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Nitrogen Uptake and Dry Matter Production by Tomato Plants under Salt Stress

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Abstract: A greenhouse study was conducted on tomato plants (*Lycopersicon esculentum* Mill var. Roma) to monitor the effects of salt (NaCl) stress on dry matter yield and nitrogen (total and ^{15}N) uptake. The significant difference in the dry matter production, total-N, and ^{15}N content of plants, was first noted on day 15 of the ^{15}N treatment, and this difference continued to the end of the study period. Moreover, differences in both the parameters i.e., dry matter production and ^{15}N uptake, also appeared in the last (30 days) harvest between the two saline treatments.

Key words: Green house, salt stress, *Lycopersicus esculentum*

Introduction

Previous work indicates that subjecting plants to saline conditions reduces their growth and nutrient uptake. However, the type of salt is an important factor, since the extent of the decrease in germination of seed with increasing salt concentration varies with the species and type of salt (Ryan *et al.*, 1975). Among the soluble salts, NaCl is the most abundant and probably the most detrimental to plant growth and nutrient uptake.

Pessarakli and Tucker (1988) found that dry matter production of tomato (*Lycopersicum esculentum* Mill) plants was significantly decreased with increasing NaCl salinity. They also reported that medium and high levels of salinity substantially reduced the ^{15}N uptake rate by plants. Kafkafi *et al.* (1982) found a decline in dry matter yield of tomatoes with increasing NaCl concentration in solution at all NO_3 and H_2PO_4 levels. Increasing the osmotic pressure of the culture solution also decreased dry matter production, N absorption, and water uptake of corn (*Zea mays* L.) (Pessarakli *et al.*, 1989). Dry matter production of alfalfa decreased almost linearly with increasing external NaCl (Khan *et al.*, 1994). There was also a substantial reduction in ^{15}N uptake and significant decrease in dry matter production of egg plant (*Solanum melongena* L.) as a result of increasing the salinity of culture solutions (Pessarakli and Tucker 1988). Either NaCl or water stress significantly decreased absorption of NH^+_4 and NO^-_3 in red kidney beans (*Phaseolus vulgaris* L.) (Frota and Tucker, 1978). Abdul-kadir and Paulsen (1982) reported that salinity stress treatments retarded growth and decreased N content of the whole plant in wheat. They further observed that adverse effects of salinity were more pronounced on vegetative than on reproductive growth stages. In contrast, Strogonov (1994) found that alfalfa (*Medicago sativa* L.) and tomato plants were more sensitive to salt stress during flowering than at the early vegetative stage.

The reduced growth was also reported to be a result of decreased N uptake with increasing salinity level (Khan *et al.*, 1994). Although scientists generally agree that salt stress impairs growth, dry matter production, and nutrient uptake, it is not yet well understood, at what growth stage plants are most sensitive to stress.

The objectives of this study were to determine the effect of NaCl salinity stress on dry matter production and nitrogen (total and ^{15}N) uptake of tomato plants at the period of flower bud formation.

Materials and Methods

This study was conducted in a greenhouse of the National Agricultural Research Center, Islamabad. The temperature in ranged from 15 to 35°C during the day over the treatment period. A month after germination of tomato (*Lycopersicum esculentum* Mill., var. Roma) seeds in sand culture trays, the seedlings were transplanted into individual disposable cups, containing sand. One half strength Hoagland nutrient solution was applied with irrigation water. A month later, each of the plants for the study was transplanted into a pot containing 2.0 kg quartz sand and irrigated with complete Hoagland nutrient solution. The plants were established in the new regime for 10 days before any harvest was made.

The first pretreatment harvest was made after five days. Two plants were harvested, their roots and shoots were washed, dried and total dry weights of plants were determined. The same procedure was repeated for the second pretreatment harvest, 5 days later. Then, the salt treatments were started. At the start of the salt treatments the seedlings were 80 days old and had not yet formed flower buds.

The treatments were as follows: (I) Control (0.3 bar) Hoagland nutrient solution, (ii) Medium saline water of 4 bars osmotic pressure which was obtained by adding 24 mmol NaCl per litre of the culture solution for each bar of stress (Pessarakli and Tucker 1988) and (iii) High saline water in which an osmotic pressure of 8 bars was also obtained by adding NaCl. The ^{15}N treatments were split into three doses, each applied at 10-day interval. The ^{15}N was added as 10 mg per pot on days 1, 11, and 21 of the ^{15}N treatment period. The form of ^{15}N applied was $K^{15}NO_3$ in a completely randomized design, There were two replicates (2 plants) in each treatment that were harvested every 5 days and there were 6 post-treatment harvests over a 30-day period. The plants were irrigated daily to avoid excess salt accumulation. Flower buds began to form a week after ^{15}N treatments started. All flowers were removed during the treatment period.

At each harvest, shoots and roots were separated, the roots were washed, the plant parts dried and total dry weights of plants (shoots plus roots) were measured and recorded. The plant parts were then ground in a Wiley mill to pass through a 2 mm sieve and total N and ^{15}N determinations were made using micro-Kjeldahl (Winkleman *et al.*, 1990) and mass spectrometric methods (Pessarakli *et al.*, 1989), respectively. From the N values and the total dry weight data, total N and ^{15}N uptake were calculated for each treatment and harvest time. The statistical analysis was performed using procedures described by Steel and Torrie (1980). The means were compered by the least significant difference (LSD) test at the 0.05 level of significance.

Results and Discussion

Dry Matter Production: In ^{15}N treatment period, on days 5 and 10, there was no significant difference in dry matter production among the three treatment means. However, on day 15, there was a significant difference between the control and the two saline treatments and the gap between them increased as the treatment period progressed, with the high saline treatment having the lowest yield and resulting in significantly lower yield than the medium saline treatment by the last harvest, day 30, (Table 1). Pessarakli and Tucker (1988) found similar results of decline of dry matter yield of tomato plants with increasing NaCl concentration. These results are also in accord with the findings of Naeem *et al.*, 1998.

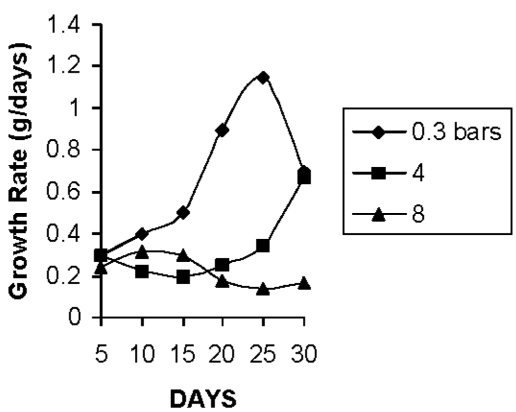

Fig. 1: The growth rate of the tomato plants for the three salinity levels during the 30 day ^{15}N uptake period.

The growth rate pattern for the three treatments are shown in Fig.1. The control plants had a typical growth rate curve, whereas, the salinized plants showed reduced and delayed growth curves. The growth rate pattern for the 4 and the 8 bar treatments was similar until the last two harvests (days 25 and 30), when the 4 bar salinized plants showed an increase in growth rate.

Total N Uptake: A significant difference in total N content of plants appeared on day 15 between the control and the two saline treatments which prevailed until the end of the treatment period (Table 2). There was no significant difference between the two saline treatment means, except on the last harvest (day 30). These results agree with those obtained by Pessarakli and Tucker (1988) that NaCl added to the culture solution or irrigation water significantly reduced total N uptake.

Nitrogen (^{15}N) uptake: A significant difference in ^{15}N uptake occurred between the control and saline treatments on day 15 of the ^{15}N treatment, and this difference continued to the end of the study period (Table 2).
The medium saline treatment had significantly higher ^{15}N uptake means than the high saline treatment on days 15 and 20. However, there was no significant difference among the two saline treatment means on days 25 and 30. This may indicate that the plants had better adjusted and were more tolerant to salinity at the later stage than at the earlier stage of growth.
These results are in agreement with studies conducted by Pessarakli and Tucker (1988) and Al-Rawahy *et al.* (1990) with tomatoes and by Frota and Tucker (1978) with red kidney beans, both of which reported a reduction in ^{15}N uptake as a result of subjecting the plants to salt stress.
The above results show that there is a time lag before significant difference among treatments appear in dry weight and nitrogen (total and ^{15}N) uptake after exposing the plants to salt stress. Within the same specie and same variety, the difference in this time lag may be largely due to the stage of plant growth. In this study significant difference between the control and the two saline treatments was first noted on day 15. The treatments were started on 80 day old plants.

Table 1: Dry weight of tomato plants for the three NaCl treatments at the six harvest times

Salt Treatment (Osmotic Pressure)	Dry weight* Harvest time (days)					
	5	10	15	20	25	30
Bar	g pot^{-1}					
0.3 (Control)	4.50	5.69	8.48	13.24	18.93	19.94
4	4.05	5.41	6.97	8.33	10.13	13.45
8	3.95	5.37	6.58	7.65	8.05	8.78
LSD (0.05)**	1.36	1.69	0.98	2.12	4.05	3.16

*Average of 2 replications of pots with 1 plant each.
**LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

Table 2: Nitrogen (total and ^{15}N) uptake in tomato plants for the three saline (NaCl) treatments at the six harvest times.

Salt Treatment (Osmotic Pressure)	Harvest time (days)											
	5	10	15	20	25	30	5	10	15	20	25	30
Bar	N uptake, mg pot^{-1}*						^{15}N uptake, mg pot^{-1}*					
0.3 (Control)	110	180	246	494	573	634	1.80	3.07	5.41	8.85	14.96	16.32
4	97	133	168	202	286	358	1.30	2.18	3.27	3.77	5.49	7.73
8	71	118	141	166	194	212	1.01	1.45	2.11	2.30	3.44	3.98
LSD (0.05)**	40	52	45	78	116	141	0.79	1.19	0.83	1.41	3.19	3.81

*Represents mg N or mg ^{15}N absorbed in plant.
**LSD (0.05) = Least significant difference between the treatment means at the 0.05 probability level.

Pessarakli and Tucker (1988) found that with tomatoes of the same variety, the treatment means showed a significant difference in the above parameters within 7 days of starting ^{15}N treatment. The older plants used in this study were larger in size, better established and therefore more tolerant to salinity. For older plants, it probably takes a longer time for stress to show adverse effects on some of the processes within the system than it takes younger plants. This is in agreement with Maas *et al.* (1986) findings that the vegetative stage is the most sensitive growth stage of plants to salinity and the maturation stage is the least sensitive. The results of this study indicate that the detrimental effect of NaCl stress on growth of tomato plants is reflected in lower dry weights and decreased nitrogen (total and ^{15}N) uptake. The reduction of these parameters due to increased salinity may be the result of combination of osmotic and specific ion effects on Cl^- and/or Na^+. As far specific ion effects, it may involve direct toxicity of Cl^- and/or Na^+ and an antagonistic effect of Cl^- on NO^-_3 uptake.

The medium saline (4 bars) and high saline (8 bars) treatments did not show a significant difference in dry weights and total N uptake, except on the last harvest (day 30). Perhaps the plants at the stage of growth (flower bud formation stage), at which this study was conducted were less sensitive to sodium chloride stress than at the earlier vegetative stage of growth (Pessarakli and Tucker 1988).

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