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Effect of different Soil Sodicity levels on growth, yield and Na/k ratio in cotton

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Abstract
The world agriculture is suffering due to development of salinity and poses a major setback in increasing the yield of cotton. The ability of the plant system to maintain low sodium concentration is a critical component for its tolerance to salt affected conditions. The plant Na/K concentration in the plant was studied to understand the cotton crop for their tolerance to different sodicity levels (Different ESP levels) and to assess its effect on yield. The cotton varieties (SVPR 2 and Surabi) and Bt cotton (RCH -20) was tested in the field experiment under different ESP levels. The yield of cotton varieties and Bt cotton was recorded at different ESP levels. The yield was higher in Bt cotton compared to other two verities and the ESP level of 38-41 is fixed as to get 50% yield. This was mainly exclusion of Na in the cotton leads to the lower level of Na/K ratio in the Bt cotton plants than the varieties tested.

Keywords: ESP, Sodicity, cotton variety and hybrid, yield, Na/K ratio

Introduction
About 7% of the total land around the globe is salt-affected causing a great loss to agriculture. Salt stress refers to the excessive amount of soluble salts in the root zone which induce osmotic stress and ion toxicity in the growing plant. Among toxic ions, sodium (Na^+) has the most adverse effects on plant growth by its detrimental influence on plant metabolism in inhibiting enzyme activities. Intensity of sodicity problems is generally quantified by measuring exchangeable sodium percentage (ESP) and relevant soil properties (Sumner 1993). Adverse effects of sodicity on crop growth mainly results in from the breakdown of soil structure through dispersion of aggregated particles (Loveday 1984; Rengasamy *et al.* 1991) [8, 10]. The sodicity problem has been addressed through improvements in production practices and the introduction of tolerant varieties. In India has 6.73 Mha of salt-affected soils, of which 3.72 Mha is sodic soils and in Tamil Nadu State 3,54,784 ha are affected by soil sodicity (Singh, *et al.*, 2020) [9]. Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. It provides the basic raw material (cotton fibre) to cotton textile industry. The present study was undertaken to study the tolerance of cotton varieties and Bt cotton under different ESP levels crop on growth, yield and Na/K ratio.

Materials and Methods
A field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute Farm during 2012-13 and 2013-14 in split plot design (SPD) with three replications. The soil of the experimental field had the following characteristics: texture clay loam, pH 8.9, EC 0.41 dS m^{-1}, available N 175 kg ha^{-1}, P 9.6 kg ha^{-1}, K 180 kg ha^{-1}, CEC 18 cmol (p+)/kg and an ESP of 16. Taxonomically the soil of the experimental field belongs to fine, mixed, calcareous *isohyperthemic Vertic Ustropept*. The water used for irrigation is highly alkali with pH of 8.8, EC 1.42, RSC 9.2. The main plot treatments comprised of four ESP levels *viz*., ESP of 9.8(M1), 17(M2), 30(M3) and 41(M4) were artificially created by application sodium bicarbonate and the cotton hybrid (RCH-20) and varieties (Surabi and SVPR-2) were tested in the subplots. The experimental plot size was 40 m^2 (8m x 5 m). The fertilizer dose of N, P and K @ 80:40:40 was applied in the form of Urea, SSP and Muriate of poash, respectively to cotton varieties *viz*., Surabi (S1) and SVPR-2 (S3).

Whereas the fertilizer dose of N, P and K @ 120:60:60 was applied to Bt hybrid cotton (RCH-20) (S2). For both cotton varieties and hybrid, the N and K fertilizers were applied at four splits and full dose of P fertiliser was applied as basal. The recommended agronomic practices and crop protection measures were followed as per the Crop Production Guide (CPG) developed by Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The Sodium and potassium was measured by flame photometry according to Jackson (1973) [7].

Results and Discussion

Among the different hybrid and varieties tried at different ESP levels the Bt cotton hybrid RCH-20 recorded the highest plant height (96.25 cm) and the variety SVPR-2 recorded the lowest plant height (63.5 cm) at the lowest ESP of 9.8 during 2012-13. During 2013-14 the same Bt hybrid cotton (RCH-20) recorded the the highest plant height of 100 cm and the variety SVPR-2 recorded the lowest plant height of 64 cm at the lowest ESP (ESP 9.6) (Table 1). The observation on yield attributing characters *viz*., monopodial branches and, symbodial branches under different ESP levels, the result showed that a significant difference was recorded by hybrid and varieties at all ESP levels during 2012-13 and 2013-14 (Tables 2 and 3). Among varieties and hybrid tested, RCH-20 performed better in producing the more monopodial and symbodial branches than the varieties. In general, the growth parameter and yield attributing parameters were decreased as the ESP level increases. The increase in ESP (exchangeable sodium percentage) markedly suppressed the plant growth especially plant height (Alka Upadhyay *et al*. 2012) [1]. Dinesh *et al*. (2004) [2] also observed decrease in height of plants, branching/leaves and flowers with increase in soil ESP. Relative growth rate of many agricultural crops has been observed to be retarded under sodic conditions in soil (Hocking, 1993; Gill and Qadar, 1998) [5, 6]. The reduction in plant growth could be attributed might be due to the presence of high Na content in soil in available form (Garg and Malhotra, 2008) [3].

The results of the field experiment showed that the cotton hybrid RCH-20 recorded the maximum seed cotton yield of 1332 and 2164 kg ha^{-1} and the variety SVPR-2 recorded the lowest seed cotton yield of 807 and 844 kg ha^{-1} during 2012-13 and 2013-14, respectively (Table 4). In both the years, the seed cotton yields of each hybrid and varieties had significantly reduced yields with progressive increase in ESP levels. Among ESP levels tried, ESP 9.8 recorded significantly higher yield of 1410 kg ha^{-1} compared to other three ESP levels. Irrespective of the hybrid and varieties tested the yield was decreased from 1410 to 698 kg ha^{-1} for ESP level of 9.8 to 41 during 2012-13 and1554 to 737 kg ha-1 for ESP level of 9.2 to 38 during 2013-14. The percent yield reduction was observed as 18 (ESP 17), 33 (ESP 30) and 50 (ESP 41) during 2012-13 Whereas, 21%, 36% and 52% at ESP level of 18.5, 29 and 38 during 2013-14. Grain yields of soybean showed highly significant negative relationships with increasing surface soil ESP was observed by Harnam Gill (2010) [5].

The results of the Na/K ratio revealed that, the varieties recorded higher values at all ESP levels compared to hybrid during 2012-13 and 2013-14. The hybrid cotton has the tolerance mechanism at higher ESP levels by exclusion of sodium ions in the plant system than the varieties and this was reflected in growth parameters and yield potential of the Bt hybrid cotton than varieties. This is in conformity with the findings of (Walia *et al*., 2005). An optimal potassium (K^+): Na^+ ratio is vital to activate enzymatic reactions in the cytoplasm necessary for maintenance of plant growth and yield development. Although most soils have adequate amounts of K^+, in many soils available K^+ has become insufficient because of large amounts of K^+ removal by high-yielding crops. This problem is exacerbated under sodic or saline-sodic soil conditions as a consequence of K^+-Na^+ antagonism. Here, K^+ uptake by plants is severely affected by the presence of Na^+ in the nutrient medium. Due to its similar physicochemical properties, Na^+ competes with K^+ in plant uptake specifically through high-affinity potassium transporters (HKTs) and nonselective cation channels (NSCCs). Membrane depolarization caused by Na^+ makes it difficult for K^+ to be taken up by K^+ inward-rectifying channels (KIRs) and increases K^+ leakage from the cell by activating potassium outward-rectifying channels (KORs). Minimizing Na^+ uptake and preventing K^+ losses from the cell may help to maintain a K^+: Na^+ ratio optimum for plant metabolism in the cytoplasm under salt-stress conditions

Table 1: Plant height of cotton plants under different ESP levels (cm)

ESP levels	2012-13				2013-14				
	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean	ESP levels	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean
M1(9.8)	119	148	101	122.6	M1 (9.6)	121	156	101	126
M2 (17)	91	111	71	91.0	M2 (18.5)	92	115	72	93
M3 (30)	62	84	54	66.6	M3 (29)	62	85	54	67
M4(41)	34	42	28	34.6	M4 (38)	35	44	29	36
Mean	76.5	96.25	63.5			78	100	64	
CD (P=0.05%)	M 3.2	S 2.86	MXS 5.65	SXM 5.73		M 3.02	S 2.5	MxS 5.09	SxM 5.02

Table 2: Number of monopodia /plant under different ESP levels

ESP levels	2012-13				2013-14				
	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean	ESP levels	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean
M1 (9.8)	2.3	3.8	1.9	2.67	M1 (9.6)	2.5	4.1	2.0	2.9
M2 (17)	2.0	2.9	1.2	2.03	M2 (18.5)	2.1	3.1	1.4	2.2
M3 (30)	1.7	2.4	1.1	1.80	M3 (29)	1.8	2.8	1.3	2.0
M4(41)	1.1	1.2	1.1	1.80	M4 (38)	1.3	1.6	1.3	1.4
Mean	1.8	2.6	1.3			1.9	2.9	1.5	
CD (P=0.05%)	M 0.8	S 0.72	MXS 1.41	SXM 1.43		M 0.09	S 0.07	MxS 0.14	SxM 0.13

Table 3: Number of symbodia /plant under different ESP levels

ESP levels	2012-13				2013-14				
	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean	ESP levels	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean
M1(9.8)	31	39	21	30.3	M1 (9.6)	32	42	22	32
M2 (17)	19	26	13	19.3	M2 (18.5)	19	28	14	20
M3 (30)	11	18	9	12.6	M3 (29)	12	20	10	14
M4(41)	8	11	8	9.0	M4 (38)	9	13	8	10
Mean	17.25	23.5	12.75			18	26	14	
CD (P=0.05%)	M 1.3	S 1.16	MXS 2.29	SXM 2.33		M 0.67	S 0.72	MxS 1.35	SxM 1.44

Table 4: Seed cotton yield under different ESP levels (kg ha^{-1})

ESP levels	2012-13					2013-14					% yield reduction
	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean	% yield reduction	ESP levels	S1 (Surabhi)	S2 (RCH-20)	S3(SVPR-2)	Mean	
M1(9.8)	1265	1881	1083	1410	-	M1 (9.6)	1356	2164	1141	1554	-
M2 (17)	1132	1434	881	1149	18	M2 (18.5)	1205	1556	918	1226	21
M3 (30)	930	1135	733	932	33	M3 (29)	987	1232	763	994	36
M4(41)	685	879	532	698	50	M4 (38)	715	944	553	737	52
Mean	1003	1332	807				1066	1474	844		
CD (P=0.05%)	M 44	S 32	MxS 69	SxM 66			M 79	S 71	MxS 139	SxM 142	

Table 5: Na/K ratio in cotton crop under different ESP levels

ESP levels	2012-13				2013-14				
	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean	ESP levels	S1 (Surabhi)	S2 (RCH-20)	S3 (SVPR-2)	Mean
M1(9.8)	1.17	0.75	1.7	1.21	M1 (9.6)	1.51	0.78	1.94	1.41
M2 (17)	1.33	0.82	1.79	1.31	M2 (18.5)	1.67	0.85	2.03	1.52
M3 (30)	1.41	0.91	1.89	1.40	M3 (29)	1.75	0.94	2.13	1.61
M4(41)	1.51	0.97	2.02	1.50	M4 (38)	1.85	1.00	2.26	1.70
Mean	1.35	0.86	1.85	1.35		1.69	0.89	2.09	

Conclusions

Generally, the salt present in the soil adversely affects the biomass production *viz*., decrease in plant height, number od branches, bolls and boll weight and ultimately brings about decrease in seed cotton yield. From the present investigation, it could be concluded that the Bt hybrid cotton (RCH-20) is sodicity tolerant and maintain low Na to K ratio in plant tissue and may be less stressed at the cellular level gave higher plant growth compared to varieties tested *viz*., Surabhi and SVPR-2.

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