



Inheritance of salt tolerance in cucumber (*Cucumis sativus*)

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ABSTRACT

Inheritance pattern of salinity tolerance of cucumber was studied by combining ability and gene action analysis of salt-tolerant and salt-sensitive cucumber inbreds (produced through five generation of selfing) and its hybrids at two salinity levels, i.e. control (0.43 dS/m) and 4 dS/m. The higher values of general combining ability than that of specific combining ability, predictability ratio more than 0.5, average degree of dominance in between 0 and 1, and narrow sense heritability in between 50 and 100% indicated the predominance of additive gene action for salt tolerance in cucumber. The results demonstrate either hybridization and selection or simple recurrent selection methods for improvement of salinity tolerance in cucumber.

Key words: Combining ability, Cucumber, Gene action, General combining ability, Salinity, Specific combining ability

High level of salinity is an increasing agricultural problem in arid and semi-arid soils of our country. In India, 8.5 million ha area is affected by salinity and further potential salinity area is another 27% of cultivable land in Punjab, Haryana, Uttar Pradesh, Gujarat, Rajasthan, West Bengal, Maharashtra, Orissa, Andhra Pradesh, Karnataka and Tamil Nadu (Dubey *et al.* 2006). Cucumber is sensitive to salinity (Dorota 1997). Therefore, cucumber production in saline soils requires salt tolerant varieties. For breeding salt-tolerant cucumber, an understanding of the mechanism of inheritance pattern, i.e. nature of gene action involved in salinity tolerance is required. Development of high-yielding variety mainly depends upon the genetically superior parents, extent of genetic variability present in it coupled with suitable breeding methodology. Hence, selection carried out from wider genetic base genotypes should have faster and higher magnitude of success.

Despite the fact that cucumber is native to India and availability of vast genetic variability in cucumber, no information is available for improvement of salinity tolerance of this crop from India. Further, no well-defined indicators are available to facilitate the improvement of salinity

tolerance in cucumber (Malik *et al.* 2010). However, they evaluated the biochemical/physiological performances of cucumber genotypes for salt tolerance by *in vitro* screening and identified the parameters that can be used as index for *in vitro* salt tolerance in cucumber. Cucumber is cross-pollinated crop and lacks inbreeding depression in which improvement is possible through inbreds (Munshi *et al.* 2006). The present study was carried out to elucidate the role of sodium (Na⁺)/potassium (K⁺) ratio at different level of Na⁺ and K⁺ salts levels in cucumber inbreds and its hybrids and inheritance of salinity tolerance in cucumber.

MATERIALS AND METHODS

Genetic material

Six inbred lines, viz P₁, P₂, P₃, P₄, P₅ and P₆ produced through five generation of selfing of cucumber advance breeding lines/variety, namely 'CRC 8', 'CHC 2', 'G 338', 'CH 20', 'Pusa Uday' and 'DC 1', respectively were used in the study. Among these, three namely 'CRC 8', 'CHC 2' and 'G 338' had salinity tolerance up to 4 dS/m, whereas 'CH 20', 'Pusa Uday' and 'DC 1' were sensitive to salinity (Table 1). However, 'CH 20', 'Pusa Uday' and 'DC 1' were good combiners for yield and its component traits in cucumber (Tiwari *et al.* 2009). Seeds of inbreds were sown in the field in three replications and all packages of practices were followed to grow successful crop. The salinity-tolerant and sensitive inbred lines were crossed in 6 × 6 half-diallel fashion (excluding reciprocals) to obtain 15 F₁ hybrids (Hayman 1954).

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Table 1 Survival percentage and total fruit production per plant of cucumber inbreds at different salinity level

Parent	Source	Survival percentage		Fruit production/plant	
		Control	4 dS/m	Control	4 dS/m
'CRC 8'	Saharanpur (Uttar Pradesh)	100.0	58.22	2.50	1.33
'CHC 2'	HARP, Ranchi (Jharkhand)	100.0	56.86	2.35	1.19
'G 338'	Delhi	100.0	53.45	2.20	1.03
'CH 20'	HARP, Ranchi (Jharkhand)	100.0	32.92	1.85	0.35
'Pusa Uday'	Rae Barelli (Uttar Pradesh)	100.0	37.21	2.10	0.37
'DC 1'	Muzaffarpur (Bihar)	100.0	32.77	2.30	0.34

To determine the inheritance pattern of salinity tolerance in cucumber, Na^+/K^+ ratio was estimated in the parents (inbreds) and hybrids in following manner. Bulk surface soil (0–15 cm) was air dried, mixed thoroughly, and passed through 2 mm sieve. Earthen pots of 30 cm size were lined with polythene sheet and filled with 5 kg soil/pot. The soil was sandy loam with pH 7.7 with an electrical conductivity (EC) of 0.43 dS/m. The pots with untreated soil were used as control and the plants were exposed to two levels of salinity, viz 0 (control = 0.43 dS/m) and 4 dS/m. Soil salinity was developed by combination of NaCl, Na_2CO_3 and K_2SO_4 salts to get the ratio of $\text{Cl}^-:\text{CO}_3^{2-}:\text{SO}_4^{2-}$ in 2: 1: 1 as these anions are predominantly found in most of the natural salt affected soils of India. For this purpose, stock solutions of NaCl (400 me Cl^-), Na_2CO_3 (200 me CO_3^{2-}) and K_2SO_4 (200 me SO_4^{2-}) were used for inducing 4 dS/m salinity (Dubey *et al.* 2006). One week before sowing pots were irrigated with 1 litre of tap water (control) or salt solutions.

Evaluation

The experiment was laid out in a completely randomized design (CRD) with three replications during 2006–07. Five pots per replication per treatment were maintained. In a pot five seeds of each inbreds and hybrids were sown one week after the salt treatment to the pots. Subsequent irrigation was given using tap water having EC of 0.45 dS/m and pH 7.3. After germination, one vine was retained in each pot. The EC of the soil in pots was tested at regular intervals and final salinity level was recorded to be 0.43 and 3.82 dS/m in pots with control and 4 dS/m salinity treatments, respectively at the end of the experiment (60 DAS). The last observations on the experiment was taken at 60 DAS as majority of the genotypes started showing wilting symptoms and could not survive beyond 70 DAS due to the high temperature (38–40°C) during that period.

The Na^+/K^+ ratios were estimated from Na^+ and K^+ contents at two levels of salinity, viz control (0.43 dS/m) and 4 dS/m according to wet digestion with diacid (10 ml nitric acid and 4 ml/chloric acid) as outlined by US Salinity Laboratory Staff (1954). Mature non-senescent leaf samples of 30 days youngest fully expanded leaf from 4th or 5th node from apex collected from two vines per genotype per

replicate for estimation of sodium and potassium contents. The digestion extract was used for the estimation of Na^+ and K^+ content by Flame Photometry (US Salinity Laboratory Staff 1954).

The combining ability analysis at three salinity levels, i.e control (0.43 dS/m) and 4 dS/m of Na^+/K^+ ratios of inbreds and hybrids was estimated according to Method 2, Model 1 of Griffing (1956) (without reciprocals) using SPAR 1. Genetic component of variance σ^2_g , σ^2_s and σ^2_e , Predictability Ratio (PR) and the Average Degree of Dominance (ADD) were estimated as per Baker (1978).

Gene action analysis

Gene action was studied at two salinity levels, i.e control (0.43 dS/m) and 4 dS/m of Na^+/K^+ ratios of inbreds and hybrids by the diallel method of numerical approach given by Hayman (1954) using SPAR 1 software. The genetic parameters, viz $(H/D)^{1/2}$, $(H_2/4H_1)$, $[(4DH_1)^{1/2}+F/(4DH_1)^{1/2}-F]$, (h_2/H_2) , narrow sense heritability (h_2) were estimated to find out gene action.

RESULTS AND DISCUSSION

Analysis of variance for combining ability analysis

Mean squares were significant for both general combining ability (gca) and specific combining ability (sca) at salinity level of control (0.43 dS/m) and 4 dS/m for Na^+/K^+ ratio (Table 2). The values of gca were greater than sca which

Table 2 Analysis of variance for combining ability estimates of cucumber inbreds and hybrids for different salinity level of Na^+/K^+ ratio

Source	df	Soil salinity tolerance level (Na^+/K^+ ratio)	
		Control (0.43 dS/m)	4 dS/m
gca	5	0.00194**	0.00198**
sca	15	0.00042*	0.00046*
Error	40	0.00021	0.00013
σ^2_g	0.00019	0.00019	
σ^2_s	0.00021	0.00033	
PR	0.64	0.54	
ADD	0.55	0.87	

* $P=0.05$, ** $P=0.01$; df, degrees of freedom

showed the preponderance of additive gene action components for inheritance of soil salinity tolerance in cucumber. In addition, predictability ratio (PR) was 0.64 and 0.54 at control (0.43 dS/m) and 4 dS/m, respectively; and average degree of dominance was 0.55 and 0.87 at control (0.43 dS/m) and 4 dS/m, respectively which indicated the predominance of additive gene action for controlling salinity tolerance. Therefore, simple selection procedure might be useful for the improvement salinity tolerance in cucumber.

Combining ability

Table 3 revealed that in control (0.43 dS/m), the highest positive effects was recorded in inbred 'CRC 8' (0.0223), followed by 'CHC 2' (0.0162) and 'G 338' (0.0116) while, maximum positive sca effects were estimated in hybrids 'CRC 8' × 'Pusa Uday' (0.0476), followed by 'CRC 8' × 'DC 1' (0.0133). At 4 dS/m salinity level, inbred 'CRC 8' (0.0209) followed by 'CHC 2' (0.0168) and 'G 338' (0.0047) had significant positive gca effects whereas, maximum sca effects was recorded in hybrid 'CRC 8' × 'Pusa Uday' (0.0289), followed by 'CRC 8' × 'DC 1' (0.0198). Thus, on the basis

Table 3 Estimates of general combining ability (GCA) and specific combining ability (SCA) of Na⁺/K⁺ at different salinity level ratio in cucumber inbreds and hybrids

Inbred line	Soil salinity tolerance level (Na ⁺ /K ⁺ ratio)	
	Control (0.43 dS/m)	4 dS/m
'GCA'		
'CRC 8'	0.0223**	0.0209**
'CHC 2'	0.0162**	0.0168**
'G 338'	0.0116*	0.0047*
'CH 20'	0.0070	0.0029
'Pusa Uday'	-0.0170	-0.0117
'DC 1'	-0.0124	0.0028
SE (gi)	0.0040	0.0022
Hybrids (SCA)		
'CRC 8' × 'CHC 2'	-0.0257	0.0151*
'CRC 8' × 'G 338'	0.0037	0.0098
'CRC 8' × 'CH 20'	0.0125**	0.0110
'CRC 8' × 'Pusa Uday'	0.0476**	0.0289**
'CRC 8' × 'DC 1'	0.0133**	0.0198*
'CHC 2' × 'G 338'	-0.0010	-0.0074
'CHC 2' × 'CH 20'	0.0106**	0.0195*
'CHC 2' × 'Pusa Uday'	0.0174**	0.0197*
'CHC 2' × 'DC 1'	0.0073*	0.0056
'G 338' × 'CH 20'	0.0080*	0.0118
'G 338' × 'Pusa Uday'	-0.0115	0.0098
'G 338' × 'DC 1'	0.0050	0.0110
'CH 20' × 'Pusa Uday'	0.0034	0.0087
'CH 20' × 'DC 1'	-0.0092	-0.0065
'Pusa Uday' × 'DC 1'	0.0026	0.0068
SE (sjj)	0.0030	0.0062

*P=0.05, **P=0.01

of gca effects good combiners parents (inbreds) were identified as 'CRC 8', 'CHC 2' and 'G 338' while positively significant effects of sca values indicated superior hybrids 'CRC 8' × 'Pusa Uday', 'CRC 8' × 'DC 1' and 'CHC 2' × 'Pusa Uday' at 4 dS/m salinity level.

The salt tolerant and sensitive inbreds with its high gca values and higher genetic base due to diverse source from different parts of the states in India produced hybrids with higher sca effects on salinity tolerance for faster and higher magnitude of success. The nature of gene action is measured in terms of genetic components of variance or combining ability variance and effects. The gca effect of parent is primarily a function of additive and additive × additive gene effects and it determines the breeding value of the parent. The additive gene actions are more stable due to polygenic fixable components of genetic variation and therefore, it is of more use for breeders for selection of particular trait (Griffing 1956).

Gene action

The genetic component of variation, additive (D) and dominance (H) genetic variance were significant at all salinity level (Table 4). In control, statistical parameters D, H1, H2, h2 and F were found significant. The value of D was greater than H1 which indicates the presence of additive gene action. The mean degree of dominance (H1/D)^{1/2} was 0.85 indicating partial dominance. The proportion of dominance and recessive genes [(4DH1)^{1/2} + F/(4DH1)^{1/2} - F] in the parents

Table 4 Estimates of genetic components of variation and various statistical parameters of Na⁺/K⁺ ratio at different level of salinity of cucumber inbreds and its hybrids

Genetic parameter	Soil salinity tolerance level (Na ⁺ /K ⁺ ratio)	
	Control (0.43 dS/m)	4 dS/m
(D) Additive effect	0.0021**	0.0022**
	±0.0002	±0.0004
(H) Dominance effect H ₁ H ₂ H ₂	0.0018**	0.0021**
	±0.0005	±0.0005
	0.00086**	0.0018*
	±0.0004	±0.0008
	0.0008**	0.0001
	±0.0001	±0.0003
(F) Gene distribution	0.0011**	0.0020**
	±0.0003	±0.0006
(E) Environmental effect	0.0004	0.0006
	±0.0003	±0.0004
(H ₁ /D) ^{1/2}	0.85	0.98
H ₂ /4H ₁	0.22	0.21
[(4DH1) ^{1/2} + F]/[(4DH1) ^{1/2} - F]	1.06	1.05
H ² /H ₂	1.28	1.12
Heritability% (ns)	64.55	53.34

*P=0.05, **P=0.01

was 1.06 which indicate the excess of dominant genes and the number of dominant group of genes (h^2/H^2) was 1.28. Narrow sense heritability (64.55%) showed preponderance of additive gene action. At salinity level of 4 dS/m, components of genetic variation revealed that estimates of D, H1, H2 and F were significant while h^2 was not significant. The value of D was slightly higher than H1, indicating the pre-dominance of additive genes. The value of degree of dominance ($(H1/D)^{1/2}$) (0.98) indicated partial dominance. The narrow sense heritability (53.34%) indicated the predominant role of additive type of gene action for salinity tolerance. Thus, at all level of salinity, i.e. control (0.43 dS/m) and 4 dS/m, degree of dominance ($(H1/D)^{1/2}$) was observed in between 0 and 1 and narrow sense heritability was observed in between 50% and 100% indicating partial dominance and predominance of additive gene action in controlling the salinity tolerance in cucumber.

According to Yeo *et al.* (1988) and Cuartero and Fernandez-Munoz (1999) breeding of tolerant cultivars of cucumber to moderate salinity level will occur only after pyramiding of desired genes for several characteristics in a single genotype. Saranga *et al.* (1992) and Foolad (1996) in tomato observed increase of narrow sense heritability and additive genetic components with the increase in salinity level. Based on the estimates of genetic parameters for salt tolerance in tomato (Foolad 1996), it was found that salt tolerance was genetically governed by additive genetic component and significant advances for salinity tolerance might be possible through simple selection.

Our study reveals higher values of gca than that of sca , predictability ratio more than 0.5, average degree of dominance in between 0 and 1 and narrow sense heritability in between 50% and 100%, thus indicating the predominance of additive gene action components for salinity tolerance in cucumber. The estimation of various genetic parameters of gene action, viz degree of dominance, narrow sense heritability etc. would also be necessary for deciding breeding methods for the improvement of cucumber, particularly salt-tolerant. The degree of dominance requires the estimates of dominance and additive genetic variance. The estimates of narrow sense heritability are directly proportional to the additive genetic variance which is a measure of additive gene action. High value of narrow sense heritability for a character

indicates the importance of additive gene action in expression of that character. Hence, our results demonstrate either hybridization and selection or simple recurrent selection methods for improvement of salinity tolerance in cucumber.

REFERENCES

- Baker R J. 1978. Issues in diallel analysis. *Crop Science* **18**: 533–5.
- Cuartero J and Fernandez-Munoz R. 1999. Tomato and salinity. *Scientia Horticulturae* **78**: 83–125.
- Dorota Z. 1997. Irrigating with high salinity water. *Bulletin* 322, Agricultural and Biological Engineering Dep; Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, University of Florida, USA.
- Dubey A K, Srivastav M, Singh R, Pandey R N and Deshmukh P S R. 2006. Response of mango (*Mangifera indica*) genotype to graded level of salinity. *Indian Journal of Agricultural Sciences* **76** (11): 670–2.
- Foolad M R. 1996. Response of selection for tolerance during germination in tomato seed derived from P 1-174263. *Journal of American Society of Horticultural Sciences* **121**: 1006–11.
- Griffing J B. 1956. Concepts of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences* **9**: 663–93.
- Hayman B I. 1954. The theory and analysis of diallel crosses. *Biometrics* **10**: 235–44.
- Malik A A, Li W G, Lou, L N, Weng J H and Chen J F. 2010. Biochemical/physiological characterization and evaluation of *in vitro* salt tolerance in cucumber. *African Journal of Biotechnology* **9** (22): 3284–92.
- Munshi A D, Kumar R and Panda B. 2006. Studies on genetic components of variation in cucumber (*Cucumis sativus* L.). *Indian Journal of Horticulture* **63**: 213–4.
- Saranga Y, Cahner A, Zamir D, Marani A and Rudich J. 1992. Breeding tomato for salt tolerance: Inheritance of salt tolerance and related traits in inter specific populations. *Theoretical and Applied Genetics* **84**: 390–6.
- Tiwari J K, Munshi A D, Kumar R, Sharma R K and Sureja A K. 2009. Combining ability for yield and related traits in cucumber (*Cucumis sativus* L.). *Vegetable Science* **36** (2): 159–62.
- US Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. US Department Agriculture Handbook No 60, USSL, Riverside, CA, USA.
- Yeo A R, Yeo M E, Flowers S A and Flowers T J. 1988. Screening of rice genotype for physiological characters contributing to salinity resistance and their relationship to overall performance. *Theoretical and Applied Genetics* **79**: 377–84.