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ROLE OF SELECTION INDICES IN ASCERTAINING HIGH YIELDING DROUGHT STRESS TOLERANT CHICKPEA (*CICERARIETINUM* L.)

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ABSTRACT

Drought is one of the major causes of limited crop production. The present study investigated the influence of drought stress on seed yield characteristics in twenty (10 Desi and 10 Kabuli) chickpea genotypes. RCB design with three replicates was used to carry out a field experiment with two humidity regimes (stressed and non-stressed). Significant differences were observed among genotypes for potential yield (YP) and stressed yield (YS) as well as for eight selection indices. There was significant and positive correlation of potential yield (YP) and stressed yield (YS) with MP, HM, GMP, and STI under both the environments, whilst yield showed significant negative correlation with TOL under rainfed condition and significant positive correlation with TOL under irrigated condition. The STI, K1STI, MP, GMP and PI indices exhibited strong correlation with YP, while YI showed strong correlation with YS; therefore, YS can discriminate drought tolerant genotypes with high grain yield under stress conditions. Genotype NKC-5-S-20 and NKC-5-S-17 showed highest TOL, STI and lowest YTI, Moreover they revealed greater yield under non-stress and stress conditions. So, these genotypes could be suggested for release as cultivars after multi location tests. The studied germplasm is highly variable and could be efficiently used in future chickpea breeding programs.

Key words: chick pea, correlation coefficient, drought, polygenic, selection index

INTRODUCTION

The productivity of a crop is severely affected by water deficiency. Chickpea is known for its fine performance under drought condition. Though, the yield of chickpea genotypes fluctuates greatly under drought stress, it is difficult to measure the degree of drought tolerance for a single parameter, because factors are complicated in nature and mostly interactive for the expression of a trait (Paramesh and Salimath, 2008). The severity of water stress is altered from time to time. Water stress basically depends upon the quantity and distribution of water. For the improvement of sustainability of yield, additional irrigations are must at the critical stages of crop growth and development (Soltani *et al.,* 2001). Plants need water for growth because most of the cellular functions of a plant need a medium which *is* provided by water (Condon *et al.,* 2002). For a reduced use of fresh water resources for agricultural purposes and to enhance productivity, the most economical approach is to improve crop tolerance to water constraint. There are many biochemical, morphological and physiological reactions and responses in the plant to bear or tolerate the stress conditions. (Gao *et al.,* 2008).

The enhancement of genotypes'/cultivars' adaptation to rainfed environment through agronomic as well as genetic tactics is indispensable (Yadav*et al.,* 2004). For any breeding program genetic variation is the basic necessity of genotypes' improvement. Nevertheless, for the selection of best varieties, strong basis are provided by association among yield and its components (Kwon and Torrie, 1964). Conduction of a standard breeding program is greatly affected in water deficient environment due to variation in seasonal magnitude of drought stress and expected lower yield of selected genotypes. This may hamper the development of drought resistant varieties of chickpea and in many other crops. On the basis of mathematical relationship among stress and normal environments, various selection indices have been mentioned for the differentiation of genotypes resistant to drought (Clarke *et al.,* 1984). Under different conditions, various selection indices have been employed by researchers e.g. Tolerance (TOL), stress tolerance index (STI) and stress susceptibility index (SSI) (Fischer and Maurer, 1978), mean productivity (MP) (McCaig and Clarke, 1982), and geometric mean productivity (GMP) (Fernandez, 1992). Fischer and Maurer (1978) explained that genotypes which shows lower than unit SSI are considered as drought resistant, because the mean yield reduction of these genotypes is little as compare to the yield reduction of other all genotypes.

One of the major responsibilities of plant breeder is to develop improved stress tolerant varieties for stressful environments by selection of different genotypes under stressed environmental conditions to improve the stress-tolerant cultivars (Clarke *et al.,* 1984). Keeping in view the above mentioned facts, the present research were planned to define selection criteria for identifying drought tolerance in chickpea genotypes using stress selection indices.

MATERIALS AND METHODS

Under rainfed and irrigated production systems, twenty chickpea genotypes (10 Kabuli and 10 Desi) were assessed as independent experiments during 2013-14 cropping season (Table 1). Randomized complete block (RCB) design with three replications was used under each environment. Both fields of stress and non-stress conditions were established adjacently to avoid environmental bias. However, field that is treated as stress/rainfed was not irrigated during the whole growing season.

In order to find out the selection indices (as suggested by several researchers) the irrigated and non-irrigated experiments were measured as non-stress and stress conditions, respectively. Stress selection indices *viz.* tolerance index (TOL), mean productivity (MP), harmonic mean (HM), stress susceptibility index (SSI), geometric mean productivity (GMP), stress tolerance index (STI), and yield stability index (YSI) based on performance of 20 chickpea genotypes under non-stress(irrigated) and stress (rainfed)condition. Data were recorded for primary branches plant^{-1}, secondary branches plant^{-1}, pods plant^{-1}, 100 seed weight, biological yield plant^{-1} and seed yield plant^{-1}.

Let Y_p= Yield of a given genotype in non-stress environment; Y_s= Yield of a given genotype in stress environment; $\hat{Y_p}$= mean yield under non-stress environment and $\hat{Y_s}$ = mean yield under stress environment. The following stress selection indices were calculated from these four measurements.

Tolerance index (TOL) was calculated using the following formula suggested by (Rosielle and Hamblin, 1981)"$TOL = Y_p - Y_S$". For the measurement of mean productivity (MP) formula proposed by Khayatnezhad *et al.* (2010) "$MP = \frac{Y_P + Y_S}{2}$ "was used. Harmonic mean (HM) was measured by following the technique of Chakherchaman *et al.,(*2009) "$HM = \frac{2\,(Y_p \times Y_s)}{Y_P + Y_s}$". Stress susceptibility (SSI) index was calculated by the formula suggested by Fisher and Maurer, (1978) "$SSI = 1 - \frac{\left(\frac{Y_s}{Y_p}\right)}{1-\left(\frac{\hat{Y_s}}{\hat{Y_p}}\right)}$". Measurement of geometric mean productivity (GMP) and Stress tolerance index (STI) was carried out by following the formulas proposed by Fernandez, 1992 I.E. "$GMP = \sqrt{(Y_p \times Y_s)}$" and "$STI = \frac{(Y_p + Y_s)}{(\hat{Y_p})^2}$". Yield index (YI) was calculated using the procedure of Gavuzzi *et al.,* 2006 "$YI = \frac{Y_s}{\hat{Y_s}}$". Yield stability index (YSI) was measured by following the method suggested by Bouslama and Schapaugh, 1984 "$YSI = \frac{Y_s}{Y_p}$".

Genotypic (r_g) correlations among various traits of chickpea were worked out under irrigated and rainfed environment separately from genetic and environmental covariance's following the procedure of Singh and Chaudhery (1997)

RESULTS

All the studied parameters revealed highly significant differences amongst genotypes under stress and non-stress conditions (Table 1). This indicates the presence of immense variability in the experimental material. Investigation of Gul *et al*. (2013), Malik *et al*. (2010), Ali *et al*. (2008) and Saleem *et al*. (2002) are similar to our results of significant variation among chickpea genotypes.

A valuable selection criterion for the identification and selection of suitable genotypes for stress and non-stress environments could be the combination of numerous indices. TOL is exhibited by the difference of yield in stress and non-stress environments, therefore the reduction in yield under rainfed condition will be more if the TOL value is greater and also the stress sensitivity will be higher and vice versa. For primary branches plant^{-1}, TOL index ranged from -1.13 (NKC-5-S-17) to 0.63(NKC-5-S-14) (Graph 1). Secondary branches plant^{-1} revealed the TOL index ranged from -8.73 (NKC-5-S-21) to 8.27 (NKC-5-S-20) (Graph 2). For pods plant^{-1} TOL index ranged from -18.6 (Karak-1) to 15.9 (NKC-5-S-13) shown in graph 3. TOL index of 100 seed weight ranged from -2.67 (Kara-3) to 3.33 (NKC-5-S-14) (graph 4), whilst graph 5 & 6 presents TOL index regarding biological yield plan^{-1} and seed yield plant^{-1} which ranged from -17.0 (NKC-5-S-21) to 25.8 (NKC-5-S-20) and from -9.00 (NDC -4 -20 -1) to 6.40 (NKC-5-S-20), respectively.

Across two environments the mean performance of a genotype showed the mean productivity (MP) index. For primary branches plant^{-1} maximum MP, HM and GMP value of 4.44 was recorded for genotype ICC-19183, while minimum MP, HM and GMP value of 2.99 was observed for genotype NDC-4-20-5 (Graph 1). For secondary branches plant^{-1}, highest value of MP, HM and GMP i.e. 26.87, 26.23 and 26.55 was recorded for genotype NKC-5-S-20, respectively, while lowest MP, HM and GMP value of 14.17, 14.16 and 14.17 was observed for genotype Karak-1 (Graph 2). Highest value of MP, HM and GMP index for pods plant^{-1} was recorded for genotype NIFA-2005 (68.2), while lowest MP, HM and GMP values of 33.8, 33.6 and 33.7 was observed for genotype SL-3-29 (Graph-1,2,&3). For 100 seed weight, maximum value of MP, HM and GMP was recorded for genotype NKC-5-S-17 and NKC-5-S-15 (each with 31.2), while minimum MP, HM and GMP value (14.3) was observed for genotype SL-3-29 (Graph 3 & 4). Maximum MP, HM and GMP of biological yield plant^{-1} was recorded for genotype NKC-5-S-20 i.e. 63.5, 60.9, 62.2, respectively, while minimum MP, HM and GMP value (each with 29.2) was observed for genotype SL-3-29. For seed yield plant^{-1}, maximum value of MP, HM and GMP was recorded for genotype NKC-5-S-15 (26.9, 25.5 and 26.7), respectively, while minimum MP, HM and GMP index of 11.8, 11.7 and 11.7 was observed for SL-3-29 (Graph 5 & 6). Above mentioned results revealed that same capability was shown by MP, GMP and HM to differentiate genotypes for drought sensitiveness and tolerance.

Under stress conditions the reduction in yield or the degree of susceptibility is measured by stress susceptibility index (SSI). Values of SSI presented in graph 1 to 6 shows that SSI of primary branches ranged from -4.82 (NKC-5-S-14) to 10.12 (NKC-5-S-17), for secondary branches plant^{-1} it ranged from -636.15 (SL 3-29) to 321.42 (NKC-5-S-20) while, for pods plant^{-1} its range was -12.1 (NKC-5-S-13) to 22.3 (NDC-4-20-1). SSI of 100 seed weight ranged from - 11.7 (Karak-3) to 12.0 (NKC-5-S-14). Maximum positive and negative SSI value of biological yield plant^{-1} was recorded for genotype NKC-5-S-20 (10.4) and NKC-5-S-21 (-12.8), respectively. For seed yield plant^{-1} maximum positive and negative value of SSI was recorded for genotype NDC-4-20-1 (9.24) and NKC-5-S-20 (-3.18), respectively.

Genotypes are considered drought tolerant when their GMP and STI values are greater while the SSI is low. In the current study maximum STI value of primary branches plant^{-1} was recorded for genotype ICC-19183 (1.38), whereas minimum STI value of 0.63 was estimated for genotype NDC-4-20-5 (Graph 1). STI of secondary branches plant^{-1} ranged from 0.56 (SL-3-29) to 1.78 (NKC-5-S-20) whereas, highest value of STI for pods pant^{-1}was recorded for NIFA-2005 (1.41) and lowest value of STI (0.34) was estimated for genotype SL-3-29 (Graph 2 & 3). Maximum value of STI was recorded for NKC-5-S-17 and NKC-5-S-15 (1.46), whilst, minimum value of STI (0.31) was estimated for genotype SL-3-29 (Graph 4). STI for biological yield plant^{-1} ranged from 0.37 (SL-3-29) to 1.66 (NKC-5-S-20). Maximum value of STI was recorded for NKC-5-S-20 (1.46), whereas minimum value of STI (0.28) was estimated for genotype SL-3-29 (Graph 5 & 6). Earlier researchers also reported that STI and GMP is the best predictor of yield in rainfed condition, and these two indices could be suggested for evaluation of drought tolerant chickpea genotypes (Farshadfer, 2013).

Under stress environment only YI rank the genotypes on the basis of their performance. YI is measured in stress conditions by yield of genotype to mean yield of all the studied genotype. Maximum and minimum YI values of primary branches were recorded for genotypes NKC-5-S-17 (1.32) and NDC-4-20-5 (0.85), respectively (Graph 1). Highest and lowest YI values of secondary branches plant^{-1} were recorded for genotypes NKC-5-S-21 (1.35) and Karak-1 (0.72), respectively (Graph 2). Graph 3 shows the YI of pods plant^{-1}, maximum and minimum YI values of pods plant^{-1} were recorded for commercial cultivar Karak-1 (1.26) and SL-3-29 (0.64), respectively (Graph 3). Maximum and minimum YI values of 100 seed weight were recorded for NKC-5-S-15 (1.23) and Karak-1 (0.80), respectively (Graph 4). Greatest and smallest YI values of biological yield plant $^{-1}$ were noted for genotypes NKC-5-S-17 (1.25) and SL-3-29 (0.62). Maximum and minimum YI values of seed yield plant^{-1} were recorded for NKC-5-S-17 (1.24) and SL-3-29 (0.58), respectively (Graph 5 & 6).

The comparative yield of genotypes in stress and non-stress condition determines their YSI. Details of YSI of studied parameters are shown in graphs 1-6. YSI of primary branches plant^{-1} ranged from 0.86 to 1.29 in genotype NKC-5-S-14 and NKC-5-S-17, respectively. YSI estimates of secondary branches plant^{-1} was ranged 0.73 to 1.53 in genotype NKC-5-S-20 and SL-3-29, respectively. YSI estimates of pods plant^{-1} ranged from 0.77 to 1.43 in genotype NKC-5-S-13 and NDC-4-20-1, respectively. YSI estimates of 100 seed weight ranged from 0.89 to 1.11 in genotype NKC-5-S-14, NDC-122 and Karak-3, respectively. YSI of biological yield plant^{-1} ranged from 0.66 to 1.42 in genotype NKC-5-S-20 and NKC-5 -S -21, respectively. YSI estimates for seed yield plant^{-1} ranged from 0.79 to 1.62 in genotype NKC-5-S-20 and NDC-4-20-1, respectively. Genotypes with lowest value of YSI reveals greater yield in stress as well as under non-stress environments and therefore minimum YSI might also be a sign of drought resistance in genotype. Our study reveals that YSI value of genotype NKC-5-S-20 is lowermost which suggest it as best suited for both environments, specifically under drought conditions. The performance of a genotype is better when the value of YSI is higher than 1.

Genotype NKC-5-S-20 showed highest TOL as well as maximum STI which demonstrates that these genotypes are best suited for rainfed conditions. Because, TOL is exhibited by the difference of yield in stress and non-stress environments, hence the reduction in yield under rainfed condition will be more if the TOL value is greater and also the stress sensitivity will be higher and vice versa. Similarly, stress tolerance index (STI) is used for the identification of genotypes with high yield under both rainfed and irrigated environment. The findings of Fernandez (1992) authenticate our results, who reported higher stress tolerance and greater potential of yield for genotypes which had larger value of STI under stress environment (Fernandez, 1992).

Correlation coefficient: Correlation coefficient between yield component of chickpea and stress selection indices were calculated to identify the most appropriate selection indices as selection criteria. Correlation analysis (Table 2) revealed that under irrigated environment, primary branches plant^{-1} is significantly and positively associated with TOL (r = 0.59**), MP (r = 0.89**), HM (r = 0.90**), GMP (r = 0.89**) and STI (r = 0.89**), however its correlation was significantly negative with SSI (r = -0.60**) and YSI (r = -0.60**). Under rainfed condition, significantly positive association of primary branches was recorded with MP (r = 0.85**), HM (r = 0.84**), GMP (r = 0.84**) and STI (r = 0.85**), whereas relationship of primary branches Plant^{-}1 was significant negative with TOL (r = -0.39*). Correlation of secondary branches plant^{-1} was significant and positive with TOL (r = 0.73**), MP (r = 0.92**), HM (r = 0.93**), SSI (r = 0.69**), GMP (r = 0.93**) and STI (r = 0.93**), however significant negative relationship with YSI (r = -0.69**) under irrigated condition. Association of secondary branches plant^{-1} under rainfed environment was significant positive with MP (r = 0.83**), with HM (r = 0.81**), GMP (r = 0.82**) and STI (r = 0.81**), whereas non-significant association with TOL and YSI. Pods plant^{-1} under non-stress (irrigated) condition exhibited positively significant correlation with TOL (r = 0.61**), MP (r = 0.89**), HM (r = 0.90**), GMP (r = 0.90**) and STI (r = 0.89**), while significant negative relationship with SSI (r = -0.68**) and YSI (r = -0.69**). Under rainfed, pods plant^{-1} exhibited significantly positive correlation with MP (r = 0.85**), HM (r = 0.84**), GMP (r = 0.84**) and STI (r = 0.84**), whereas non-significant association with TOL, SSI and YSI. 100 seed weight under non-stress (irrigated) condition exhibited significantly positive correlation with TOL (r = 0.44*), MP (r = 0.98**), HM (r = 0.98**), SSI (r = 0.45**), GMP (r = 0.98**), and STI (r = 0.98**), although significantly negative relationship with YSI (r=-0.45**). Under rainfed, 100 seed weight exhibited significant positive correlation with MP (r=0.98**), HM (r = 0.98**), GMP (r = 0.98**) and STI (r = 0.97**), whereas non-significant association with TOL, SSI and YSI. Biological yield plant^{-1} showed significant positive correlation with TOL (r = 0.80**), MP (r = 0.93**), HM (r = 0.93**), SSI (r = 0.78**), GMP (r = 0.93**) and STI (r = 0.94**) under irrigated condition. Under rainfed, biological yield plant^{-1} exhibited significant positive correlation with MP (r = 0.80**), with HM (r = 0.81**), GMP (r = 0.81**) and STI (r = 0.78**), while non significant association with TOL, SSI and YSI. Seed yield plant^{-1} showed significant positive correlation with TOL (r = 0.66**), MP (r = 0.92**), HM (r = 0.93**), GMP (r = 0.92**) and STI (r = 0.93**), whereas, significant negative relationship with SSI and YSI (r = -0.63** each) under non-stress (irrigated) condition. Under rainfed, seed yield plant $^{-1}$ exhibited significant positive correlation with MP (r = 0.85**), HM (r = 0.84**), GMP (r = 0.85**) and STI (r = 0.81**), whereas non-significant association with TOL, SSI and YSI (Table 2).

Correlation analysis among yield traits vs. stress selection indices displayed that MP, HM, GMP, and STI had strong positive association with all the traits under both production systems. TOL had significant positive and negative correlation with all the studies traits under irrigated vs. rainfed, respectively, YI (yield index) showed positive association with all the traits only under rainfed conditions. Furthermore, SSI and YSI exhibit significant negative relationship with almost all the traits under irrigated conditions Positive association of selection indices with most of the yield component under both irrigated and rainfed conditions shows that these indices could provide better selection criteria in selecting drought tolerant genotypes. The observed relationship among the studied indices and yield components are in agreements with the earlier findings made by Andarab (2013), Banayjedi *et al*. (2012), Pouresmaeil *et al*. (2012), Ganjeali *et al*. (2011), and Talebi *et al*. (2011) in chickpea. Similarly, Azizi-Chakherchaman *et al*. (2009), and Sio-Se Mardeh *et al*. (2006) observed that GMP and STI are reliable indices for identifying drought tolerant lines/genotypes. Farshadfer *et al*., (2013) also reported that, in stress condition, grain yield was significantly and positively correlated with STI, GMP, MP, HM, YI, and YSI while association of gain yield was significant and negative with SSI under stress and non-stress conditions

Table 1. Analysis of variance of different polygenic characters in chickpea genotypes under irrigated and rainfed condition during Rabi 2013-14.

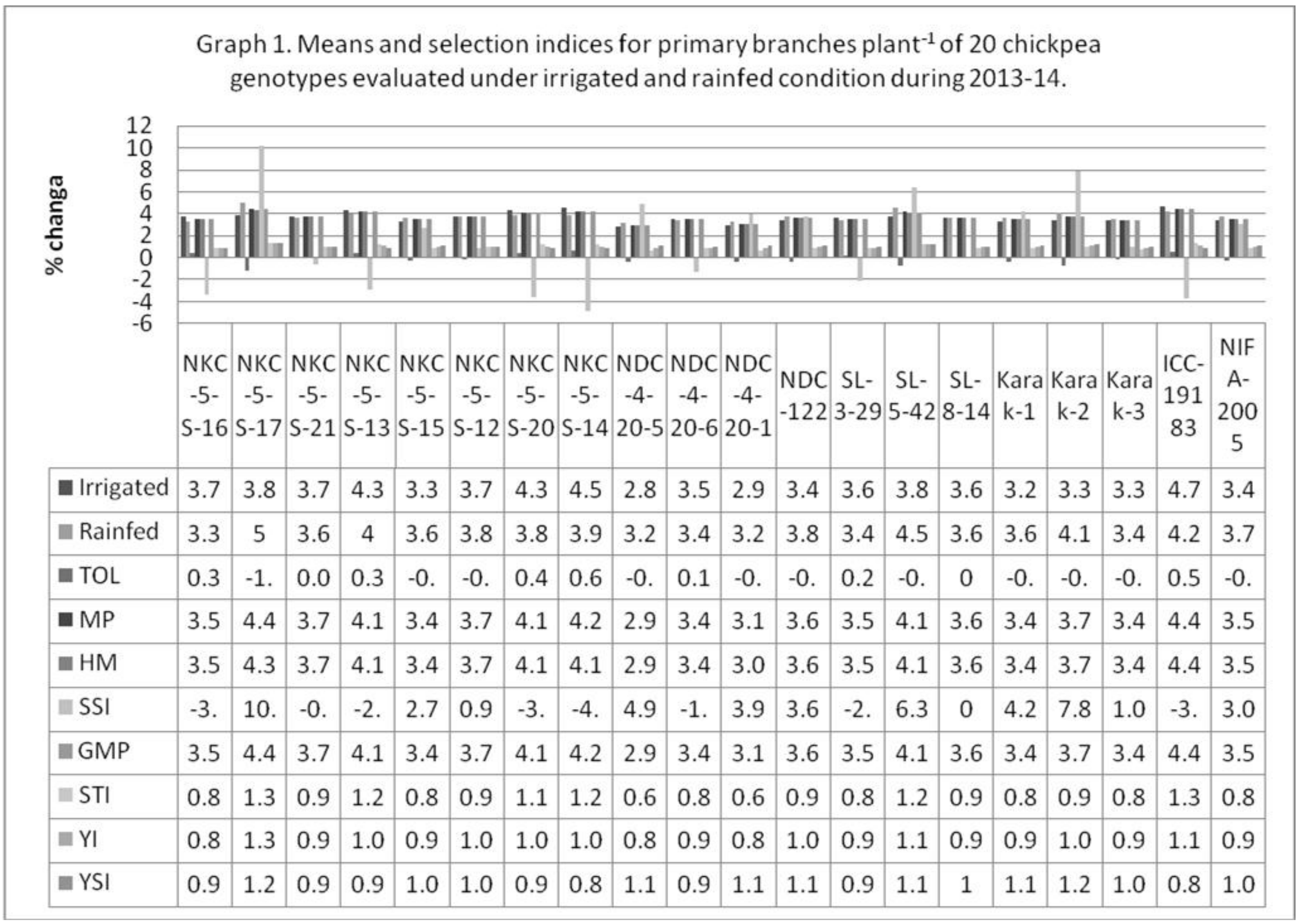
Traits	IRRIGATED			RAINFED		
	Replication	Genotype	Error	Replication	Genotypes	Error
PBR	0.17	0.74**	0.11	0.28	0.58**	0.27
SBR	8.47	62.11**	3.66	2.32	29.63**	2.65
PPP	18.72	421.24**	9.03	0.15	301.46**	9.92
HSW	0.22	58.51**	0.76	0.52	47.80**	0.71
BY	0.98	389.70**	14.92	2.52	176.80**	4.44
SY	9.09	71.05**	3.47	8.72	43.52**	2.41

PBR= Primary branches, SBR= Secondary branches, PPP= Pods plant^{-1}, HSW= 100-seed weight, BY= Biological yield and SY = seed yield

Table 2. Correlation coefficients among yield components and stress selection indices under irrigated and rainfed environment.

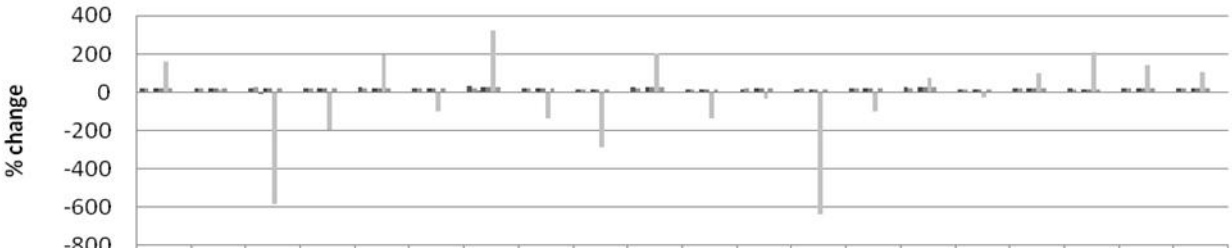
Traits	Environment	TOL	MP	HM	SSI	GMP	STI	YSI
Primary branches	Irrigated	0.59**	0.89**	0.90**	-0.60**	0.89**	0.89**	-0.60**
plant^{-1}	Rainfed	-0.39*	0.85**	0.84**	0.38	0.84**	0.85**	0.38
Secondary	Irrigated	0.73**	0.92**	0.93**	0.69**	0.93**	0.93**	-0.69**
branches plant^{-1}	Rainfed	-0.18	0.83**	0.81**	-0.19	0.82**	0.81**	0.19
	Irrigated	0.61**	0.89**	0.90**	-0.68**	0.90**	0.89**	-0.69**
Pods plant^{-1}	Rainfed	-0.36	0.85**	0.84**	0.26	0.84**	0.84**	0.26
	Irrigated	0.44*	0.98**	0.98**	0.45**	0.98**	0.98**	-0.45**
100 seed weight	Rainfed	0.05	0.98**	0.98**	0.07	0.98**	0.97**	-0.07
	Irrigated	0.80**	0.93**	0.93**	0.78**	0.93**	0.94**	-0.78
Biological yield	Rainfed	-0.08	0.80**	0.81**	-0.09	0.81**	0.78**	0.09
	Irrigated	0.66**	0.92**	0.93**	-0.63	0.92**	0.93**	-0.63**
Seed yield	Rainfed	-0.24	0.85**	0.84**	0.25	0.85**	0.81**	0.25
	Irrigated	0.33	0.92**	0.93**	-0.34	0.92**	0.93**	-0.34**
Harvest index	Rainfed	-0.44	0.93**	0.92**	0.44*	0.92**	0.91**	0.44*

* and ** = Significant at 5 and 1% probability level, respectively; without staric= non Significant



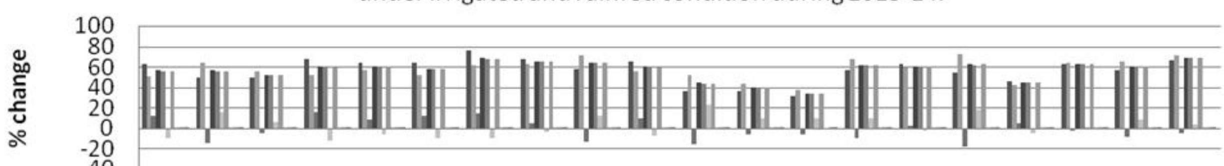
	NKC-5-S-16	NKC-5-S-17	NKC-5-S-21	NKC-5-S-13	NKC-5-S-15	NKC-5-S-12	NKC-5-S-20	NKC-5-S-14	NDC-4-20-5	NDC-4-20-6	NDC-4-20-1	NDC-122	SL-3-29	SL-5-42	SL-8-14	Karak-1	Karak-2	Karak-3	ICC-19183	NIFA-2005
Irrigated	3.7	3.8	3.7	4.3	3.3	3.7	4.3	4.5	2.8	3.5	2.9	3.4	3.6	3.8	3.6	3.2	3.3	3.3	4.7	3.4
Rainfed	3.3	5	3.6	4	3.6	3.8	3.8	3.9	3.2	3.4	3.2	3.8	3.4	4.5	3.6	3.6	4.1	3.4	4.2	3.7
TOL	0.3	-1.	0.0	0.3	-0.	-0.	0.4	0.6	-0.	0.1	-0.	-0.	0.2	-0.	0	-0.	-0.	-0.	0.5	-0.
MP	3.5	4.4	3.7	4.1	3.4	3.7	4.1	4.2	2.9	3.4	3.1	3.6	3.5	4.1	3.6	3.4	3.7	3.4	4.4	3.5
HM	3.5	4.3	3.7	4.1	3.4	3.7	4.1	4.1	2.9	3.4	3.0	3.6	3.5	4.1	3.6	3.4	3.7	3.4	4.4	3.5
SSI	-3.	10.	-0.	-2.	2.7	0.9	-3.	-4.	4.9	-1.	3.9	3.6	-2.	6.3	0	4.2	7.8	1.0	-3.	3.0
GMP	3.5	4.4	3.7	4.1	3.4	3.7	4.1	4.2	2.9	3.4	3.1	3.6	3.5	4.1	3.6	3.4	3.7	3.4	4.4	3.5
STI	0.8	1.3	0.9	1.2	0.8	0.9	1.1	1.2	0.6	0.8	0.6	0.9	0.8	1.2	0.9	0.8	0.9	0.8	1.3	0.8
YI	0.8	1.3	0.9	1.0	0.9	1.0	1.0	1.0	0.8	0.9	0.8	1.0	0.9	1.1	0.9	0.9	1.0	0.9	1.1	0.9
YSI	0.9	1.2	0.9	0.9	1.0	1.0	0.9	0.8	1.1	0.9	1.1	1.1	0.9	1.1	1	1.1	1.2	1.0	0.8	1.0

Graph 2. Means and selection indices for secondary branches plant-1 of 20 chickpea genotypes evaluated under irrigated and rainfed condition during 2013-14.



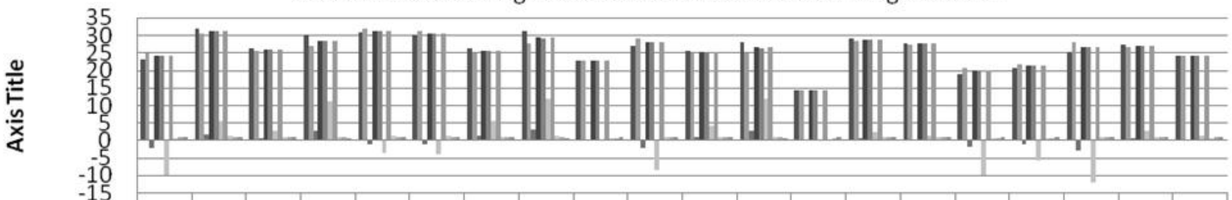
	NKC-5-S-16	NKC-5-S-17	NKC-5-S-21	NKC-5-S-13	NKC-5-S-15	NKC-5-S-12	NKC-5-S-20	NKC-5-S-14	NDC-4-20-5	NDC-4-20-6	NDC-4-20-1	NDC-122	SL-3-29	SL-5-42	SL-8-14	Karak-1	Karak-2	Karak-3	ICC-19183	NIFA-2005
Irrigated	22	22	18	18	24	22	31	20	14	26	14	17	12	21	24	14	20	18	20	19
Rainfed	19	22	27	21	20	23	23	22	17	22	16	18	18	23	23	14	19	15	18	18
TOL	2.8	0.2	-8.	-3	4	-1.	8.2	-2.	-3.	4.3	-1.	-0.	-6.	-1.	1.5	-0.	1.6	3.0	2.3	1.6
MP	20.	21.	22.	19.	22.	22.	26.	21	15.	23.	15.	17.	15.	21.	23.	14.	19.	16.	19.	18.
HM	20.	21.	21.	19.	22.	22.	26.	21	15.	23.	15.	17.	14.	21.	23.	14.	19.	16.	19.	18.
SSI	158	11.	-58	-19	197	-10	321	-13	-28	200	-13	-33	-63	-10	75.	-29	99.	205	138	104
GMP	20.	21.	21.	19.	22.	22.	26.	21	15.	23.	15.	17.	14.	21.	23.	14.	19.	16.	19.	18.
STI	1.0	1.1	1.2	0.9	1.2	1.2	1.7	1.1	0.6	1.4	0.5	0.7	0.5	1.2	1.4	0.5	0.9	0.6	0.9	0.8
YI	0.9	1.0	1.3	1.0	1.0	1.1	1.1	1.1	0.8	1.0	0.8	0.8	0.9	1.1	1.1	0.7	0.9	0.7	0.9	0.8
YSI	0.8	0.9	1.4	1.1	0.8	1.0	0.7	1.1	1.2	0.8	1.1	1.0	1.5	1.0	0.9	1.0	0.9	0.8	0.8	0.9

Graph 3. Means and selection indices for pods plant-1 of 20 chickpea genotypes evaluated under irrigated and rainfed condition during 2013-14.



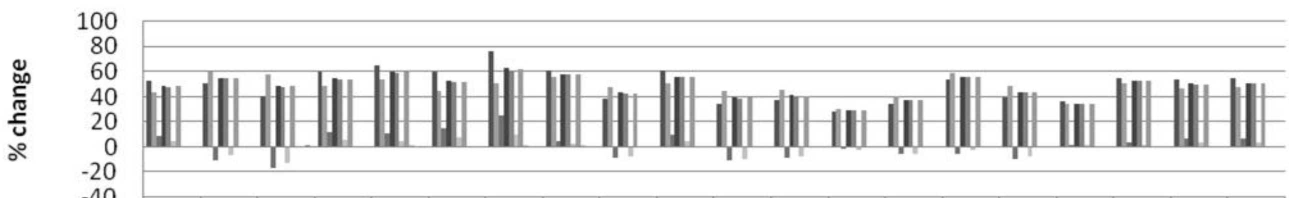
	NKC-5-S-16	NKC-5-S-17	NKC-5-S-21	NKC-5-S-13	NKC-5-S-15	NKC-5-S-12	NKC-5-S-20	NKC-5-S-14	NDC-4-20-5	NDC-4-20-6	NDC-4-20-1	NDC-122	SL-3-29	SL-5-42	SL-8-14	Karak-1	Karak-2	Karak-3	ICC-19183	NIFA-2005
Irrigated	62	49	49	68	64	64	76	68	58	65	36	36	31	56	62	54	46	62	56	66
Rainfed	50	64	55	52	56	52	61	63	71	55	52	43	37	67	59	72	42	64	65	71
TOL	11.	-15	-5.	15.	8	12.	14.	4.7	-13	10	-16	-6.	-5.	-10	2.3	-19	4.9	-2	-9.	-5
MP	56.	56.	52.	60	60	58.	68.	65.	64.	59.	44.	39.	33.	61.	60.	63	44.	63	60.	68.
HM	55.	55.	52	58.	59.	57.	67.	65.	63.	59.	42.	39.	33.	61.	60.	61.	43.	63	60.	68.
SSI	-9.	15.	5.7	-12	-6.	-9.	-10	-3.	11.	-8	22.	8.9	9.4	9.4	-2	17.	-5.	1.6	8.5	3.9
GMP	55.	55.	52	59.	59.	57.	67.	65.	64	59.	43.	39.	33.	61.	60.	62.	44	63	60.	68.
STI	0.9	0.9	0.8	1.0	1.0	1.0	1.4	1.3	1.2	1.0	0.5	0.4	0.3	1.1	1.1	1.1	0.5	1.2	1.1	1.4
YI	0.8	1.1	0.9	0.9	0.9	0.9	1.0	1.1	1.2	0.9	0.9	0.7	0.6	1.1	1.0	1.2	0.7	1.1	1.1	1.2
YSI	0.8	1.3	1.1	0.7	0.8	0.8	0.8	0.9	1.2	0.8	1.4	1.1	1.1	1.1	0.9	1.3	0.9	1.0	1.1	1.0

Graph 4. Means and selection indices for 100 seed weight (g) of 20 chickpea genotypes evaluated under irrigated and rainfed condition during 2013-14.



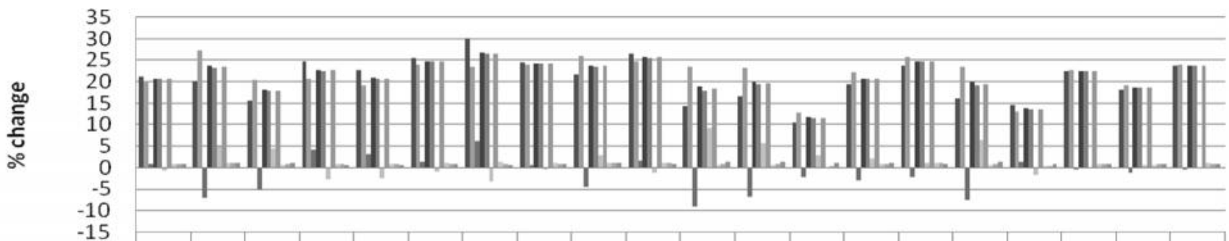
	NKC-5-S-16	NKC-5-S-17	NKC-5-S-21	NKC-5-S-13	NKC-5-S-15	NKC-5-S-12	NKC-5-S-20	NKC-5-S-14	NDC-4-20-5	NDC-4-20-6	NDC-4-20-1	NDC-122	SL-3-29	SL-5-42	SL-8-14	Karak-1	Karak-2	Karak-3	ICC-19183	NIFA-2005
Irrigated	23	32	26.	30	30.	30	26.	31	22.	27	25.	28	14.	29	27.	19	20.	25.	27.	24.
Rainfed	25	30.	25.	27	31.	31	25	27.	22.	29	24.	25	14.	28.	27.	20.	21.	28	26.	24
TOL	-2	1.6	0.6	3	-1	-1	1.3	3.3	0	-2	1	3	0	0.6	0.3	-1.	-1	-2.	0.6	0.3
MP	24	31.	26	28.	31.	30.	25.	29.	22.	28	25.	26.	14.	28.	27.	19.	21.	26.	27	24.
HM	24	31.	26	28.	31.	30.	25.	29.	22.	28	25.	26.	14.	28.	27.	19.	21.	26.	27	24.
SSI	-9.	5.8	2.8	11.	-3.	-3.	5.6	12	0	-8.	4.3	11.	0	2.6	1.3	-9.	-5.	-12	2.7	1.5
GMP	24	31.	26	28.	31.	30.	25.	29.	22.	28	25.	26.	14.	28.	27.	19.	21.	26.	27	24.
STI	0.8	1.4	1.0	1.2	1.4	1.4	0.9	1.2	0.7	1.1	0.9	1.0	0.3	1.2	1.1	0.5	0.6	1.0	1.1	0.8
YI	0.9	1.1	1	1.0	1.2	1.2	0.9	1.0	0.8	1.1	0.9	0.9	0.5	1.1	1.0	0.8	0.8	1.0	1.0	0.9
YSI	1.0	0.9	0.9	0.9	1.0	1.0	0.9	0.8	1	1.0	0.9	0.8	1	0.9	0.9	1.0	1.0	1.1	0.9	0.9

Graph 5. Means and selection indices for biological yield plant-1(g) of 20 chickpea genotypes evaluated under irrigated and rainfed condition during 2013-14.



	NKC-5-S-16	NKC-5-S-17	NKC-5-S-21	NKC-5-S-13	NKC-5-S-15	NKC-5-S-12	NKC-5-S-20	NKC-5-S-14	NDC-4-20-5	NDC-4-20-6	NDC-4-20-1	NDC-122	SL-3-29	SL-5-42	SL-8-14	Karak-1	Karak-2	Karak-3	ICC-19183	NIFA-2005
Irrigated	53.	50.	40.	60.	65.	60.	76.	61.	39	61.	34.	37.	28.	34.	54	39.	36.	54.	54.	54.
Rainfed	44.	60.	57.	48.	54.	44.	50.	56.	47.	51.	45.	45.	30	40.	58.	48.	34.	50.	46.	47.
TOL	9	-10	-17	11.	11.	15.	25.	4.9	-8.	9.9	-11	-8.	-1.	-5.	-4.	-9.	2	3.9	7.5	6.9
MP	48.	55.	49.	54.	59.	52.	63.	58.	43.	56.	39.	41.	29.	37.	56.	44.	35.	52.	50.	51.
HM	48.	55	47.	54	59.	51.	60.	58.	42.	55.	39.	41	29.	37.	56.	43.	35.	52.	50.	50.
SSI	5.2	-6.	-13	6	5.2	7.9	10.	2.5	-6.	5	-9.	-6.	-1.	-5	-2.	-7.	1.7	2.2	4.2	3.9
GMP	48.	55.	48.	54.	59.	52	62.	58.	43.	56.	39.	41.	29.	37.	56.	43.	35.	52.	50.	51.
STI	1.0	1.3	1.0	1.2	1.5	1.1	1.6	1.4	0.8	1.3	0.6	0.7	0.3	0.6	1.3	0.8	0.5	1.1	1.0	1.1
YI	0.9	1.2	1.2	1.0	1.1	0.9	1.0	1.1	0.9	1.0	0.9	0.9	0.6	0.8	1.2	1.0	0.7	1.0	0.9	0.9
YSI	0.8	1.2	1.4	0.8	0.8	0.7	0.6	0.9	1.2	0.8	1.3	1.2	1.0	1.1	1.0	1.2	0.9	0.9	0.8	0.8

Graph 6. Means and selection indices for seed yield plant^{-1} (g) of 20 chickpea genotypes evaluated under irrigated and rainfed condition during 2013-14.



	NKC-5-S-16	NKC-5-S-17	NKC-5-S-21	NKC-5-S-13	NKC-5-S-15	NKC-5-S-12	NKC-5-S-20	NKC-5-S-14	NDC-4-20-5	NDC-4-20-6	NDC-4-20-1	NDC-122	SL-3-29	SL-5-42	SL-8-14	Karak-1	Karak-2	Karak-3	ICC-19183	NIFA-2005
Irrigated	21.	20.	15.	24.	22.	25.	30.	24.	21.	26.	14.	16.	10.	19.	23.	16.	14.	22.	18.	23.
Rainfed	20.	27.	20.	20.	19.	24.	23.	24	26.	24.	23.	23.	12.	22.	25.	23.	13.	22.	19.	24.
TOL	0.8	-7	-4.	4.2	3.3	1.4	6.4	0.6	-4.	1.6	-9	-6.	-2.	-2.	-2.	-7.	1.4	-0.	-0.	-0.
MP	20.	23.	18.	22.	21	24.	26.	24.	23.	25.	19	20.	11.	20.	24.	20	13.	22.	18.	23.
HM	20.	23.	17.	22.	20.	24.	26.	24.	23.	25.	18	19.	11.	20.	24.	19.	13.	22.	18.	23.
SSI	-0.	5.1	4.5	-2.	-2.	-0.	-3.	-0.	3.0	-0.	9.2	5.9	3.0	2.2	1.3	6.6	-1.	0.2	0.7	0.1
GMP	20.	23.	18	22.	20.	24.	26.	24.	23.	25.	18.	19.	11.	20.	24.	19.	13.	22.	18.	23.
STI	0.8	1.1	0.6	1.0	0.9	1.2	1.4	1.2	1.1	1.3	0.7	0.8	0.2	0.8	1.2	0.7	0.3	1.0	0.7	1.1
YI	0.9	1.2	0.9	0.9	0.8	1.0	1.0	1.0	1.1	1.1	1.0	1.0	0.5	1.0	1.1	1.0	0.5	1.0	0.8	1.0
YSI	0.9	1.3	1.3	0.8	0.8	0.9	0.7	0.9	1.2	0.9	1.6	1.4	1.2	1.1	1.0	1.4	0.9	1.0	1.0	1.0

Conclusions: Highly significant variability in the studied germplasm, allows these twenty (Desi as well as Kabuli) genotypes to be used for the development of improved chickpea varieties specifically for the production of drought tolerant varieties of Desi and Kabuli chickpea. Stress selection indices viz. MP, HM, GMP and STI and YI had strong associating with yield under respective production systems, and validate that these indices could be used effectively as selection criteria, in selecting drought tolerant genotypes. Genotypes NKC-5-S-20 and NKC-5-S-17 best suited to both irrigated and rainfed environments. These genotypes also remained at the top in seed yield under irrigated and rainfed environments, respectively and could be recommended for general cultivation after necessary multi locations testing.

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