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Influence of sodicity on cation composition, growth, yield and quality of chilli (*Capsicum annuum* L.)

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Abstract

Field trials conducted at Lucknow (Uttar Pradesh) to study the performance of chilli (*Capsicum annuum*) in sodic soil with four genotypes (Jwala, PC-1, KDCS-810 and LCA-235) and five levels of exchangeable sodium percentage (ESP) (10, 20, 30, 40 and 50) indicated the adverse effect of sodicity and hence picking of red ripe fruits may be stopped after the sixth one when there is about 25% reduction in fruit size. Maximum mean yield (fresh) was obtained in LCA-235 (16.2 t ha^{-1}) followed by KDCS-810 (13.1 t ha^{-1}), PC-1 (12.0 t ha^{-1}) and Jwala (10.3 t ha^{-1}). There was less reduction in yield of LCA-235 and KDCS-810 than Jwala and PC-1 at higher sodicity level (ESP=40) revealing greater sodicity tolerance. Cation composition of different plant parts indicated salt (Na) exclusion mechanism and higher K/Na and Ca/Na ratio supporting the potential of chilli crop to endure greater degree of sodicity. Physical fruit quality with respect to length, diameter and pod weight were affected by soil sodicity and decreased with increase in soil sodicity. Oleoresin and capsaicin contents did not vary with increase in sodicity, whereas, ascorbic acid content was reduced.

Keywords: *Capsicum annuum*, chilli, growth, quality, sodicity, yield.

Introduction

Chilli (*Capsicum annuum* L.) has good potential for cultivation on salt affected soil since it is reported as moderately sensitive to soil salinity (Navarro *et al*. 2002). However, there is little information on the performance of chilli in sodic lands. Hence, the present study was undertaken with the objective to assess the influence of soil sodicity on growth, cation composition, yield and quality of chilli.

Materials and methods

The field experiments were conducted at Banthra Research Station of National Botanical Research Institute, Lucknow (Uttar Pradesh) during *kharif* season of 2001-03. The soil of the experimental site was silty loam in texture with pH 8.5-10.0 having medium organic C and total N, low to deficient P_2O_5 and high K_2O contents (Table 1). In general, organic C, total N and cation exchange capacity (CEC) showed decreasing trend with

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Table 1. Soil characteristics before transplanting of chilli (Mean±SD)

Treatment	pH (1:2 Soil)	EC (d Sm^{-1})	OC (%)	Total N (%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})	CEC (c mol kg^{-1})	ESP
10 ESP	8.08 ± 0.13	0.38 ± 0.11	0.69 ± 0.07	0.155 ± 0.019	13.71 ± 0.95	1226.40 ± 69.64	20.05 ± 1.10	8.58 ± 1.28
20 ESP	8.64 ± 0.27	0.28 ± 0.02	0.57 ± 0.10	0.113 ± 0.025	10.23 ± 0.55	890.03 ± 61.31	18.52 ± 0.70	19.81 ± 0.49
30 ESP	9.19 ± 0.20	0.33 ± 0.07	0.50 ± 0.04	0.101 ± 0.030	8.43 ± 1.06	794.45 ± 88.63	17.08 ± 0.80	28.41 ± 1.29
40 ESP	9.50 ± 0.13	0.43 ± 0.03	0.44 ± 0.02	0.107 ± 0.010	8.65 ± 1.62	744.05 ± 22.87	16.46 ± 0.33	39.25 ± 1.41
50 ESP	9.76 ± 0.08	0.43 ± 0.06	0.43 ± 0.01	0.096 ± 0.015	7.31 ± 1.50	728.37 ± 42.54	13.46 ± 1.82	51.30 ± 4.85

CEC=Cation exchange capacity; ESP=Exchangeable sodium percentage; EC=Electrical conductivity; OC=Organic carbon

increasing levels of soil exchangeable sodium percentage (ESP). Soil pH increased with rise of soil ESP, however, EC showed an erratic variation with rise of ESP. There were 20 treatment combinations laid out in a split plot design with 3 replications consisting of 5 levels of ESP namely, 10, 20, 30, 40, and 50 created on the surface soil by adding gypsum/sodium carbonate and 4 genotypes namely, Jwala, PC-1, KDCS-810 and LCA-235. The sodicity levels were taken as the main plots and the cultivars were arranged in the sub plots.

The seeds were sown during the first week of June each year. The seedlings became ready for transplanting when they were about 60 days old. In both the years, the seedlings were transplanted during the first week of August in beds of $1m^2$ (with inter and intra row spacing of 45 cm and 30 cm, respectively) in a manner to protect them from all sides by 1 m distance from each bed so that the neighbouring sodicity may not affect the treatment plot and a light irrigation was given after transplanting. The fertilizer doses applied were: 100 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1}. Full dose of phosphorus, potassium and half of the N was given 1 week before transplanting. Rest of N was given 50 days after transplanting. Farmyard manure (FYM) @ 25 t ha^{-1} was also mixed in soil before transplanting. Other cultural operations and plant protection measures were followed uniformly. Observations were recorded on survival of seedlings, vegetative growth (plant height and number of branches) and yield of fruits. Red ripe chillies were plucked from 1st week of November at 2 weeks interval. Totally six pickings of red fruits were done and the data were pooled to obtain the total yield.

Samples of leaf, shoot and root were collected separately at harvest and were washed with deionized water, dried in oven at 70°C and powdered in a mill and analyzed for determination of cation composition. The dry sample (1 g) was digested in nitric and perchloric acid following wet digestion method. K, Na, Ca and Mg were estimated following standard methods (Richards 1954). The data recorded on different parameters for both the years were pooled and mean data over 2 years were presented and subjected to statistical analysis for test of significance (Panse & Sukhatme 1961).

Physical quality parameters such as fruit length, fruit diameter, 100-pod weight, percentage of seed and proportion of pericarp of the fruit were recorded. To determine the chemical quality of fruit, red ripe chillies were oven dried, ground to a fine powder and analyzed for capsaicin content by colorimetric method (Balsubramanian *et al.* 1982). Oleoresin was extracted in a soxhlet apparatus using solvent acetone. The ascorbic acid content of fruits was estimated by 2, 6-dicholorophenol indophenol dye method (Sadasivam & Manickam 1992).

Results and discussion

Survival and growth

The transplanted plants established in 10-12 days and showed erratic response to ESP levels. About 22% mortality in cultivars Jwala and PC-1 and about 11% in cultivars KDCS-810 and LCA-235 were observed (Fig. 1). Plant height of all the cultivars was greater than control that did not show any marked influence of sodicity. Plant height was minimum in KDCS-810 (42 cm) and maximum in LCA-235 (69 cm). The varied response of plant height was probably due to the genotypic character of the cultivars. There was little variation in branching pattern of cvs. Jwala and LCA-235 but in cvs. PC-1 and KDCS-810, emergence of branches were adversely affected due to influence of sodicity. This may be discernable to osmotic reduction in water availability although not investigated. However, reduction in growth has also been observed in chilli with increasing of ESP levels (Gunes *et al.* 1996).

The length of fruits varied from 8.58 cm (KDCS-810) to 11.14 cm (Jwala) at first picking and it decreased to 6.67 cm and 8.74 cm respectively, at sixth picking in these cultivars. The results revealed that the picking can be stopped when there is about 25% reduction in fruit size (Fig. 2).

Yield

The mean (two years) yield of fresh red ripe chilli varied from 1426 g m^{-2} (Jwala) to 1940 g m^{-2} (LCA-235) in control. It was less affected up to 30 ESP and after this the reduction in yield was greater with rise of soil ESP. The reduction in yield was greater particularly in Jwala at 40 and 50 ESP (Table 2). Yields of

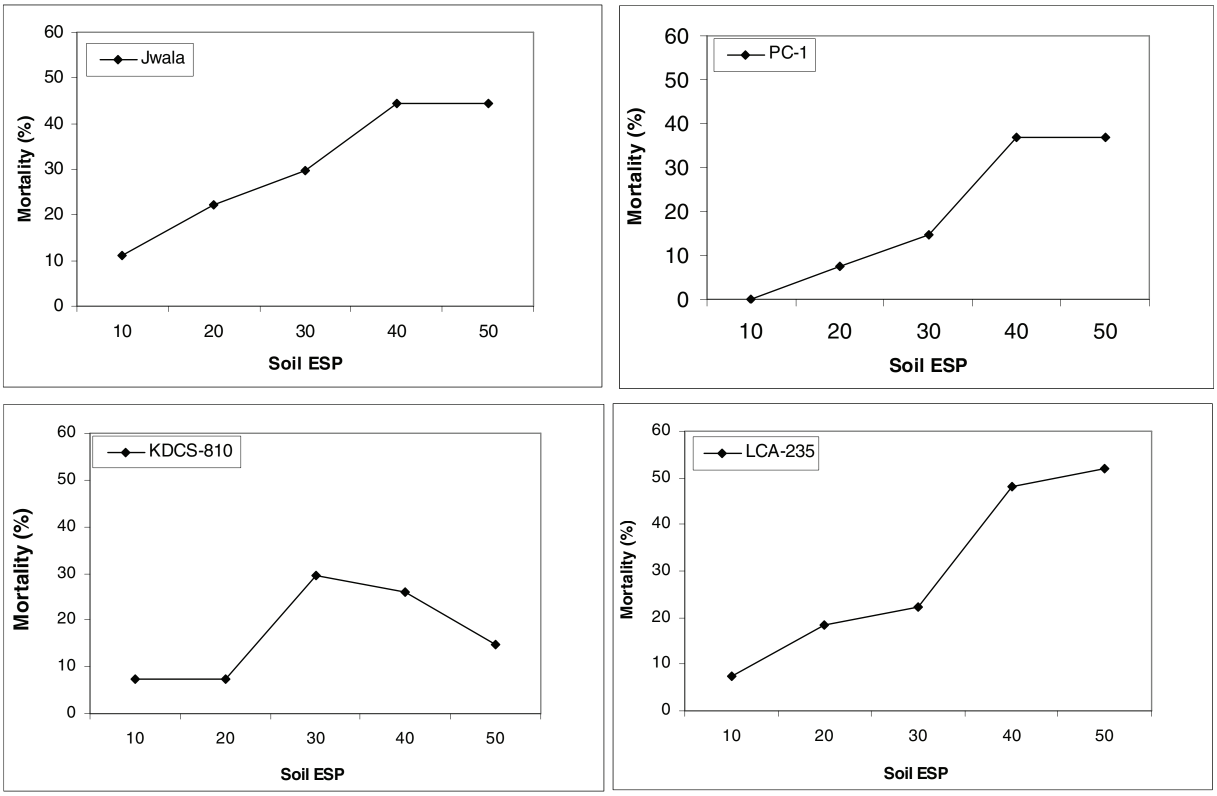

Fig. 1. Mortality (%) of various cultivars of chilli grown at different levels of soil ESP.

Table 2. Fresh red ripe yield of chilli grown at different levels of soil ESP

Treatment	Yield (g m^{-2})
Cultivar	
Jwala	1038.0
PC-1	1205.3
KDCS-810	1317.9
LCA-235	1623.9
CD (P=0.05)	241.3
ESP level	
10	1610.0
20	1432.5
30	1324.6
40	1220.0
50	894.3
CD (P=0.05)	241.3
Interaction	662.8

Interaction effect of sodicity levels and cultivar yield (g m^{-2})

Cultivar	10 ESP	20 ESP	30 ESP	40 ESP	50 ESP
Jwala	1426.6	1073.3	1040.0	936.6	713.3
PC-1	1510.0	1410.0	1301.6	1223.3	850.3
KDCS-810	1506.7	1446.7	1240.0	1220.0	1176.0
LCA-235	1996.7	1800.0	1716.7	1500.0	1106.3

ESP=Exchangeable sodium percentage

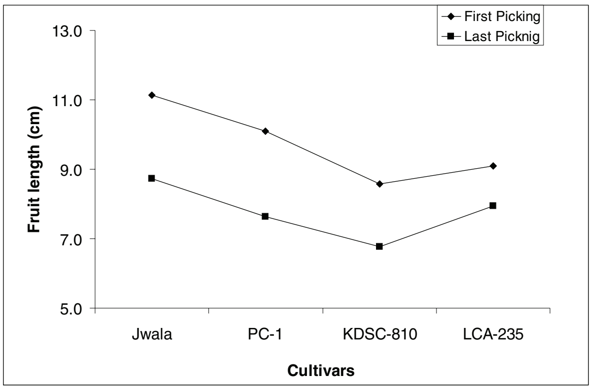

Fig. 2. Length of fruit of different cultivars of chilli at initial and last picking.

fresh red ripe chilli on normal soil generally vary from 1500 to 2500 g m^{-2} (Pruthi 1998). In the present study the maximum yield of 1716.7 g m^{-2} at 30 ESP was obtained in LCA-235 that was at par with that of normal soil yield. However, the yield reduced further at 50 ESP, which was slightly lower than the normal range. The effect of cultivar was significant with regard to yield. However, soil ESP grades were not significant. The interaction of ESP and cultivar was also not significant. Maximum mean yield (fresh) was obtained in LCA-235 (16.2 t ha^{-1}) followed by KDCS-810 (13.1 t ha^{-1}) (Table 2). However, the estimated yield of dry pod would be about 1.2-2.0 t ha^{-1} comparable with other workers (Shibhila & Balkrishan 1990; Murugun *et al.* 2002). Assuming 50% reduction in yield taken as criterion of sodicity tolerance, the cultivars LCA-235 and KDCS-810 showed less reduction in yield than Jwala and PC-1 at higher sodicity (ESP=40) indicative of their relatively greater tolerance.

Cation composition

In general, cation composition of leaf showed greater concentration of K and Ca, which ranged from 19.2 mg g^{-1} to 24.1 mg g^{-1} and 37.3 mg g^{-1} to 50.6 mg g^{-1}, respectively. Their contents were lower in roots varying from 6.6 mg g^{-1} to 11.0 mg $g^{-1}$and 11.7 mg g^{-1} to 13.8 mg g^{-1}, respectively. These cations were intermediary in case of stem indicating that the roots of chilli plant absorb sufficient amount of Ca and transport to the leaf where it is stored. There was little variation in Na and Mg concentrations in different parts of the plant (Table 3). Accumulation of leaf Ca was exceptionally higher than other crops like coriander and fennel grown in sodic stress soils where its contents ranged from 11.5 to 13.7 mg g^{-1} (Garg *et al*. 2004). Salt tolerant plants could be best identified as those that maintain sufficient K and Ca in shoot tissue under such stress conditions. Besides, higher K/Na and Ca/Na ratio in leaf tissue is indicative of greater tolerance of soil sodicity (Table 3). Plants generally differ in their ability to accumulate or exclude Na ions when grown in saline/sodic stress conditions. In our study, this salt (Na) exclusion mechanism in the plant tissue of chilli does not show any deficiency or toxicity during growth and development. Therefore, this study leads to postulate that the chilli crop has potential to endure greater degree of sodicity (ESP 50).

Table 3. Cation composition of different parts of chilli grown in sodic soil (Mean±SD)

Cultivar	K (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	Na (mg g^{-1})	K/Na	Ca/Na
			Leaf			
Jwala	24.1±2.9	38.0±10.0	5.21±5.1	4.8±1.8	5.02	7.91
PC-1	23.8±3.2	43.7±3.1	2.8±1.3	2.2±0.7	10.8	19.86
KDCS-810	23.9±0.9	50.6±4.3	8.0±3.3	2.9±2.0	8.24	17.44
LCA-235	19.2±8.9	37.3±22.0	9.0±2.4	2.7±1.4	9.11	13.81
			Stem			
Cultivar	K (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	Na (mg g^{-1})	K/Na	Ca/Na
Jwala	25.5±8.56	28.9±9.41	4.3±0.87	3.5±0.84	7.28	8.25
PC-1	22.8±2.96	29.5±5.94	7.1±2.29	3.2±0.84	9.12	9.21
KDCS-810	25.1±4.80	35.2±6.70	5.0±0.34	2.8±0.31	8.96	12.57
LCA-235	20.7±3.79	27.7±4.42	2.9±1.16	2.4±0.68	8.62	11.54
			Root			
Cultivar	K (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	Na (mg g^{-1})	K/Na	Ca/Na
Jwala	10.9±1.61	15.3±3.56	9.5±1.18	4.31±0.97	2.52	3.54
PC-1	6.6±3.45	11.7±5.6	8.4±1.74	3.6±0.86	1.83	3.25
KDCS-810	11.0±2.34	13.8±6.63	9.6±3.13	2.9±0.69	3.79	4.75
LCA-235	9.6±2.4	12.0±4.12	10.2±1.87	2.6±0.31	3.69	4.61

Physical quality

In view of the good performance and potential of the crop to tolerate high degree of sodicity, physical and chemical quality parameters were assessed at ESP 40 and 50 only to know the difference, if any. In general, physical quality parameters like pod length, pod diameter, and 100-pod weight decreased with increasing ESP levels except in KDCS-810 for 100-pod weight. Seed weight and proportion of pericarp showed an erratic variation with the rise of soil ESP. The fruits of cv. Jwala were long (108 mm) and of cv. KDCS-810 were smaller (84 mm) but the reverse trend was observed for pod diameter. The 100-pod weight of Jwala was highest in non sodic soil but it decreased with rise of sodicity levels except in KDCS-810 showing static weight (Table 4). Generally, the length of fruits of Jwala and PC-1 varied from 90 to 100 mm and 60 to 70 mm respectively, and their diameter ranged from 30 to 35 mm

Table 4. Physical parameters of chilli cultivars grown in non-sodic and sodic soils

Treatment	Fruit length (mm)	Diameter (mm)	100-pod weight (g)	Seed weight (%)	Plant size	Visual colour
*Control**						
Jwala	108	6.9	78.0	42.1	Large	Bright red
PC-1	99	7.0	66.2	40.5	Small	Light red
KDCS-810	84	8.0	51.8	46.7	Small	Dark red
LCA-235	91	7.6	65.7	39.0	Medium	Dark red
ESP-40						
Jwala	97	6.2	75.6	35.7	Large	Bright red
PC-1	86	6.4	50.6	50.6	Small	Light red
KDCS-810	75	7.0	54.3	43.1	Small	Dark red
LCA-235	82	6.7	64.2	41.9	Medium	Dark red
ESP-50						
Jwala	86	5.8	58.0	38.1	Large	Bright red
PC-1	79	6.3	60.3	46.1	Small	Light red
KDCS-810	70	6.5	53.5	47.9	Small	Dark red
LCA-235	77	6.7	43.9	37.7	Medium	Dark red
CD (P=0.05)	14	0.8	2.1			

* ESP=10; ESP=Exchangeable sodium percentage

(Pruthi 1998). The study revealed that edaphic factors influenced fruit size (Dahal *et al*. 2006). The fruits of Jwala and PC-1 became slender and showed more reduction in yield at greater sodicity levels and appeared to be less tolerant whereas, LCA-235 and KDCS-810 though smaller, became fluffy and showed less reduction in yield at higher ESP levels and show higher tolerance to soil sodicity.

Chemical quality

There was a narrow variation for oleoresin content from 5.9% (KDCS-810) to 8.22% (Jwala) with a mean of 7.3% in control (non-sodic soil). It increased slightly with rise of sodicity and ranged from 7.13% (PC-1) to 12.5% (Jwala) with an average of 9.5%. Oleoresin was maximum in Jwala followed by LCA-235, grown in sodic soil (Table 5). In chilli species, genotypes and agro-climate play a dominant role on quality parameters (Rani 1996; Singh *et al*. 2003). In the present study, oleoresin content of Jwala was higher even in sodic soil but its yield was reduced drastically on such land. Thus, the cultivars LCA-235 and KDCS-810 are promising for oleoresin and yield traits, being able to tolerate sodicity.

Capsaicin varied within narrow limits of 0.365% to 0.647% on non-sodic soil (control). Similar content of capsaicin was also reported by Pruthi (1998) and Singh *et al*. (2003). The low capsaicin content in all the genotypes might be due to edaphic factors. There was an inconsistent variation in capsaicin content on sodic soil except an increase in LCA-235 (Table 5). Such variation due to cultivars, environmental factors and size of fruit, thickness of pericarp, height of plant, weight of fruit/plant, ratio of seed to pericarp and yield have also been observed by Singh *et al*. (2003).

The nutritive value of chilli is chiefly assessed by the contents of ascorbic acid. It varied from 153.8 mg 100 g^{-1} in LCA-235 to 192.3 mg 100 g^{-1} in Jwala with an average of 173.7 mg 100 g^{-1} in non-sodic soil (control). It decreased with rise of soil sodicity varying from 100 mg 100 g^{-1} to 153.8 mg 100 g^{-1} (Table 5). There was less reduction of its content at 50 ESP than 40 ESP. The small sized fruit (KDCS-810) with greater seed pericarp ratio showed less reduction of ascorbic acid than long sized fruit (Jwala) at higher ESP level (Dahal *et al*. 2006). The cultivars Jwala and KDCS-810

Table 5. Chemical quality parameters (MFB) of chilli cultivars grown in non-sodic and sodic soils

Treatment	Oleoresin (%)	Capsaicin (%)	Ascorbic acid (mg $100g^{-1}$)
*Control**			
Jwala	8.22	0.647	192.3
PC-1	7.42	0.410	160.1
KDCS-810	5.90	0.576	188.5
LCA-235	7.82	0.365	153.8
ESP-40			
Jwala	12.50	0.612	138.5
PC-1	7.23	0.435	145.5
KDCS-810	9.72	0.588	153.8
LCA-235	10.40	0.413	134.6
ESP-50			
Jwala	11.68	0.687	138.5
PC-1	7.13	0.413	129.2
KDCS-810	8.19	0.549	100.0
LCA-235	9.20	0.533	126.9
CD (P=0.05)	0.46	0.054	6.5

* Non-sodic soil; MFB=Moisture free basis; ESP=Exchangeable sodium percentage

with high ascorbic acid content are thus, suitable for vegetable purpose even when grown on sodic soil. It may be pointed out that the ascorbic acid content decreases gradually as the maturity of plant advances (Murugan 2001). It also depends on species, geographical origin of the genotype and climatic conditions (Robi & Sreelathakumary 2006).

The present study indicated that the chilli crop has great potential to endure soil sodicity up to 40 ESP. However, further investigations are needed to screen genotypes on different types of sodic soil existing in different agro climatic zones.

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