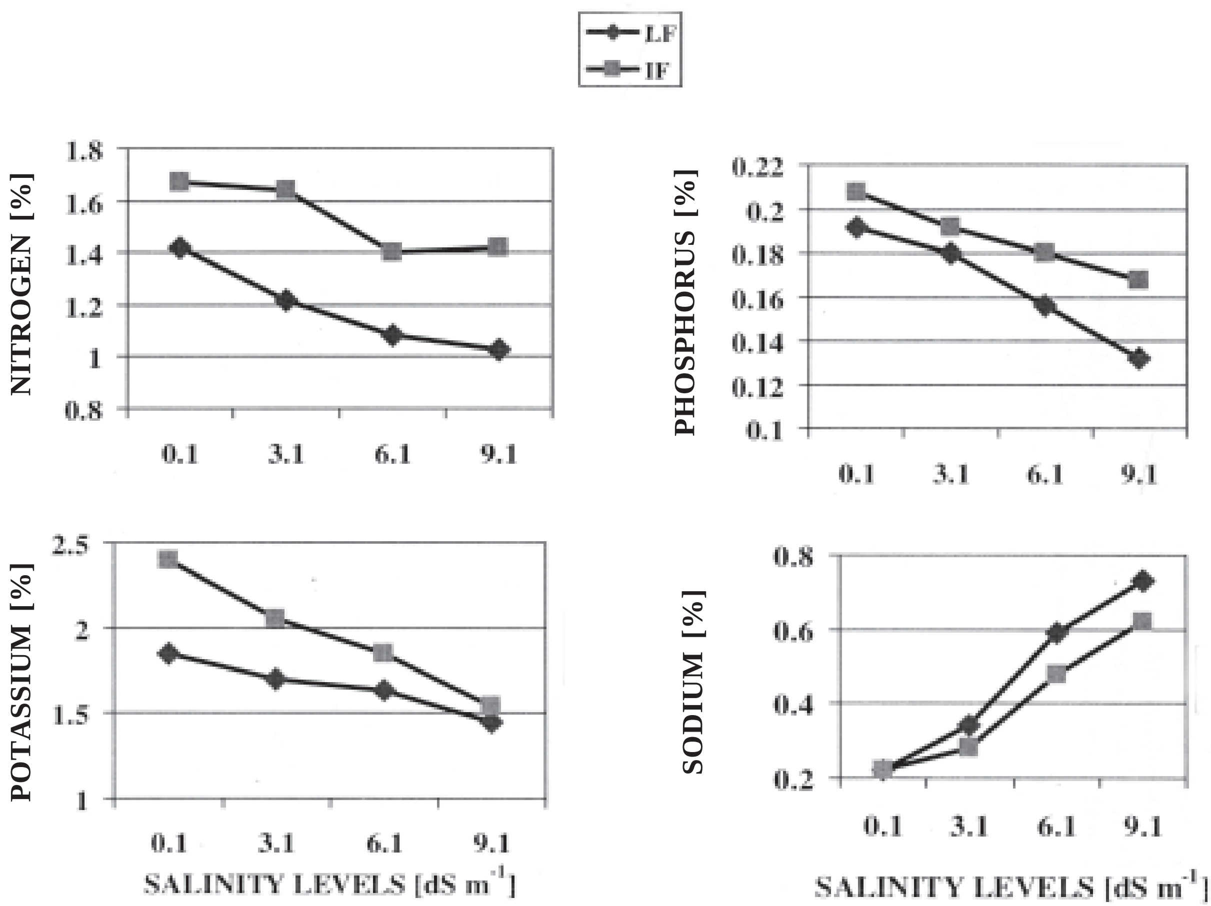

Fig. 1. Influence of salt stress on concentrations of N, P, K and Na in shoots of sesame grown under low (LF) and improved (IF) soil fertility conditions. The LSD values at P=0.05 for salinity [S], fertility [F] and their interaction [SxF] were 0.13, 0.09 and 0.18 for N, 0.13, 0.01 and NS for P, 0.14, 0.1 and 0.2 for K and 0.09, 0.06 and NS for Na in the sequence mentioned

decrease in concentrations of N and P with increased salinity was consistently less in IF as compared with LF plants. However, the per cent decrease in K was more in IF than LF plants at all salinity levels. Sodium concentration increased to a lesser extent in IF then LF plants with an increase in salinity.

The gradual but progressive decline in K concentration and a sharp increase in Na concentration with increasing salinity levels had detrimental effect on K: Na ratio under both the fertility conditions. However, IF plants maintained higher K : Na ratio than LF plants at all salinity levels. For instance K:Na ratio decreased from 10.91 (control) to 7.32, 3.85 and 2.98 at 3, 6 and 9 dS m^{-1} salinity levels, respectively, in IF plants while the decrease was from 8.41 (control) to 5.00, 2.76 and 1.99 in LF plants at the corresponding salinity levels. This phenomenon has also been observed earlier in wheat (Garg *et al*. 1990), Indian mustard (Garg *et al*. 1993) and Isabgol (Burman *et al.* 2002) grown under saline water irrigation. The maintenance of high K:Na ratio has been reported to be associated with the higher salt tolerance of crops (Greenway and Munns 1980). The results indicate that adequate nutrition favorably modulates the K : Na ratio and that contributes to increased salt tolerance.

Increasing salinity progressively decreased net photosynthetic rate (Pn) at both the growth stages. However, Pn was consistently higher in plants grown under improved soil fertility as compared to low fertility at all salinity levels (Table 2). Furthermore, IF plants maintained lower diffusive resistance than LF plants, particularly at the vegetative stage. Notwithstanding the favourable effects of fertility, the decrease in photosynthesis under salt stress was associated with an increase in leaf diffusive resistance at both the growth stages. The detrimental effects of salt stress on photosynthesis due to stomatal and non-stomatal effects are well documented (Downton 1977, Dubey 1996). Garg *et al*.(2001) also reported depressive effects of increasing salinity on net photosynthetic rates of pearl millet which were associated with decreased stomatal conductance and increased leaf diffusive resistance. Kumawat *et al.* (1991) and Sharma and Gill (1992) made similar observations in pearl millet under saline conditions.

A progressive and significant decrease in the chlorophyll concentration with increased salinity was also noticed. However, the maintenance of higher chlorophyll concentration in IF plants than an LF plant at all salinity levels at both the growth stages was observed (Table 2). Earlier reports on beneficial effects of improved soil fertility on chlorophyll content of wheat, Indian mustard and pearl millet lend support to present observations (Garg *et al.* 1990, 1993, 2001)

The activity of the enzyme nitrate reductase (NR) declined with increasing salinity at both the vegetative and flowering stages (Table 3). However, it was consistently higher in IF as compared to LF plants at all salinity levels. On an average soil fertility treatment increased NR activity by 91.3% and 46.7% at vegetative and flowering stages, respectively. The data on NR activity further revealed that the magnitude of salt induced decrease was generally less under improved soil fertility condition as compared with low fertility condition at both the growth stages.

Available reports indicate a decline in NR activity under salinity stress in different crops (Heimer 1973, Lahiri *et al.* 1987, Garg *et al.* 1990, 1993) but such information is lacking in sesame. Our previous studies with wheat, mustard and pearl millet (loc. citation) also suggest that the higher nutrient availability in the form of substrate under the IF condition induced a greater activity of NR despite salt stress. This favourable response along with higher photosynthetic efficiency possibly led to enhanced plant growth and seed yield of IF plants even under salinity stress.

Our experimental observations demonstrate that an improvement in soil fertility could favorably influence the metabolic and photosynthetic efficiency along with more favourable water balance in the plants despite salt stress. A higher availability of N along with P in the soil under the IF condition possibly induced a higher NR activity leading to higher rate of nitrogen assimilation. These events contributed to the improved performance of sesame plants both under control and salinity stress.

Table 2. Influence of soil salinity on net photosynthesis, diffusive resistance and chlorophyll concentration of sesame plants grown under low and improved soil fertility conditions.

Salinity level (d Sm^{-1})	Net photosynthesis (μ mol m^{-2} s^{-1})			Leaf diffusive resistance (cm s^{-1})			Total chlorophyll (mg g^{-1} dw)		
	LF	IF	Mean	LF	IF	Mean	LF	IF	Mean
				Vegetative stage					
0.14	20.4	24.6	22.5	0.35	0.34	0.34	6.42	8.30	7.36
3.07	18.9	24.5	21.7	0.36	0.37	0.36	5.70	8.12	6.91
6.12	18.2	22.6	20.4	0.40	0.37	0.38	5.28	7.06	6.17
9.08	17.6	21.6	19.6	0.62	0.48	0.55	5.02	6.72	5.87
Mean	18.8	23.3	-	0.43	0.39	-	5.60	7.55	-
LSD (0.05)	Salinity	Fertility	S x F	Salinity	Fertility	S x F	Salinity	Fertility	S x F
	1.29	0.91	NS	0.05	0.03	0.06	0.47	0.33	NS
				Flowering stage					
0.14	19.6	22.7	21.1	0.70	0.63	0.67	5.40	6.04	5.72
3.07	19.7	20.8	20.3	0.77	0.75	0.76	4.82	5.60	5.21
6.12	18.0	19.9	18.9	0.86	0.85	0.86	4.45	5.11	4.78
9.08	15.3	18.1	16.7	0.92	1.00	0.96	4.10	4.70	4.40
Mean	18.1	20.4	-	0.81	0.81	-	4.69	5.36	-
LSD (0.05)	Salinity	Fertility	S x F	Salinity	Fertility	S x F	Salinity	Fertility	S x F
	1.19	0.84	NS	0.10	NS	0.14	0.40	0.29	NS

Table 3. Influence of soil salinity on NR activity ($\mu g NO_2^-$ g^{-1} dw h^{-1}) of sesame plants at vegetative and flowering stages grown under low and improved soil fertility conditions.

Salinity level (d Sm^{-1})	Vegetative stage			Flowering stage		
	LF	IF	Mean	LF	IF	Mean
0.14	84.5	145.3	114.9	191.4	261.8	226.6
3.07	58.8	109.6	84.2	150.4	226.6	188.3
6.12	41.5	85.5	63.5	128.7	192.9	160.5
9.08	22.5	56.1	39.3	104.7	162.3	133.5
Mean	51.8	99.1	-	143.8	210.9	-
LSD(0.05)	Salinity	Fertility	S x F	Salinity	Fertility	S x F
	11.2	7.9	15.9	24.4	17.3	34.6

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