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# EFFECT OF SALINE SOILS, AMENDED WITH CALCIUM NITRATE ON THE GROWTH AND CHEMICAL CONSTITUENTS OF POTATO PLANTS*

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## Abstract

Saline soils of different regimes were amended with calcium nitrate to elucidate its effect on the growth and chemical composition of potato plants. The effects of salinity on the foliage growth were more pronounced in cv. Rheinhort than in the Patrones and Cardinal. Chlorophyll content increased upto 0.8% amended salinity. Accumulation of organic solutes (sugars, proteins, proline) in plants under salt stress suggests the basis of osmoregulation for building up salt tolerance. The ability of potato plants to discriminate between $Na^+$ and $K^+$ uptake from saline soils provides a criteria to forecast salt tolerance. On the basis of yield, cv. Rheinhort is considered as highly tolerant, Patrones as tolerant and Cardinal as moderately tolerant to salinity. TGA level was significantly reduced by the amendments under saline conditions.

## Introduction

Cultivated potato (*Solanum tuberosum* L.) contains two main glycoalkaloids α-solanine and α-chaconine (Wood & Young, 1974) which are nitrogen analogues of sapogenins (Heftmann, 1963). Studies have been made to see the effect of fertilizer, temperature and altitudes on total glycoalkaloid (TGA) content of potato; (Zitnak, 1961; Sinden & Webb, 1974; Cronk *et al.* 1974). Relatively little information is available on the effect of salinity on potato tubers with reference to TGA levels (Strogonov, 1970; Ahmad & Abdullah, 1979). During the past few years research on the role of $Ca^{++}$ for potato tuberization have indicated that $Ca^{++}$ plays a major role in tuber growth (Krauss & Marschner, 1971; Dyson & Digby, 1975; Collier *et al,* 1978). There are some reports that $Ca^{++}$ has a beneficial effect on plant growth under saline conditions (Gerard & Hinojosa, 1973; Gerard, 1971; Mason & Cuttridge, 1974). The ameliorative effect of nitrogen under saline conditions has been also investigated (Bajwa *et al,* 1975; Bernstein *et al,* 1974; Gaber *et al.* 1975). In our study (Ahmad & Abdullah, 1979), different cultivars of potato varied in their response depending upon their ability to withstand different salinity levels. It was inferred that the TGA level decreased in all the cultivars with increas-

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ing concentration of salts. To elucidate the formation of TGA under amended saline condition, it is important to understand the effect of amendments on growth as compared to no amendment (Ahmad & Abdullah, 1979). In the present paper the effects of calcium and nitrogen on growth and chemical composition of potato with special reference to TGA under amended saline soil are reported.

## Materials and Methods

Cvs Patrones and Cardinal were obtained from the Ayub Agricultural Research Institute, Faisalabad, and cv. Rheinhort from Sind Horticulture Institute, Mirpur Khas. The experiements were started under field conditions during November 1979 using china crocks which contained 15 kg sandy loam soil. The method of sowing and salinization was the same as described earlier (Ahmad & Abdullah, 1979). Calcium Nitrate amendment to the soil were made of 20 mM calcium and 19.8 mM Nitrogen per kg soil using $Ca(NO_3)_2 4H_2O$ as amending medium. Temperature during the experimental period ranged between 22.7°C – 28.1°C. Average rainfall was 42 mm and relative humidity ranged from 74 to 83%. After two and three months of emergence the plants were harvested for analyses here-in-after called as 1st harvest and 2nd harvest, respectively. Specific gravity of potato tubers was recorded as mentioned by Manzer *et al* (1965). Chlorophyll was extracted as described by Maclachlam & Zalik (1963). $Na^+$ and $K^+$ were analysed as described in the USDA Handbook 60 (1954) and proline estimated by the method of Bates (1973). TGA was extracted and measured as described by Baker *et al* (1955) and sugars were estimated by Nelson's method (1944). Five plants were used for each analysis.

## Results

Plants of different cultivars at various stages of development differed markedly upon their ability to combat salinity (Table 1). Promotion of foliage growth during the first two months was observed in cvs Patrones and Cardinal at 0.2% amended salinities and beyond 0.6% salitity growth was ratarded (Table 1). In cv. Rheinhort however the foliage growth was linearly inhibited with increasing concentrations of amended salinities.

After two months of growth, the yield of potato tubers was more than control in cvs Patrones and Rheinhort up to 0.6 and 0.4% amended salinities. At higher levels of salinity the yield declined. In cv. Cardinal tuber yield was more at each level of salinity and was found grezter at 1% amended salinity than the control. After three months of growth the tuber yields of cvs Patrrones and Cardinal increased up to 0.8% amended salinities. In cv. Rheinhort low levels of salinity caused an increased yield which declined as the salt concentration was increased and even at the highest level tested (1% amended salinity), the yield was greater than the control.

Table 1. Growth response of potato cvs. Patones, Cardinal and Rheinhort under salt stress.

| Growth Parameters | % of amended salinity in soil | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
| 1st Harvest | | | | | | |
| PATRONES | | | | | | |
| Weight of foliage (g)/plant. | 64.97 | 67.97 | 67.33 | 58.33 | 58.43 | 45.67 |
| Weight of tubers (g)/plant. | 171.97 | 211.27 | 189.93 | 174.83 | 167.43 | 152.87 |
| Number of tubers/plant. | 5 | 8 | 7 | 7 | 6 | 4 |
| CARDINAL | | | | | | |
| Weight of foliage (g)/plant. | 26.87 | 37.00 | 32.60 | 27.77 | 24.77 | 25.57 |
| Weight of tubers (g)/plant. | 64.03 | 102.10 | 77.90 | 68.67 | 69.63 | 64.83 |
| Number of tubers/plant. | 4 | 12 | 9 | 7 | 6 | 3 |
| RHEINHORT | | | | | | |
| Weight of foliage (g)/plant. | 42.40 | 37,06 | 35.47 | 33.63 | 31.60 | 22.77 |
| Weight of tubers (g)/plant. | 124.83 | 190.25 | 142.80 | 119.17 | 103.63 | 94.53 |
| Number of tubers/plant. | 5 | 9 | 9 | 9 | 8 | 6 |
| 2nd Harvest | | | | | | |
| PATRONES | | | | | | |
| Weight of tubers (g)/plant. | 268.66 | 372.16 | 329.20 | 282.72 | 378.90 | 253.90 |
| Number of tubers/plant. | 5 | 7 | 5 | 5 | 5 | 4 |
| CARDINAL | | | | | | |
| Weight of tubers (g)/plant. | 173.94 | 213.80 | 211.06 | 201.54 | 194.68 | 164.10 |
| Number of tubers/plant. | 5 | 8 | 8 | 6 | 5 | 5 |
| REHINHORT | | | | | | |
| Weight of tubers (g)/plant. | 188.30 | 262.46 | 254.80 | 243.72 | 242.44 | 237.74 |
| Number of tubers/plant. | 6 | 10 | 9 | 9 | 7 | 5 |

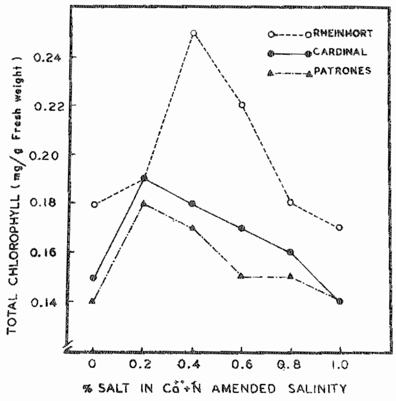

Fig. 1. Effect of different regimes of salinity on the total chlorophyll content of potato leaves.

Total chlorophyll either increased or remained equal to the control in all the cultivars (Fig. 1) up to 0.8% amended salinity. No definite pattern was observed in the water content of tubers at different concentrations of amended salinity in any of the cultivars (Table 2).

The specific gravity of potato tubers (Table 2) showed minor variation at each level of salinity which was comparatively less at the exponential phase of growth (1st harvest) than at the time of maturity (2nd harvest).

Concentration of reducing sugars in the tuber (Table 2) did not show any definite pattern at both stages of growth. There were variations at various salinity levels in different cultivars. The concentration of protein was more than that of the control with few exceptions at higher salinities at both the observed stages of growth. However in cv. Rheinhort, the degree of promotion persisted up to 1% amended salinity (Table 2).

The glycoalkaloid content of all the cultivars decreased with increasing concentrations of salinity (Table 2), the level of TGA being higher during the exponential phase of growth than at harvest. The level of proline in the amino acid pool increased in salt stressed potato plants (Fig. 2). Analysis of various plant parts showed a higher accumulation of proline in leaves than in roots and least accumulation was noticed in tubers. With increasing concentration of soil salinity the level of proline in leaves, roots and tubers after two month of growth period increased linearly in all the cultivars (Fig. 2). The degree of proline accumulation in potato tubers was more after two months than after three months of growth period (Fig. 3).

The $Na^+$ content increased in plant parts in all the cultivars with increasing concentrations of salts in the growth medium (Figs. 4 & 5). Rate of $Na^+$ accumulation was

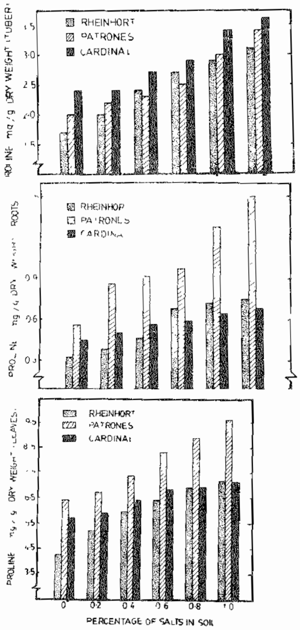

Fig. 2. Salinity-induced changes in the Proline level of potato plants after two months of growth period.

higher in leaves than in roots. It is interesting to note that some accumulation of $Na^+$ was also observed in potato tubers (Fig. 5).,The $K^+$ content in cvs Rheinhort and Cardinal declined at higher salinities. In tubers the $K^+$ content was found to be higher than control at the exponential growth phase as well as at maturity in all the cultivars (Fig. 4).

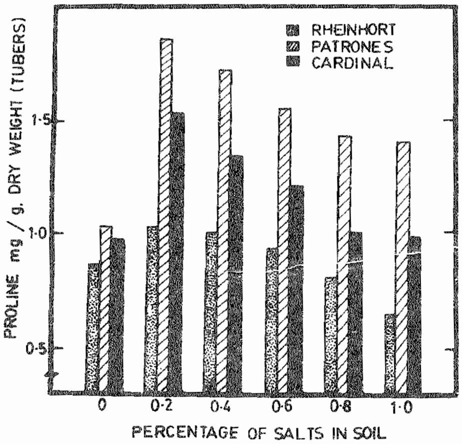

Fig. 3. Salinity-induced changes in the Proline level of potato tubers after three months of growth period.

Table 2. **Salinity-induced changes in the water content, specific gravity, reducing sugars, total proteins and the glycoalkaloid content in potato tubers of cvs Patrones, Rheinhort and Candinal.**

| | % of amended salinity in soil | | | | | |
|---|---|---|---|---|---|---|
| Cultivars | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
| Water content<br>(% of Fresh Weight) | | | | | | |
| Ist Harvest | | | | | | |
| Patrones | 78.37 | 81.15 | 83.28 | 86.62 | 82.77 | 82.11 |
| Rheinhort | 81.40 | 79.94 | 82.61 | 83.00 | 80.74 | 84.76 |
| Cardinal | 81.57 | 80.45 | 76.26 | 80.26 | 77.21 | 80.47 |
| 2nd Harvest | | | | | | |
| Patrones | 82.93 | 73.50 | 83.60 | 82.73 | 83.10 | 83.30 |
| Rheinhort | 84.43 | 76.35 | 80.46 | 82.00 | 84.07 | 85.60 |
| Cardinal | 84.90 | 80.00 | 83.33 | 83.93 | 84.87 | 85.37 |
| Specific gravity<br>Ist Harvest | | | | | | |
| Patrones | 1.077 | 1.066 | 1.053 | 1.043 | 1.063 | 1.066 |
| Rheinhort | 1.060 | 1.071 | 1.063 | 1.064 | 1.068 | 1.052 |
| Cardinal | 1.024 | 1.049 | 1.072 | 1.052 | 1.055 | 1.056 |
| 2nd Harvest | | | | | | |
| Patrones | 1.078 | 1.089 | 1.072 | 1.069 | 1.068 | 1.067 |
| Rheinhort | 1.065 | 1.097 | 1.089 | 1.076 | 1.068 | 1.062 |
| Cardinal | 1.069 | 1.072 | 1.072 | 1.071 | 1.071 | 1.070 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Reducing sugars (% dry wt) | | | | | | |
| Ist Harvest | | | | | | |
| Patrones | 6.35 | 5.93 | 8.37 | 13.00 | 11.29 | 11.25 |
| Rheinhort | 7.42 | 2.09 | 2.67 | 1.41 | 2.28 | 4.19 |
| Cardinal | 6.29 | 6.24 | 4.63 | 8.28 | 7.99 | 2.87 |
| 2nd Harvest | | | | | | |
| Patrones | 4.37 | 2.78 | 8.29 | 4.42 | 5.38 | 4.38 |
| Rheinhort | 9.17 | 5.57 | 6.41 | 8.02 | 10.48 | 7.40 |
| Cardinal | 6.79 | 5.95 | 8.06 | 8.50 | 6.42 | 9.91 |
| Total Proteins (% of dry wt) | | | | | | |
| Ist Harvest | | | | | | |
| Patrones | 6.42 | 8.56 | 8.14 | 7.83 | 6.94 | 6.18 |
| Rheinhort | 5.23 | 8.17 | 7.76 | 7.42 | 7.11 | 6.88 |
| Cardinal | 5.47 | 6.49 | 6.15 | 5.84 | 5.52 | 5.22 |
| 2nd Harvest | | | | | | |
| Patrones | 7.36 | 8.88 | 8.65 | 8.24 | 7.53 | 7.21 |
| Rheinhort | 6.14 | 8.54 | 8.15 | 7.63 | 7.44 | 7.13 |
| Cardinal | 5.93 | 6.84 | 6.62 | 6.27 | 5.94 | 5.56 |
| Total Glycoalkaloids (mg/100 & F.wt) | | | | | | |
| Ist Harvest | | | | | | |
| Patrones | 17.85 | 17.74 | 14.42 | 8.59 | 6.82 | 6.33 |
| Rheinhort | 17.16 | 16.33 | 14.59 | 10.66 | 10.42 | 9.82 |
| Cardinal | 16.46 | 14.74 | 12.41 | 12.13 | 10.64 | 6.89 |
| 2nd Harvest | | | | | | |
| Patrones | 17.45 | 14.42 | 11.01 | 8.55 | 6.75 | 6.05 |
| Rheinhort | 11.16 | 10.37 | 10.89 | 8.80 | 8.18 | 5.6 |
| Cardinal | 15.43 | 13.34 | 11.16 | 10.56 | 10.43 | 5.69 |

## Discussion

Crop salt tolerance has usually been expressed as the yield decrease expected for a given level of soluble salts in the root medium as compared with yield under non-saline conditions. Different responses were observed in foliage growth and tuber yield in cvs Cardinal, Patrones and Rheinhort exposed to various regimes of amended salinity. The effects of salinity on the foliage growth was more pronounced in cv Rheinhort than in the other two cultivars (Table 1). The yield and number of tubers/plant was highest in cv Rheinhort upto 1% amended salinity (Table 2) whereas in cvs Cardinal and Patrones the degree of promotion in yield was achieved only up to 0.8% amended salinity. It could be argued that these results were achieved due to amendments in the saline soil. There is evidence that $Ca^{++}$ is translocated preferentially towards the shoot apex. Isermann (1970) found that the adsorbed $Ca^{++}$ in the xylem tissue can be exchanged by other cation and that such an exchange favours the upward translocation of $Ca^{++}$. During growth an IAA stimulated proton afflux pump in the elongation zones of the shoot apex increased the formation of new cation exchange sites so that the growing tip becomes a centre for $Ca^{++}$ accumulation. This relationship has been investigated by Marschner & Ossenberg-Nauhans (1977) using the IAA transport inhibitor 2, 4, 5-triiodobenzioic acid (TIBA). The rate of downward translocation of $Ca^{++}$ is very low due to the fact that $Ca^{++}$ is hardly transported in the phloem (Marshner & Richter, 1974). Hence for developing potato tubers the surface absorption of $Ca^{++}$ is essential. The presence of higher amounts of $Ca^{++}$ in the saline soils (20 mM/kg soil) have shown beneficial effect on tuber yield (Table 2). Application of phosphorus and nitrogen in saline soils had resulted in

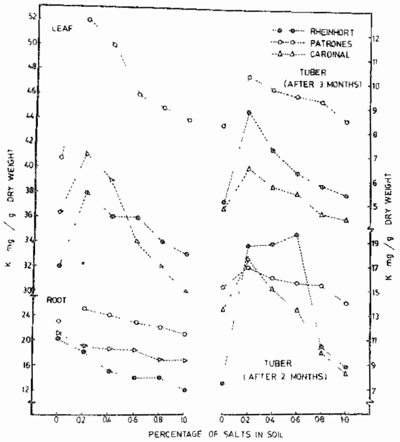

Fig. 4. Salinity-induced changes in $K^+$ content after 2 months (leaf, root & tuber) and 3 months (tuber) of growth period.

higher production o millet and clover (Ravikovitch & Yoles, 1971). Addition of NaCl or KCl alone in the soil resulted in a decrease in number of tubers and total yield of potato tubers (Munro *et al.* 1977; Udovenko *et al.* 1976; Hojmark, 1977). While using dilutions of sea water in irrigation medium, Bartolomaens (1976) and Ahmad & Abdullah (1980) noticed that salt content exceeding 1,300 mg/1 and 2,000 ppm in irrigation water respectively becomes very toxic for the growth of potatoes. Amoendment of calcium and nitrogen under various regimes of salinity increased the salt tolerance of Patrones and Cardinal as compared to their ability to tolerate saline soils without amendments (Ahmad & Abdullah, 1979).

Changes involved in the concentration of chlorophyll under saline conditions reflect on the efficiency of the photosynthetic system. The level of chlorophyll increased in all the varieties up to 0.8% amended salinity. Increase in the chlorophyll content under salt stress is considered as an adaptive response of the plant to combat the toxic effect of salinity (Chimiklis & Karlander, 1973). At 1% amended salt level, reduction in chlorophyll could be due to higher accumulation of iron-containing enzymes which otherwise inactivate the biosynthesis of chlorophyll (Rubin & Artskihovskaya, 1964), while in the opinion of Basslavskaya & Syroeshkina (1936) the decrease in chlorophyll was mainly due to higher accumulation of Cl under salt stress. The specific gravity of potato tubers of cvs Rheinhort and Cardinal was found higher under saline conditions than when grown in normal soils. This could be due to a shift in the $K^+$/Na+ ratio in the facour of $Na^+$, having a direct effect on the activity of starch synthetase (Abdullah *et al,* 1978). According to Rush & Epstein (1976) and Abdullah, *et al,* (1978) $Na^+$ is utilized more rapidly than $K^+$, possibly being used as a substitute for it in metabolic functions. Cv. Patrones

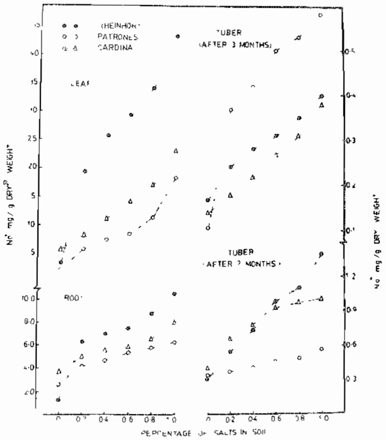

Fig. 5. Salinity-induced changes in $Na^+$ content after 2 months (leaf, root & tuber) and 3 months (tuber) of growth period.

shows a greater specificity for $K^+$ accumulation in the tuber at maturity permitting the maintenance of higher internal levels of this ion despite high external and internal levels of $Na^+$ (Fig. 7) The rate of $Na^+$ and $K^+$ accumulation in different parts was also different in these there cultivars. This would suggest that salt tolerance depends upon the ability of the plant to discriminate between $Na^+$ and $K^+$ in uptake, transport and function. Higher accumulation of $K^+$ within the tubers at maturity under all saline regimes was beneficial for tuber growth. The capacity to maintain high levels of $K^+$ in the presence of high $Na^+$ is strongly correlated with salt tolerance in halophytic bacteria and halophtic bacterial and halophytic plants (Brown, 1964, Rains, 19770.

Small changes in the water content of potato tubers under various amended salinity levels show that they have a capability of osmotic adjustment. The lower water potential at certain salinities was compensated by the accumulation of organic solutes. Plant tissues invariably accumulate unusual metabolites when subjected to physiological stress. Increase in reducing sugars, total proteins and proline up to various levels of salinity may serve as osmotically active substances for osmoregulation under salt strees. In the present investigation accumulation of higher concentration of proline in the amino acid pool in considered as one of the key mechanisms for inducing salt tolerance in potato plants under salt stress. The significance of proline accumulation in halophytes has been well documented (Stweart & Lee 1974, Cavalieri & Huang 1979).

The TGA level was found to be reduced in potato tubers with increasing concentration of salts. The lower level of TGA under these conditions indicates the probability that $Ca^{++}$ or $Na^+$ have formed chelates with steroidal compounds (TGA) in the leaves, thus leaving behind less unbound TGA for translocation to the tubers. $Ca^{++}$ has been reported to form chelates with phenolic compounds (Dekock *et al*, 1975). It is also reported that ABA concentration increased under salt stress (Jones, 1978), and ABA treatment has a salutary effect on tuberization showing reduction in TGA content of potato tubers (Abdullah & Ahmad, 1980). Decrease in TGA content under different saline regimes could be attributed to higher accumulation of ABA in potato plants exposed to salt stress. The exact mechanism responsible for lowering the TGA level in potato plants growing on saline soils amended with calcium and nitrogen needs investigation.

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