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SALINITY INDUCED CHANGES IN THE GROWTH AND CHEMICAL COMPOSITION OF POTATO*

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Abstract

Potato cv. Patrones, Cardinal, Multa, Red Bed, Norland, Chieftain and Red Lasoda were grown in soil containing various concentrations of salts at par with saline soils of Pakistan. Lower concentration of salts upto 0.4% were promotory in tuberization whereas higher salinity levels of 1% were inhibitory. Protein contents of tubers increased at low and decreased at high salinity levels in all potato varieties. Total sugar content of tubers increased with increasing concentrations of salts. In Red Bed total chlorophyll content decreased with increasing salt concentrations while in rest of the varieties the reduction was observed above 0.4% salt level. Total Glycoalkaloids (TGA) level in all the varietis at maturity was much below the considered poisonous limit of 20mg/100g fresh weight and it decreased at higher salinities. On the basis of yield Patrones, Norland and Red Lasoda were classed as tolerant to salinity whereas Red Bed, Chieftain and Cardinal were susceptible. Potato cv. Multa although susceptible to salinity but its yield was 14% more than that of Patrones at 1% salt level.

Introduction

Cultivated potato (*Solanum tuberosum*) contains two main glycoalkaloids, solanine and chaconine (Wood & Young, 1974) which renders them poisonous and unfit for human consumption if present in more than 20 mg/100g fresh weight of tubers, (Nishie *et al,* 1971, Sinden & Webb, 1974, Nishie *et al,* 1975). Studies have been made to see the effect of fertilizers, temperature and altitudes on TGA content of potatoes (Wolf & Duggar, 1946; Zitnak, 1955; Baerug, 1962; Strogonov, 1971, Sinden, 1971; Sinden & Webb, 1974; Cronk *et al,* 1974; Wood & Young, 1974). The affect of salt stress on TGA content in potato tubers has also been reported (Aslanov, 1974; Azizbekova & Aslanov, 1973). In the present study 7 different potato varieties were tested for their relative salt tolerance to elucidate the salinity induced changes in growth, tuberization and chemical composition with special reference to total glycoalkaloid (TGA) content.

Materials and Methods

Potato cv. Cardinal, Patrones and Red Bed were obtained from Punjab Agricultural Research Institute, Faisalabad; Multa from Sind Agricultural Research Institute,

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Mirpur Khas; Chieftain, Norland and Red Lasoda from Agricultural Research Institute, Sariab, Quetta. Potato tubers were kept in plastic bags containing 1 kg sand for sprouting and later transplanted in earthen pots having 25 kg sandy loam. Control pots were saturated with Hoagland & Arnon's nutrient solution (1938) and those for salinization were saturated with saline medium of different compositions. Soil was salinized on percentage basis with different salts giving ionic composition very close to soil salinity of Pakistan (Abdullah, *et al,* 1978). Sodium chloride (NaCl), Magnesium sulphate ($MgSO_4$ $7H_2O$), Calcium chloride ($CaCl_2$. $2H_2O$) and Sodium bicarbonate ($NaHCO_3$) were used for salinization. The ionic composition in one gram of salt mixture was as follows:

Proportion of Cations		**Proportion of Anions**	
Na^+	73%	Cl^-	56%
Mg^{++}	16%	SO_4^{--}	30%
Ca^{++}	11%	HCO_3^-	14%

Salt mixture of the above composition was added to soil in the following ratios:

Ist Set

0.2% mix salinity
0.4% ,, ,,
0.6% ,, ,, for Cardinal, Patrones, Red Bed and Multa
0.8% ,, ,,
1.0% ,, ,,

2nd Set

0.3% mix salinity
0.6% ,, ,, for Norland, Chieftain and Red Lasoda. (Our unpublished results showed that these varieties were more resistant
0.9% ,, ,, to salt stress than above mentioned varieties hence
1.2% ,, ,, higher level of salinity was used for these varieties).
1.5% ,, ,,

NPK was given as recommended by Ravikovitch (1970) and the plants were irrigated periodically with tap water. Temperature during the experimental period ranged between 20.4°C 34.4°C. Average rainfall was 31 mm and relative humidity ranged from 70 to 80%.

After two months of growth period (Exponential phase of growth) the effect of salinity on the foliage, tuberization and chemical compsotion was recorded. These were analysed for total chlorophyll (Maclaclam & Zalik, 1963) reducing sugar (Nelson, 1944) protein (Frydman, 1963; Lowry *et al,* 1951) and total glycoalkaloids (Baker *et al,* 1955). Data on the number of tubers per plant and average weight per tuber was taken after

Table 1. Effect of salt stress on growth and development of potato plants at their exponential phase of growth.

Varieties	% salt concentration in soil 0	0.2	0.4	0.6	0.8	1.0
CARDINAL						
Wt. of foliage (g) /plant.	24.65	46.90	27.90	23.55	32.25	13.10
Chlorophyll content (mg/g f.wt).	0.86	0.97	0.88	0.83	0.74	0.64
Number of tuber/plant.	4	8	4	5	2	2
wt. of tuber (g) /plant.	21.60	52.75	38.45	41.55	37.20	7.74
Mean wt. of tuber (g).	5.40	6.59	9.61	8.31	18.65	3.88
PATRONES						
wt. of foliage (g) /plant.	31.45	31.10	34.10	21.9	19.25	12.05
Chlorophyll content (mg/g f.wt).	0.78	0.83	0.80	0.75	0.61	0.54
Number of tuber/plant.	5	6	4	4	6	3
wt. of tuber (g) /plant.	57.70	81.30	84.85	94.05	69.55	20.25
Mean wt. of tuber (g).	11.54	13.55	21.21	23.51	11.59	6.75
RED BED						
wt. of foliage (g) /plant.	30.75	19.35	33.10	25.72	12.04	9.00
Chlorophyll content (mg/g f.wt).	0.61	0.64	0.50	0.47	0.43	0.36
Number of tuber/plant.	3	4	7	5	2	2
wt. of tuber (g) /plant.	72.95	38.50	73.65	41.10	16.45	5.30
Mean wt. of tuber (g).	24.32	9.63	10.52	8.22	8.23	2.65
MULTA						
wt. of foliage (g) /plant.	117.2	81.1	61.8	54.09	45.9	31.3
Chlorophyll content (mg/g f.wt).	1.07	1.43	1.32	1.10	1.03	0.98
Number of tuber/plant.	18	13	6	6	5	4
wt. of tuber (g) /plant.	271.6	277.5	119.4	115.00	107.7	48.2
Mean wt. of tuber (g).	15.09	21.35	19.90	19.17	21.54	12.05

three months growing period to see the effect of salt stress on tuber initiation and rate of filling. These tubers were analysed for their total glycoalkaloids (TGA) contents.

Results

Growth studies under salt stress

Various responses were observed in different varieties of potato grown under different salt concentrations. There was an increase in foliage growth at lower salinity levels in Cardinal and Patrones. In Multa, even the lowest concentration of salinity severely reduced the foliage production (Table 1). Total chlorophyll in Patrones and Cardinal increased in 0.4% salinity whereas in Multa this increase persisted upto 0.6% salinity level. In Red Bed, chlorophyll content decreased proportionately to increasing salt concentration of the rooting medium. A comparison between the number of tubers at exponential phase of growth (Table 1) and that of final harvest (Table 2a) shows that most of the tubers were produced during the first two months. Lower concentrations of salinity appeared to promote tuber initiation in Cardinal, Patrones and Red Bed, though higher concentrations were inhibitory. In Cardinal, Patrones and Multa mean weight of potato tuber increased upto 0.8% salinity whereas in Red Bed it decreased at all the salinity levels

Table 2(a). Effect of salt stress on number and yield of potato tubers at the time of final harvest.

	% salt concentration in soil					
Varieties	0	0.2	0.4	0.6	0.8	1.0
CARDINAL						
Number of tubers/plant.	9	8	7	5	6	5
Weight of tubers/plant.	93.8	96.5	151.9	116.6	117.8	29.4
Mean weight/tuber	10.42	12.06	21.70	23.32	19.63	5.88
PATRONES						
Number of tubers/plant.	5	6	5	2	3	4
Weight of tubers (g)/plant	111.9	175.5	122.5	78.4	92.0	90.8
Mean weight (g)/tuber.	22.38	29.25	24.50	39.20	30.67	22.70
RED BED						
Number of tuber/plant.	4	6	6	4	4	1
Weight of tuber (g)/plant.	74.2	150.8	142.0	106.7	25.6	10.1
Mean weight (g)/tuber.	18.6	25.1	23.7	26.7	6.4	10.1
MULTA						
Number of tubers/plant.	23	15	10	7	6	4
Weight of tubers (g)/plant.	349.7	214.5	191.7	138.3	125.3	103.40
Mean weight (g)/tuber.	15.20	14.30	19.17	19.73	20.88	25.85

Table 2(b). Effect of salt stress on number and yield of potato tubers at the time of final harvest.

Varieties	% salt concentration in soil 9	0.3	0.6	0.9	1.2	1.5
NORLAND						
Number of tubers/plant.	9	8	6	4	4	3
Weight of tuber (g)/plant.	167.7	200.9	145.00	132.4	125.6	84.4
Mean weight (g)/tuber.	18.86	25.11	24.17	33.10	31.40	28.13
CHIEFTAIN						
Number of tubers/plant.	5	4	4	3	2	2
Weight of tuber (g)/plant.	121.9	104.3	75.3	61.3	56.1	50.7
Mean weight (g)/tuber.	24.38	26.08	18.83	20.43	28.05	25.35
RED LASODA						
Number of tubers/plant.	9	8	5	4	3	3
Weight of tuber (g)/plant.	203.3	196.00	177.4	145.7	132.00	125.00
Mean weight (g)/tuber.	22.59	24.50	35.48	36.43	44.00	41.67

High salt concentrations reduced the number of tubers per plant, although at lower salinity levels an increase in yield of tubers in Cardinal, Patrones, Red Bed and Norland was noticed (Table 2a & b). Mean weight of potato tubers increased upto 0.8% salinity with the exception of Red Bed (Table 1).

Comparing yield of potato tubers (at 1% and 0.9%) Patrones, Norland and Red Lasoda appeared to be salt tolerant varieties (Table 3). The over all productivity recorded

Table 3. Salinity induced changes in the yield of potato tubers.

Performance under non-saline conditions		Performance under saline conditions			
Grading	Name of variety	Grading	Name of variety	% reduction in yield over control	% Salt level
(1)	Multa	(1)	Patrones	18.8	1.0
(2)	Red Lasoda	(2)	Norland	21.5	0.9
(3)	Norland	(3)	Red Lasoda	28.3	0.9
(4)	Chieftain	(4)	Chieftain	49.7	0.9
(5)	Patrones	(5)	Cardinal	68.6	1.0
(6)	Cardinal	(6)	Multa	70.4	1.0
(7)	Red Bed	(7)	Red Bed	86.3	1.0

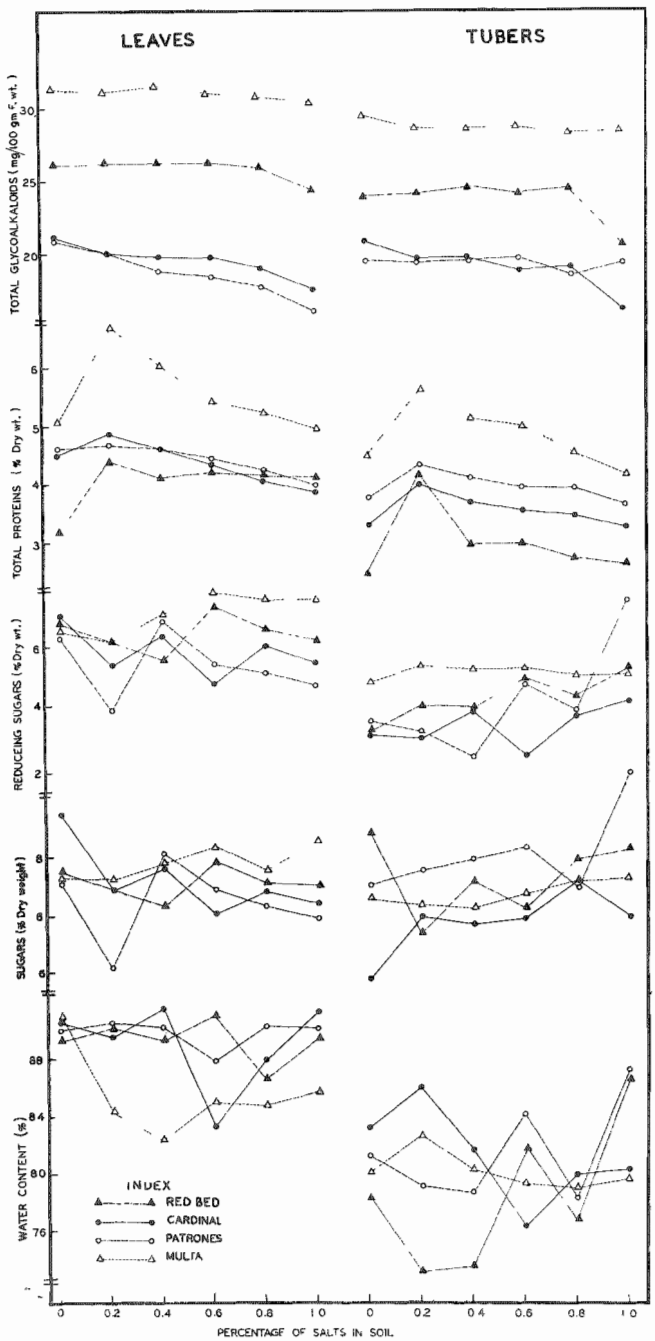

Fig. 1. Effect of salt stress on chemical composition of potato cultivars at their exponential growth phase.

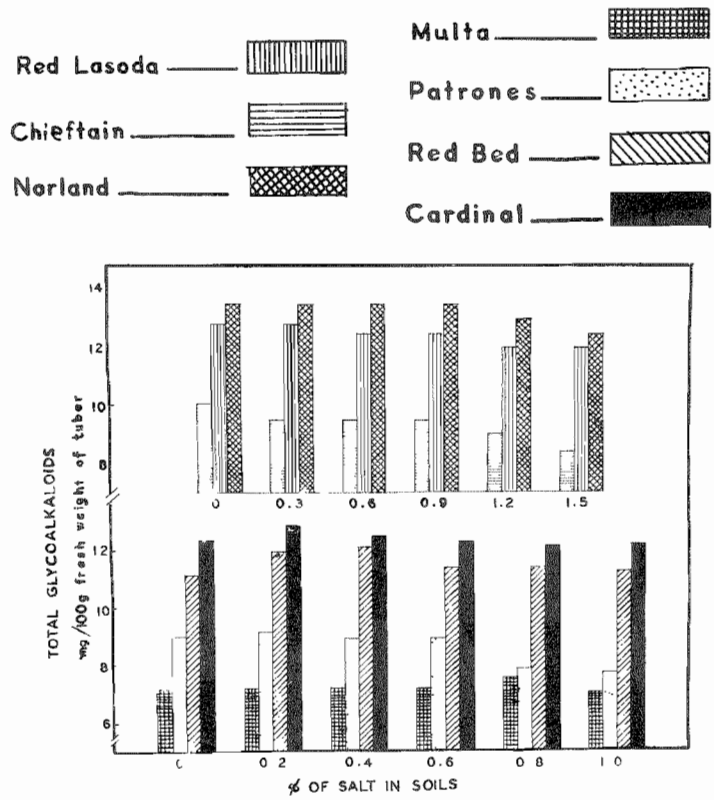

Fig. 2. Total Glycoalkaloid content of potato cultivars under salt stress at the time of final harvest.

was better in Multa since its total yield was 14% more than patrones at 1% salt level although 70.4% reduction in yield over the control was noticed in this variety.

Chemical changes under salt stress

Salinity induced changes at the exponential phase of growth in Red Bed, Cardinal, Patrones and Multa are presented in Fig. 1. There was no major difference in water contents of potato tubers in all the four varieties. Concentrations of reducing as well as total sugars increased at high salinity levels under exponential phase of growth. At lower salinities, however, the concentration of total proteins increased in the foliage as well as in tubers of all the four varieties. A decrease in total glycoalkaloid (TGA) level was also observed due to salinity but the differences were small (Fig. 2). In var. Red Bed, however, slight increase in TGA levels at 1% salinity was recorded. (Table 4).

Discussion

The results in Table 1 show that low levels of salinity increase the foliage growth and tuberization in low yielding cv. Cardinal and Red Bed. On the other hand higher concentrations of salt decreased foliage growth of the varieties whereas tuberization is

Table 4. Changes in the TGA content of potato tubers as a results of growth in saline soils.

Grading	Varieties	TGA content non-saline condition (control)	saline conditions	% Salt level
1	Norland	13.5	13.5	0.9
2	Chieftain	12.7	12.4	0.9
3	Cardinal	12.2	12.1	1.0
4	Red Bed	11.1	11.3	1.0
5	Red Lasoda	10.1	9.5	0.9
6	Patrones	8.9	7.	1.0
7	Multa	7.1	6.9	1.0

little affected. In Patrones, Cardinal, Red Bed and Norland the yield of potato increased over the control respectively at 0.4, 0.8 0.6 and 0.3% salinity levels suggesting a beneficial effect of Na^+ present in the soil for filling of potato tubers.

It is known that luxuriant foliage growth of potato plant is not necessarily responsible for better yield of tubers (Smith, 1968). This is quite apparent from the results (Table 1) that reduction in foliage due to salinity has not proportionately reduced the yield of tubers. ABA levels is known to increase rapidly under salt stress (Jones, 1978) and higher salinities decrease cytokinin levels (O' Leary, 1971). Beneficial effects of ABA on potato tuber initiation have been reported (Kruss, 1978; Abdullah & Ahmad, 1979). The release of cytokinins from roots to the leaves in also essential for tuberization (Dimalla & Staden, 1977). The increase in the yield of potato tubers in Cardinal, Patrones, Red Bed and Norland under low salt stress (Table 2a & b) could therefore be attributed to the beneficial effect of ABA synthesized during low salt treatment and that the adverse effect of higher salinities on tuberization may well be due to higher accumulation of ABA or decrease in cytokinins levels of roots.

While working on the filling of wheat grains under salt stress Abdullah, *et al,* (1978) found that the salt did not impair the synthesis of starch synthetase but promoted the activity of this enzyme. This phenomenon may also explain the increase in the mean weight of tubers upto 0.8% level of salinities.

An increase in the concentration of reducing and total sugars in tubers at higher salinity levels during exponential phase of growth would help in the maintenance of osmotic balance during saline treatments. Similarly, increase in protein content at lower levels of salinity would be of great help in maintaining concentrations of osmotically active substances in the tubers. At higher level of salinities the protein content was always less than that of control which was also reflected in terms of low yield of tubers. The

TGA was present in comparatively greater concentration in the tubers harvested at exponential phase of growth than those harvested after maturity. High amount of TGA in young tubers in comparison with mature ones was also observed by Cronk *et al* (1974). Salinity reduced the TGA levels of the tubers mostly during exponential phase of growth with further reduction at maturity. The concentration of TGA under saline environment remained below 20 mg/100g fresh weight the permissible limit for human consumption (Wood & Young, 1974) and therefore should not create physiological disorders in humans.

On the basis of reduction in yield under saline soil potato cv. Patrones, Norland and Red Lasoda could be classified as tolerant whereas Red Bed, Cardinal, Chieftain and Multa as susceptible varieties. However, the tonage in Multa, inspite of being a susceptible variety was better than Patrones which is placed among the tolerant varieties.

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