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SHORT RESEARCH ARTICLE

Response of shoot ionic (Na^+/K^+) distribution on yield and agro-physiological traits in chickpea (*Cicer arietinum* L.) recombinant inbred lines population under salinity

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Abstract

The current study reports the effects of salinity on yield and its component traits along with physiological phenotyping to identify salt tolerant recombinant inbred lines (RILs) from set of 232 F_8 RILs (ICCV 10 x DCP 92-3) population. High salt stress showed reduction in yield, relative water and chlorophyll content. Results showed, RILs genotypes 193, 157 and ICCV 10 were displaying maximum tolerance. Further lower Na^+ and higher K^+ accumulation in shoot along with significant increase in leaf proline content in tolerant genotypes with less leakage of ions under stress was key for tolerance under salt stress.

Keywords: Chickpea, Na^+/K^+ ratio, salinity, seed yield

Soil salinity is a major abiotic stress having deleterious consequences on soil health leading to osmotic stress and ion toxicity, hampering productivity and crop yields. High Na^+ ions in saline soils induce water stress and hinders transpiration demand (Ashraf et al. 2017). Chickpea being salt sensitive legume its vital physiological functions, hormonal regulation, nutritional balances, seed set, and yield is severely affected under salinity (Kumar et al. 2020; Kumar 1 et al. 2021).

In this study, we investigated growth and behavior of 232 Recombinant Inbred Lines (RILs) population derived from ICCV 10 (salt tolerant) / DCP 92-3 (salt sensitive) cross under elevated salinity environment. For experimentation 60 mM, NaCl solution was used and yield and growth parameters were analyzed along with the following physiological traits,

Equation 1:

RWC: (Fresh Weight – Dry Weight) / (Turgid Weight – Dry Weight)] × 100

Equation 2:

Electrolyte leakage (EL): [C_1 / C_2] × 100

Where C_1 is initial conductivity of 10 g sample in 10 ml distilled water at 45°C for 30 min, and C_2 is final conductivity measured at 100°C for 10 min. Total chlorophyll was analyzed according to Arnon (1949) and proline was determined as per Bates et al., (1973). Na^+ and K^+ concentrations were determined using flame photometer. The data obtained for various statistical descriptors were analyzed using R program and Salt Tolerance Index (STI) was calculated as per Fernandez et al. (1993).

Trait analysis for salt tolerance

The analysis of results showed, reduction in all observed traits under salinity when compared with control. The salt-tolerant index (STI) was worked on the basis of relative performance of genotypes under stress and control conditions to identify tolerant genotypes. STI of 232 RILs population was calculated using plant height (PH), No.

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of fruiting branches (NFB), No. of pods/plant (PPP) and Seed yield (SY) and their distribution shows the effect of salt treatments on SY, PPP and PH, NFB for the RILs and their parents (Fig. 1). Physiological variable like, relative water content (RWC) was affected in all genotypes, for ion leakage tolerant genotypes showed less ion leakage as compared to sensitive genotypes. Photosynthetic pigments like, chlorophyll was severely reduced in sensitive RILs population and sensitive parent DCP 92-3 at 60 mM salt stress, it varied from 0 to 1.99 mg/g FW with mean value of 1.12 mg/g FW. Proline concentration in tolerant genotypes and parent (ICCV 10) accumulated in higher concentrations

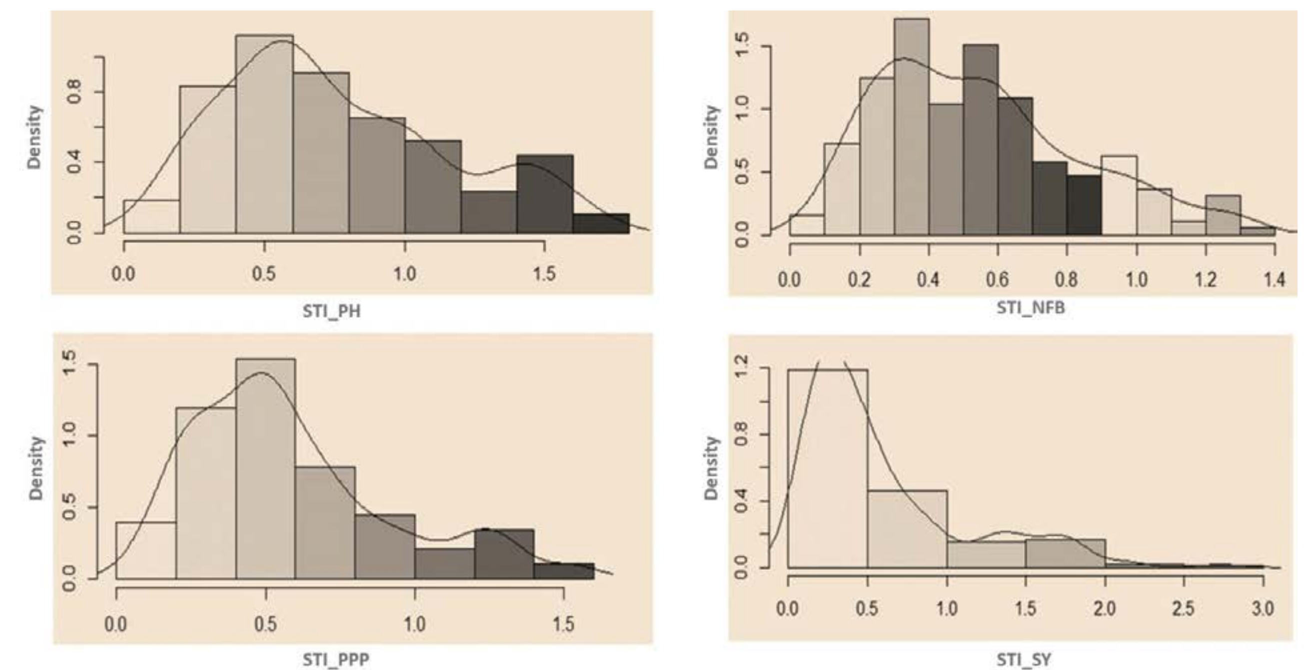

Fig. 1. Distribution of (salinity tolerance index) STI for Plant height (PH), Number of fruiting branches (NFB), Pods per plant (PPP) and Seed yield per pot (SY)

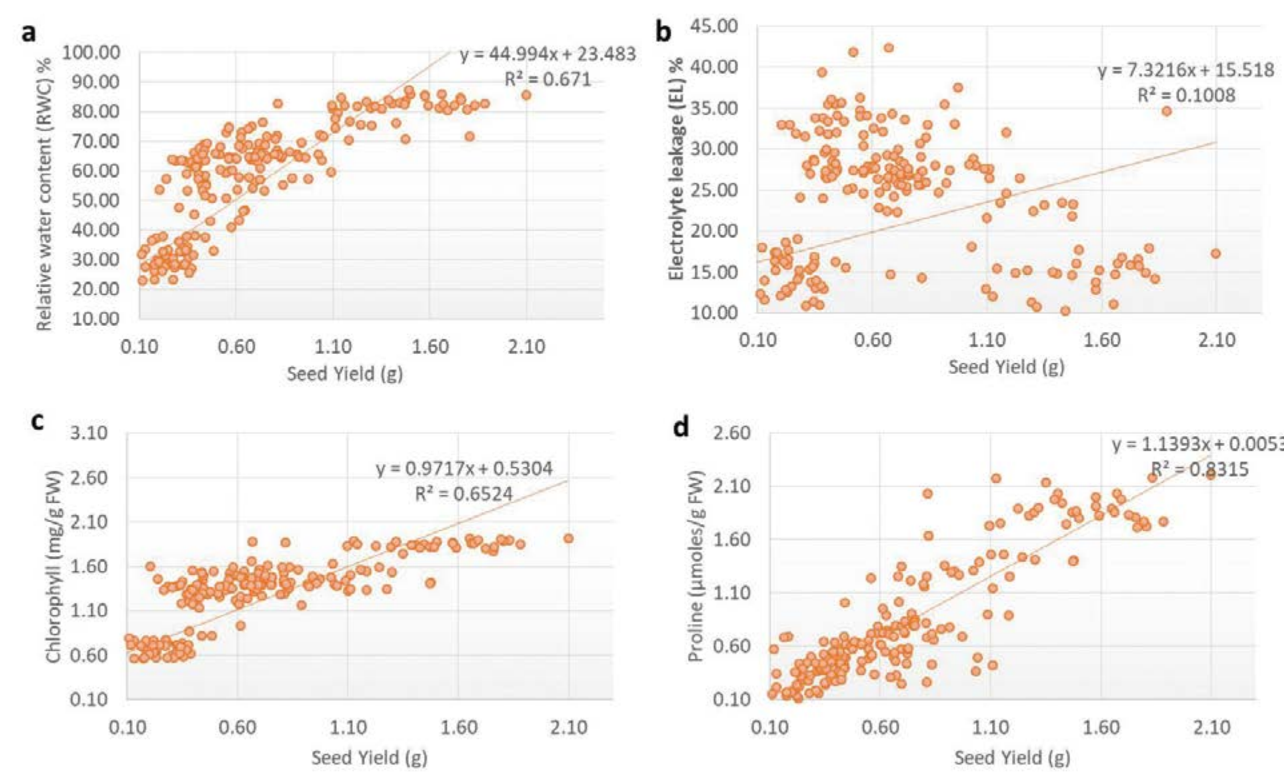

Fig. 2. Relationship between seed yield with, (a) RWC; (b) EL; (c) Chlorophyll content, and (d) Proline content

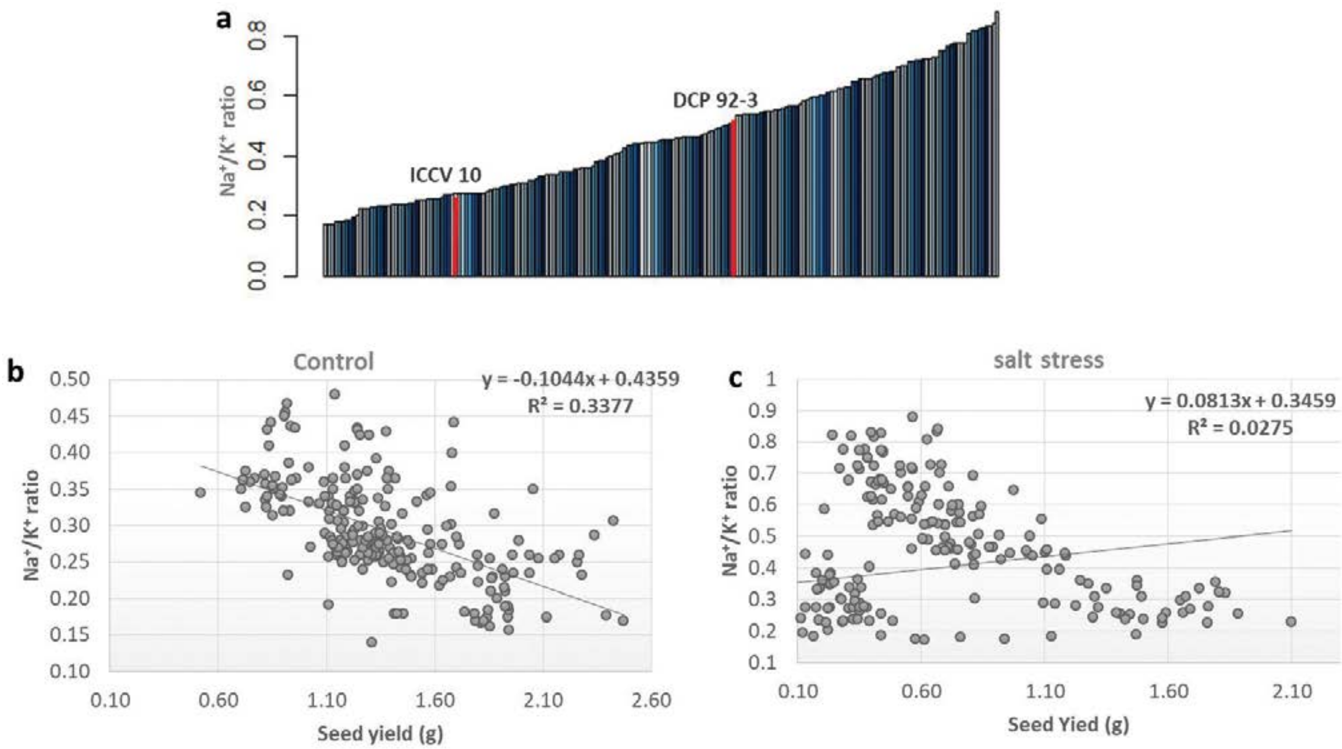

Fig. 3. (a) Performance of RILs genotypes (*x-axis*) for, (a) Shoot Na^+/K^+ ratio; (b) Relationship between seed yield with shoot Na^+/K^+ ratio under control and; (c) under salt stress conditions

Table 1. Descriptive Statistics of RILs population under 60mM of salt stress condition

S.No.	Trait	Range	Mean	SD	CV	SE
1	PH	49.48	23.26	14	4.97	1.15
2	NFB	4.75	1.94	1.25	15.77	0.3061
3	PPP	6.75	2.44	1.6	12.64	0.3082
4	SY	2.3	0.61	0.49	6.39	0.039
5	RWC	89.7	50.88	26.81	2.5	1.27
6	EL	43.12	19.98	11.26	4.02	0.8027
7	Chloro-phyll	1.99	1.12	0.5867	1.74	0.0196
8	Proline	2.27	0.7	0.61	4.92	0.0344
9	Na^+/K^+ (Sodium : Potassium ratio)	0.91	0.4	0.24	3.88	0.0153

PH = Plant height, (cm); NFB = Number of fruiting branches, numbers; PPP = Pods per plant, numbers; SY = Seed yield, (g); RWC = Relative water content, %); EL = Electrolyte leakage, %; Chlorophyll (mg/g fresh weight); Proline = µmoles/g (FW); Na^+/K^+ = Sodium : Potassium ratio; SD = Standard deviation and SE = Standard error

as compared to sensitive genotypes and parent (Fig. 2 a-d). In population it varied from 0 to 2.27 µmoles/g FW with population mean of 0.7 µmoles/g (Table 1). The Na^+/K^+ ratio in shoot tissue of all tolerant RILs / parent marked a lower values as compared to sensitive RILs/Parent (DCP 92-3) under stress (Fig. 2a). The Na^+/K^+ ratio varied ranged up to 0.91 under stress with mean value of 0.4 (Table 1) and lower Na^+/K^+ ion ratio were associated with higher seed yield under salt-stress (Fig. 2b, c).

The grouping of chickpea RILs was carried via formulating the unweighted composite score called salt tolerance value (STV) using STI and physio-biochemical traits. STV greater than 1.00 to1.50 was classified as salt tolerant, STV ranged 1.0 to 0.50 were moderately tolerant and STV less than 0.50 were having salt sensitive genotypes. In first group RILs 193,157 had maximum salt tolerance value 1.48 and 1.36 respectively, so were ranked as most tolerant RILs which also included ICCV 10 and 29 other RILs. Group second included 23 RILs and third group included DCP92-3 and other remaining RILs genotypes (Table 2).

Author contributions

Conceptualization of research (BC); Designing of the experiments (NK, SPPR, MMC, MP); Contribution of experimental materials (BC, SKR); Execution of field/lab experiments and data collection (NK, BC); Analysis of data and interpretation (AS, PBS); Preparation of the manuscript (NK, BC, MR, RKV).

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Table 2. Grouping of RILs into three groups, salt tolerant, moderately tolerant and sensitive based on salt tolerance value (STV)

Tolerant				Moderately Tolerant				Salt sensitive			
RILs No.	STV	RILs No.	STV	RILs No.	STV	RILs No.	STV	RILs No.	STV	RILs No.	STV
193	1.48	P_1	1.14	188	0.90	30	0.58	136	0.48	141	0.36
170	1.36	82	1.12	81	0.83	158	0.57	102	0.48	80	0.35
157	1.27	161	1.11	34	0.80	92	0.53	190	0.47	37	0.35
212	1.27	194	1.11	35	0.75	129	0.53	148	0.47	224	0.35
202	1.25	105	1.09	29	0.72	229	0.51	P_2	0.45	226	0.34
130	1.24	27	1.06	165	0.65	227	0.50	163	0.44	203	0.34
228	1.23	162	1.05	16	0.65			33	0.44	223	0.33
184	1.23	86	1.04	15	0.64			13	0.44	147	0.31
176	1.22	172	1.03	54	0.64			108	0.43	140	0.31
185	1.21	219	1.03	134	0.64			62	0.43	1	0.30
25	1.21	101	1.02	166	0.61			200	0.42	84	0.30
187	1.20	79	1.01	217	0.60			106	0.41	51	0.29
48	1.20			192	0.60			150	0.41	135	0.29

P_1 = ICCV 10 (salt tolerant parent) and P_2 = DCP 92-3 (salt sersitive parent)

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