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Selection parameters for genetic improvement in *Chenopodium* grain yield in sodic soil

Atul Bhargava, Sudhir Shukla, R.S. Katiyar* and Deepak Ohri

*Division of Genetics and Plant Breeding, *Banthra Research Station, National Botanical Research Institute, Lucknow-226001, India*

Abstract

A study was carried out to evaluate promising genotypes of *Chenopodium quinoa* on normal and sodic soil to compare the grain yield potential, variability and genetic association among the different component traits and their direct and indirect effects on yield. High heritability and moderate genetic advance was observed for inflorescence length and grain yield on sodic soil and for stem diameter, primary branches/plant, number of inflorescence/plant, dry weight of plant and inflorescence length on normal soil. Stem diameter and number of inflorescence/plant exhibited high direct path (0.837 and 0.761, respectively) and significant positive association (0.979 and 0.967, respectively) with grain yield on sodic soil, while dry weight of plant showed high correlation (0.889) and direct path (0.972) with grain yield on normal soil. The breeding strategies for genetical improvement in the crop grown on sodic and normal soil have been discussed.

Key words: Quinoa, sodic soil, correlation, path analysis, heritability, genetic gain, additive gene.

Introduction

Chenopodium spp. have been cultivated for centuries as leafy vegetable as well as an important subsidiary grain for human and animal foodstuff due to high protein (10-14%) (DeBruin, 1964) and a balanced amino acid spectrum with high lysine (5.1-6.4%) and methionine (0.4-1.0%) contents (Prakash and Pal, 1998). *Chenopodium quinoa* Willd. is a native of the Andean region and is a member of the subsection Cellulata of the section Chenopodium of the genus *Chenopodium*. Quinoa belongs to the group of crops known as pseudocereals (Cusack, 1984; Koziol, 1993) that includes other domesticated chenopods, amaranths and buckwheat.

Quinoa is a crop with a high level of resistance to several of the predominant adverse factors like soil salinity, drought, frost, diseases and pests (Jacobsen *et al.*, 2001; Mujica *et al.*, 2001) and has attracted worldwide attention in this respect. Thus, the crop is of immense importance for the diversification of agriculture in fallow and uncultivated barren lands in India, a large amount of which is constituted by sodic soils. Seeing its recent demand and importance, there is a definite need for its genetic improvement. Hence, the present investigation was carried out to evaluate the promising genotypes of *C. quinoa* on normal and sodic soil as well as to ascertain its prospects of cultivation on saline soils and marginal lands. Simultaneously, the study of genetic parameters, correlation among the different traits and their direct and indirect effects on yield have been done for the genetical improvement of its yield through yield contributing traits.

Materials and methods

Eight exotic genotypes of *Chenopodium quinoa* (*C. quinoa* 596498, *C. quinoa* 510537, *C. quinoa* 478414, *C. quinoa* 584524, *C. quinoa* 587173, *C. quinoa* 22158, *C. quinoa* 92/91, *C. quinoa* 71/78) were sown in a randomized block design with three replications in the crop year 2000-2001 on normal soil at National Botanical Research Institute, Lucknow, which is situated at an altitude of 120 m above sea level at 26.5^{o}N latitude and 80.5^{o}E longitude. These genotypes were also sown on sodic soil at Banthra Research Station of N.B.R.I, which is located at 26^{o}40' to 26^{o}45'N latitude and 80^{o}45' to 80^{o}53'E longitude. The experimental site soil belongs to the family of Aeric Halaquepts having silty loam texture in the surface with pH ranges from 8.6 to 10.0 and electrical conductivity (EC) seldom exceeding 2dSm^{-1}. Soils are extremely saturated with exchangeable sodium having more than 25 ESP and predominant in carbonate and bicarbonate ions. The genotypes were grown in two rows of 3m long with a row-to-row and plant-to-plant distance of 45 cm and 15 cm, respectively at both the places. Normal cultural practices were followed from time to time. The data was recorded on 5 plants from each entry and replication for seven traits namely plant height (cm), stem diameter (cm), primary branches/plant, number of inflorescence/plant, inflorescence length (cm), dry weight of plant (g) and grain yield/plant (g).

Analysis of variance for each trait was done according to Panse and Sukhatme (1978) and phenotypic and genotypic coefficient of variation, heritability and genetic advance were computed following Singh and Chaudhary (1985). The genotypic and phenotypic correlations were computed as suggested by Mullar *et al.* (1958) and path coefficient as described by Dewey and Lu (1959).

Results and discussion

The analysis of variance for all the traits showed significant differences among the genotypes in both normal and sodic soil.

Variability studies: Plant height on sodic soil ranged from 42.67-56.66 cm, while on normal soil it was comparatively higher ranging from 81.60-110.30 cm with an average of 48.63+0.87 and 97.20+3.82, respectively. The grain yield/plant on sodic soil varied between 8.95-16.69 g with a mean of 10.44+1.88, while on normal soil it was between 14.18-26.20 g with a mean of 19.16+1.60. Stem diameter

Table 1. Mean, F value and range for different traits in *C. quinoa* grown on sodic and normal soil (in parenthesis)

Characters	F value	Mean +S.E.	Range
Plant height (cm)	57.75(13.59)	48.63+0.87(97.20+3.82)	42.67-56.66(81.60-110.30)
Stem diameter (cm)	21.36(147.72)	1.70+0.04(1.33+0.06)	1.50-1.93(0.80-2.27)
Primary branches /plant	38.71(59.89)	18.08+0.39(25.94+1.22)	15.66-20.33(20.00-36.00)
Number of Inflorescence/plant	15.15(143.55)	17.91+0.66(68.79+1.91)	16.33-21.67(52.00-86.06)
Inflorescence length (cm)	11.22(13.16)	2.80+0.17(3.95+0.25)	2.33-3.33(3.00-4.76)
Dry weight of plant (g/plant)	19.10(16.30)	17.80+0.32(24.66+1.84)	17.00-19.67(18.00-34.00)
Grain yield(g/plant)	19.32(9.09)	10.44+1.88(19.16+1.60)	8.95-16.69(14.18-26.20)

Table 2. Genetic variability, heritability and genetic advance for different traits in *C. quinoa* grown on sodic and normal soil (in parenthesis)

Characters	$\sigma^2 g$	$\sigma^2 p$	$\sigma^2 e$	GCV	PCV	Heritability	Genetic advance	Genetic advance(%)
Plant height (cm)	21.65(91.84)	22.04(99.15)	0.38(7.30)	9.56(9.85)	9.65(10.24)	98.27(92.63)	9.50(19.00)	19.54(19.54)
Stem diameter (cm)	0.02(0.35)	0.02(0.36)	0.001(0.002)	8.54(44.96)	8.74(45.11)	95.31(99.32)	0.29(1.22)	17.17(92.31)
Primary branches/plant	2.95(43.88)	3.03(44.62)	0.07(0.74)	9.51(25.53)	9.63(25.75)	97.42(98.33)	3.49(13.53)	19.33(52.16)
Number of Inflorescence/plant	3.15(261.76)	3.38(263.60)	0.22(1.83)	9.92(23.51)	10.26(23.60)	93.40(99.30)	3.53(33.21)	19.75(48.27)
Inflorescence length (cm)	0.16(0.39)	0.17(0.42)	0.01(0.03)	14.26(15.90)	14.94(16.54)	91.09(92.40)	0.78(1.24)	28.04(31.50)
Dry weight of plant (g/plant)	0.98(26.08)	1.03(27.79)	0.05(1.70)	5.57(20.70)	5.72(21.37)	94.77(93.87)	1.99(10.19)	11.17(41.32)
Grain yield(g/plant)	17.61(12.27)	18.57(13.78)	0.96(1.51)	17.17(12.89)	17.63(13.67)	94.82(89.00)	8.41(6.80)	34.44(25.06)

$\sigma^2 g$ = Genotypic variance, $\sigma^2 p$ = Phenotypic variance, $\sigma^2 e$ = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation

had higher values on sodic soil (1.50-1.93 cm; mean 1.70+0.04) than corresponding values at normal soil (0.80-2.27cm; mean 1.33+0.06). Number of inflorescence/plant showed low values on sodic soil (16.33-21.67 cm; mean 17.91+0.66) in comparison to normal soil (52.00-86.06; mean 68.79+1.91). The range for primary branches/plant and dry weight was 15.66-20.33 and 17.00-19.67 g, respectively on sodic soil and 20.00-36.00 and 18.00-34.00 g on normal soil. Inflorescence length on sodic soil was slightly lower (2.33-3.33 cm; mean 2.80+0.17) than on normal soil (3.00-4.76 cm; mean 3.95+0.25) (Table 1).

Phenotypic coefficient of variation (PCV) was slightly higher than corresponding GCV on both types of soils for all the traits indicating that variability existed due to genotypic component. Variability alone is not of much help in determining the heritable portion of variation (Table 2). The amount of gain to be expected from a selection can be obtained by the study of genotypic coefficient of variability along with heritability. The heritability estimates were very high for all the traits studied in sodic as well as normal soil. Bhargava *et al.* (2003b) also obtained very high heritability values on normal soil, in the same crop for all the traits studied. Heritability in sodic soil ranged from 91.09% (inflorescence length) to 98.27% (plant height) while on normal soil it ranged from 89.00% (grain yield) to 99.32% (stem diameter).

High heritability alone does not guarantee large gain from selection unless sufficient genetic gain attributable to additive gene action is present. Genetic advance in a trait is a product of heritability and selection differential and expressed in unit of standard deviation, has an added advantage over heritability as a guiding factor in selection programmes, where improvement of characters is desired. Genetic gain on sodic soil was low in comparison to the genetic gain on normal soil. Maximum genetic gain on sodic soil was observed for grain yield (34.44%), followed by inflorescence length (28.04%), while minimum gain was observed for dry weight of plant (11.17%). Genetic gain on normal soil was maximum for stem diameter (92.31%), followed by primary branches/plant (52.16%) and number of inflorescence/plant (48.27%). The minimum value of genetic advance on normal soil was observed for plant height (19.54%). High heritability coupled with moderate genetic advance was observed for inflorescence length and grain yield on sodic soil and for stem diameter, primary branches/plant, number of inflorescence/plant, dry weight of plant and inflorescence length on normal soil. It indicates that genotypic variance for these characters is probably due to additive gene effects. Hence, the selection based on phenotypic performance for these characters would be beneficial for achieving the desired gain in *C. quinoa*.

Correlation studies: The estimates of correlation coefficients of agronomic traits with yield and among the traits themselves provide a sound base for identification of traits for selection of ideal plant types. Grain yield/plant on sodic soil was significantly positively associated with all the traits (Table 3) except for primary

Table 3. The genotypic correlation coefficients among 6 agronomic traits in *C. quinoa* grown on sodic and normal (in parenthesis) soil.

Characters	Plant height (cm)	Stem diameter (cm)	Primary branches/plant	Number of infloresence/plant	Infloresence length(cm)	Dry weight of plant(g/plant)
Grain yield(g/plant)	0.875** (-0.764*)	0.979**(0.415)	-0.797*(0.091)	0.989** (0.204)	0.762*(-0.754*)	0.967**(0.889*)
Plant height (cm)		0.895**(0.393)	-0.647(0.635)	0.966** (0.274)	0.628(0.910**)	0.947**(-0.200)
Stem diameter (cm)			-0.568 (0.958**)	0.982** (0.436)	0.888**(0.400)	0.872**(0.774*)
Primary branches/plant				-0.777* (0.376)	-0.045 (0.667)	-0.909**(0.548)
Number of infl./ plant					0.744* (0.225)	0.997**(0.610)
Inflorescence length (cm)						0.532(0.367)

*, ** Significance at 5% and 1%, respectively.

Table 4. Path coefficient analysis for 6 agronomic traits of seed yield in *C. quinoa* grown on sodic and normal (in parenthesis) soils

Characters	Plant height (cm)	Stem diameter (cm)	No.of primary branches	No. of Inflor. /plant	Inflorescence length (cm)	Dry weight (g/plant)	Seed yield(g/plant)
Plant height (cm)	**-0.442(-0.586)**	0.749(-0.166)	0.152(0.286)	0.735(-0.061)	-0.098 (-0.041)	-0.221(-0.195)	0.875**(-0.764*)
Stem diameter (cm)	-0.396(-0.230)	**0.837(-0.423)**	0.134(0.432)	0.747(-0.097)	-0.139 -(0.018)	-0.203(0.752)	0.979**(0.415)
No.of primary branches	0.286(-0.372)	-0.476(-0.406)	**-0.236(0.451)**	-0.591(-0.083)	0.007 (-0.030)	0.212(0.533)	-0.797*(0.091)
No. of inflorescence/plant	-0.427(-0.161)	0.822(-0.185)	0.183(0.169)	**0.761(-0.223)**	-0.117 (0.010)	-0.232(0.593)	0.989**(0.204)
Inflorescence length (cm)	-0.277(-0.533)	0.744(-0.169)	0.010(0.301)	0.566(0.050)	**-0.157 (-0.045)**	-0.124(-0.357)	0.762*(-0.754*)
Dry weight of plant (g)	-0.419(0.117)	0.730(-0.328)	0.214(0.247)	0.758(-0.136)	-0.083(0.016)	**-0.233(0.972)**	0.967**(0.889**)

*, ** Significance at 5% and 1% respectively. Inflor.=Inflorescence, No.= number

branches/plant, which was negatively correlated (-0.797). On normal soil seed yield was positively correlated with dry weight of plant (0.889), while it was negatively correlated with plant height (-0.764) and inflorescence length (-0.754). Significant correlation between seed yield and dry weight of plant on normal soil in *Chenopodium* was also noticed earlier (Bhargava *et al.*, 2003a). Seed yield was significantly associated with dry weight of plant on both the soils which indicated that yield could be enhanced by making the selection of genotypes with high biomass. The genotypic values for plant height showed significant positive association with number of inflorescence/ plant (0.966), dry weight of plant (0.947) and stem diameter (0.895) on sodic soil, while on normal soil only inflorescence length (0.910) had significant positive correlation with plant height. It is interesting to note that stem diameter was positively and significantly associated with dry weight of plant on both sodic and normal soils which is a general expectation that with increase in diameter, plant would be vigorous and will bear more number of inflorescence and subsequently yield would be enhanced. However, stem diameter on sodic soil also exhibited significant positive association with number of inflorescence/plant (0.982) and inflorescence length (0.888), while primary branches/plant (0.958) and dry weight of plant were significantly and positively correlated with stem diameter on normal soil. Primary branches/ plant was negatively correlated with inflorescence length, inflorescence/plant and dry weight of plant on sodic soil, but on normal soil it showed positive association with all these characters. Number of inflorescence/plant showed significant positive association with inflorescence length and dry weight of plant on sodic soil. The positive and significant genotypic association of all the traits with grain yield except primary branches/plant on sodic soil clearly indicated that all the traits under study were strongly contributing towards yield. Hence, they could be of great impetus towards enhancing grain yield.

Path studies: Correlation studies alone are often misleading because two characters may show correlation because they are correlated with a common third one (Jaiswal and Gupta, 1967). So, in such situations it becomes necessary to study path coefficient analysis, which takes into account the causal relationship as well as the degree of relationship. Hence, the genotypic correlations were partitioned into direct and indirect effects to know the relative importance of the components.

Plant height showed negative path with grain yield both on sodic and normal soils (Table 4). On sodic soil, stem diameter showed strong positive correlation and highest direct path (0.837) with grain yield. Stem diameter was negatively indirectly associated with all the traits except primary branches/plant and number of inflorescence/plant. On the contrary, on normal soil, stem diameter exhibited negative direct path (-0.423) with grain yield but was indirectly affected through dry weight of plant and primary branches/plant. Primary branches/plant showed negative path (-0.236) and significant negative correlation with grain yield on sodic soil, while on normal soil it showed positive direct path with grain yield. Number of inflorescence/plant showed highest significant genotypic association with grain yield and high positive direct path (0.761) and was indirectly affected through stem diameter and primary branches/plant on sodic soil. It is a general expectation that plants with larger number of inflorescence would give more yield. On the contrary, number of inflorescence/plant showed negative direct path (-0.233) with grain yield on normal soil, while indirectly affected through primary branches/plant, inflorescence length and dry weight of plant. On sodic soil inflorescence length and dry weight of plant showed significant positive association with grain yield but exhibited negative direct path (-0.157 and –0.233, respectively). However, in these cases the negative direct path was nullified through the positive indirect effect of stem diameter, number of inflorescence/ plant and primary branches/plant. On normal soil inflorescence length exhibited significant negative correlation and negative path value (-0.045) with grain yield. Dry weight of plant had significant positive genotypic correlation and exhibited highest direct path (0.972) towards grain yield on normal soil which confirms the findings of correlation.

It is evident from the study that on sodic soil, selection of thick-stemmed plants with more number of inflorescence/plant and high dry weight would be more desirable for breeding for high grain yield, selection of plants with high dry weight on normal soil would be advantageous for enhancing grain yield in *Chenopodium*.

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