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Assessment of different drought tolerance indices and identifying drought tolerant lines in backcross population derived from cross between ICC13124 and WR-315 in chickpea

T. P. ONTAGODI AND P. M. SALIMATH

Department of Genetics and Plant Breeding, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: timmu07uas@gmail.com

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Abstract: Drought is one of the major limiting factor in increasing the productivity of chickpea, as the crop is mainly grown under the residual soil moisture conditions under rainfed ecosystem. Hence, to identify most drought tolerant and productive lines in BC_1F_3 population, drought tolerance indices were computed by taking yield under irrigated and rainfed conditions. The population was developed by crossing a drought tolerant genotype ICC-13124 as recurrent parent and susceptible parent WR-315 is also donor for wilt resistance. Totally 224 BC_1F_3 families were subjected for evaluation under irrigated and rainfed situation to identify high yielding and drought tolerant lines based on drought tolerance indices. A drought tolerance index 'Drought and Productivity Index (DPI)' was computed along with other drought tolerance indices *viz;* DSI, TOL or TDS, MP, DTE, YI, RR, GMP and HM. Analysis of variance indicated presence of significance differences between families for seed yield under IR and RF as well as for drought tolerance indices. The highly significant and positive correlation of YIR and YRF with DPI, MP, YI, GMP and HM, indicates that selection could be effective for high DPI, MP, YI, GMP and HM. Superior genotypes can be selected by combining two to three indices and it may leads to bias in the selection if considering single index. Hence, recently reported Drought and Productivity Index (DPI) alone can be effectively used in identifying most productive and drought tolerant genotypes. Based on these indices out of 224 families 10 families were found superior and among these three families *viz;* BC_1F_3-4-1, BC_1F_3-6-3 and BC_1F_3-8-7 were found highly superior with respect to YIR, YRF and DPI compared to both the parents as well as checks.

Key words: Chickpea, Correlation, Drought tolerance indices, Population

Introduction

Chickpea is one of the most important crop in the semi arid tropics (SAT) region of the world. India stands first with respect to total world chickpea production followed by Turkey, Pakistan and Iran. In India, it tops the list of pulse crops and is cultivated in an area of 9.6 million ha, producing a total of 8.83 million tons with an average yield of 920.1 kg/ha (Anon., 2014). In SAT regions chickpea is mainly cultivated under rainfed, marginal and resource poor conditions. Under such situations crop usually faces terminal drought as it is cultivated in the residual soil moisture condition. Therefore it is necessary to develop drought tolerant superior genotypes with high yields.

Among the abiotic stresses, drought is most important constraint in improving productivity. Drought is very complex phenomena. It requires a clear understanding of the traits associated with it. Screening for drought tolerance will be very cumbersome because of its quantitative and complex nature. It is very difficult to screen the large number of genotypes for root traits and other physiological traits in field conditions to identify drought tolerant lines. Usually to identify drought tolerance genotypes researchers will go for evaluation of genotypes under irrigated and non-irrigated conditions and select the common lines which are high yielding in both the environments. But measurement of drought tolerance with single parameter will not give clear idea about the potential genotypes because of multiplicity of different factors involved and their interactions contributing to drought tolerance under field conditions. However, it is necessary for a breeder to identify not only drought tolerant line/genotype but also it should give high yield under favourable environments. Therefore, it is necessary to derive selection indices for drought tolerance based on a mathematical relation between yield under stress and non-stress condition along with yield of drought tolerant check to understand response of genotypes to drought. However, it is necessary to identify the most efficient and useful index to identify precisely the highly drought tolerant genotype. Keeping the above in view, an attempt was made to compute and compare different drought tolerance indices to identify efficiently drought tolerant lines in chickpea.

Material and methods

The material used in this study includes BC_1F_3 population developed by using two parents ICC13124 and WR-315. Parent ICC13124 (Parameswarappa *et al.,* 2012, Shivukumar *et al.,* 2013 and Jha *et al.,* 2014) is drought tolerant and agronomically superior. It was used as recurrent parent and the second one WR-315 is a well known source of resistance was used as a donor for wilt resistance but it is susceptible to drought. Parents were crossed to generate F_1 seeds during *Rabi* 2010. All the F_1s were sown in a field and by using molecular markers 18 true F_1s were identified during off season kharif-2011. These true F_1s were backcrossed to ICC13124 from which 55 BC_1F_1 seeds were harvested. These seeds were sown in the field during *rabi* 2011 and 20 true BC_1F_1s were identified by using markers linked to fusarium wilt and were selfed to get 300 BC_1F_2 seeds. These BC_1F_2 seeds were sown during *kharif* 2012 and selfed to get BC_1F_3 seeds from 240 healthy plants. Out of 240 BC_1F_3 families 224 families having sufficient seeds to replicate in two environments were selected and were evaluated during *rabi*-2012-13 under both irrigated and rainfed conditions in Botany Garden, Department of Genetics and Plant Breeding, UAS, Dharwad, Karnataka, India. Material was evaluated by following augmented design consisting of 14 blocks and 20 entries in each block including two parents and two local checks. By taking yield of lines under irrigated and rainfed conditions, following drought tolerance indices were computed.

The Drought and Productivity Index (DPI) defined by Ontagodi T. P. (2015), was computed as follows.

$$\mathrm{DPI} = \frac{(3\mathrm{YRF}+1\mathrm{YIR}-2\mathrm{DCRF})}{2}$$

Where, YRF – Grain yield of genotype under rainfed condition

YIR – Grain yield of genotype under irrigated condition

DCRF – Grain yield of drought tolerant check under rainfed

Earlier reported drought indices like Drought Susceptibility Index (DSI) of Fischer and Maurer (1978), the Drought Tolerance Efficiency (DTE %) of Fischer and Wood (1981), the Mean Productivity (MP) and TOL or Tolerance to Drought Stress (TDS) of Rosielle and Hamblin (1981), Geometric Mean Productivity (GMP) and Harmonic Mean (HM) of Fernandez (1992), Yield Index (YI) of Gavuzzi *et al.* (2006) and Relative Reduction (RR) of Sadiki (2006) were computed for selecting drought tolerant lines. Data on yield under irrigated and rainfed along with drought tolerance indices were analysed by using WINDOSAT version 9.1.

Results and discussion

Analysis of variance indicated significant differences among the families and significant differences were also found between families and checks for yield under rainfed. But there was no significant difference among genotypes as well as varieties for yield under irrigated condition. This indicates that genotypes thrown a differential expression under rainfed compared to irrigated condition. There was no significant difference between the blocks indicating that existence of sufficient uniformity across blocks and repetition of checks in each block (Table 1).

Extent of genetic variability expressed by the traits indicates scope for selection of such traits. Existence of variability for yield under rainfed and irrigated in BC_1F_3 indicates scope for selection of favourable genotypes based on the drought tolerance indices (Table 2). This can be evidenced by expression of higher GCV under rainfed (37.79) compared to irrigated (20.89) situation. Only estimation of variability may not give clear idea about the heritable portion of the trait therefore, heritability and genetic advance needs to be estimated. Seed yield per plant under rainfed situation showed highest heritability of 67.84% followed by yield index (66.67%). But yield under irrigated situation recorded least heritability of 23.25%. This indicates that existence of more phenotypic variance because of environmental influence on genotype expression. Heritability indicates only the effectiveness with which selection of genotypes can be based on their phenotypic performance but fail to indicate the amount of progress expected from selection. Therefore, heritability estimates appear to be more meaningful when accompanied by estimates of genetic advance. Highest GA (5.22) and GAM (64.12) were recorded for yield under rainfed (YRF) followed by HM (GA; 4.46 and GAM; 49.40).

Table 1. Analysis of variance for drought tolerance indices in BC_1F_3 population of cross (ICC-13124xWR-315)xICC-13124 in chickpea during *rabi* 2012-13

Source of variations	DF	YIR	YRF	DPI	DSI	TDS	MP	DTE	YI	RR	GMP	HM
Block (eliminating Check+Var.)	13	12.41	8.84	9.45	0.89	4.53	9.49	431.96	0.13*	0.043	9.39	9.36
Entries (ignoring Blocks)	227	20.17	13.93***	17.50**	0.55	4.64	16.03**	267.54	0.21***	0.027	15.86**	15.78**
Checks	3	2.52	0.98	1.48	0.06	1.16	1.46	27.57	0.01	0.003	1.37	1.27
Varieties	223	19.79	13.4***	17.20**	0.56	4.71	15.57*	270.92	0.20***	0.027	15.38**	15.28**
Checks vs. Varieties	1	157.8**	160.0***	171.0**	0.49	0.01	162.9***	235.15	2.4***	0.023	166.1***	169.1***
ERROR	39	15.48	4.48	8.50	0.75	5.93	8.49	361.79	0.07	0.036	7.78	7.17

DF- degrees of freedom; *Significance at 5%, ** Significance at 1%, *** Significance at 0.1%

Table 2. Estimation of genetic parameters for yield under irrigated and rainfed and drought tolerance indices BC_1F_3 populations of a cross (ICC-13124xWR-315)xICC-13124 in chickpea during *rabi* 2012-13.

Genetic Parameters	YIR	YRF	DPI	DSI	TDS	MP	DTE	YI	RR	GMP	HM
GCV	20.89	37.79	34.5	50.58	50.82	29.62	12.05	37.39	48.77	31.06	32.47
PCV	43.31	45.88	49.5	83.88	96.39	43.18	20.31	45.80	84.47	43.52	43.95
h^2 (%)	23.25	67.84	50.5	36.36	27.80	47.04	35.23	66.67	33.33	50.95	54.56
GA@ 5%	2.15	5.22	0.65	0.56	1.23	3.88	11.87	0.63	0.11	4.18	4.46
GAM@ 5%	20.75	64.12	63.5	62.83	55.20	41.84	14.74	62.90	58.00	45.67	49.40

Determining the associations among various traits is useful to breeders in selecting genotypes in desired direction. A strong positive correlation for the seed yield per plant between irrigated and rainfed situation was recorded (Table 3). This indicates that selecting better yielding genotypes under rainfed can also give higher yields under the irrigated situation. Yield under irrigated (YIR) recorded highly significant positive correlation with drought tolerance indices like DPI (0.91), DSI (0.46), MP (0.96), YI (0.81), RR (0.46), GMP (0.94) and HM (0.92). On the contrary, yield under rainfed (YRF) also showed significant positive correlation with DPI (0.98), MP (0.93), YI (1.0), GMP (0.95) and HM (0.96) but it is negatively correlated with DSI (-0.06) and RR (-0.06). These results are in accordance with Fernandez (1992) in mungbean, Farshadfar and Sutka (2002) in maize and Win (2011), Talebi *et al.* (2011) and Sabaghnia and Janmohammadi (2014) in chickpea. Similarly, TDS showed negative correlation of -0.74 and -0.21 with YIR and YRF respectively. Computation of TOL or TDS gives negative values. Therefore based on the correlation with yield under IR and RF, selection for lower negative TDS values needs to be done. Another index DTE had negative correlation with YIR (-0.46) but showed positive non-significant correlation with YRF (0.06). Therefore, selecting genotypes having higher mean values for MP, YI, GMP and HM can give high yielding drought tolerant lines. In similar way several studies indicate that the GMP, HM, STI, YI and MP indices are preferred in late drought condition for selecting the most favourable genotypes (Sio-Se Mardeh *et al.,* 2006; Talebi *et al.,* 2011, Pouresmaeil *et al.,* 2012 and Sabaghnia and Janmohammadi, 2014). Selection for lower values of DSI and TDS leads to selection of genotypes with low yield potential under non-stress conditions and high yield under stress conditions (Fernandez, 1992). Selection of genotypes based on single index leads to bias in selection of drought tolerant genotypes hence selection should be made by combination of 2 or 3 indices. Mean productivity is resulted in significantly positive association with all the drought tolerance indices except TDS and DTE. So selection for higher MP along with lower values of TDS and higher values of DTE as it is positively correlated with YRF is going to yield best drought tolerant genotypes. Whereas, the DPI reported by Ontagodi (2015) can alone be used for identifying most productive and drought tolerant lines in the population or germplasm evaluations.

Superior genotypes under irrigated and rainfed situation were isolated from BC_1F_3 population and their calculated drought tolerance indices is presented in Table 4. Among the selected genotypes BC_1F_3-6-3 (24.2), BC_1F_3-7-7 (22.10), BC_1F_3-8-7 (22.50), BC_1F_3-11-3(24.30) and BC_1F_3-18-8(22.30) recorded high seed yield per plant(g) under irrigated conditions compared to both parents and checks. But, under rainfed situation BC_1F_3-4-1(18.20), BC_1F_3-6-3 (21.20), BC_1F_3-8-7 and BC_1F_3-34-4 (15.50) performed better with respect to seed yield per plant(g). One genotype BC_1F_3-6-3 (24.2) performed better in both environments. Even though BC_1F_3-7-7, BC_1F_3-11-3 and BC_1F_3-18-8 gave high yields under irrigated and having higher MP values but with respects other drought tolerance indices these families showed lower values and maximum yield reduction under RF. Many reports showed reduction in yield and other related traits may be because of limited moisture available at critical stages in chickpea. So, selection of these families based on mean performance will lead to bias in selecting for drought tolerance. On the contrary, BC_1F_3-6-3 family showed maximum yield under both IR and RF along with higher values of drought tolerance indices like MP (22.70), DTE (87.60), YI (2.61), GMP (22.65) and HM (22.60) and lower values for indices like DSI (0.56), TDS (-3.0) and RR (0.12) compared to both the parents and checks. Similarly, selecting superior genotypes based on these indices have been reported by Win (2011), Ganjeali *et al.* (2011), Talebi *et al.*(2011), Ulemale *et al.*(2013) and Sabaghnia and Janmohammadi(2014) in chickpea. Another two families BC_1F_3-4-1(18.20) and BC_1F_3-34-4 (15.50) were not so high yielding under irrigated but recorded consistence performance under both environments. Therefore, these two families were superior with respect to DTE (94.30 and 90.38) and YI (2.24 and 1.91) and showed maximum lower values for DSI (0.26 and 0.44), TDS (-1.10 and -1.65) and RR (0.06 and 0.10) compared to drought tolerant parent ICC13124. Parameshwarappa *et al.,* 2012 and Shivukumar *et al.,* 2013 reported that the line ICC-13124 is having more DTE and showed low DSI, similarly in the present study ICC-13124 also recorded superiority for drought tolerance indices. Hence combination of DSI, TDS and RR can be used for selection of superior genotypes under rainfed condition

Table 3. Phenotypic correlation coefficients for yield under irrigated and rainfed and drought tolerance indices in BC_1F_3 population of a cross (ICC-13124xWR-315)xICC-13124 in chickpea during *rabi* 2012-13

Characters	YIR	DPI	DSI	TDS	MP	DTE	YI	RR	GMP	HM
YIR	1.00									
DPI	0.91***	1.00								
DSI	0.46 ***	0.13	1.00							
TDS	-0.74***	-0.44**	-0.84***	1.00						
MP	0.96***	0.98***	0.25***	-0.55***	1.00					
DTE	-0.46***	-0.13	-1.00***	0.84***	-0.25***	1.00				
YI	0.81***	0.98***	-0.06	-0.21***	0.92***	0.06	1.00			
RR	0.46***	0.13	0.99***	-0.84***	0.25***	-0.99***	-0.06	1.00		
GMP	0.94***	0.99***	0.21**	-0.49***	0.99***	-0.21**	0.95***	0.21**	1.00	
HM	0.92 ***	0.99***	0.17*	-0.44***	0.99***	-0.16 *	0.96***	0.17*	0.99***	1.00
YRF	0.81	0.98***	-0.06	-0.21	0.93	0.06	1.00	-0.06	0.95	0.96

*Significance at 5%, ** Significance at 1%, *** Significance at 0.1%

Table 4 Isolation of superior and drought tolerant BC_1F_3 families based on the yield under irrigated and rainfed situation and drought tolerance .indices

Family Name	YIR (g)	YRF (g)	DPI	DSI	TDS	MP (g)	DTE	YI	RR (g)	GMP (g)	HM (g)
BC_1F_3-2-2	17.4	13.4	13.97	1.05	-4.0	15.43	76.79	1.65	0.23	15.29	15.16
BC_1F_3-4-1	19.3	18.2	22.10	0.26	-1.1	18.75	94.3	2.24	0.06	18.74	18.73
BC_1F_3-6-3	24.2	21.2	29.05	0.56	-3.0	22.70	87.6	2.61	0.12	22.65	22.6
BC_1F_3-7-7	22.1	11.1	12.85	2.26	-11.0	16.60	50.23	1.37	0.5	15.66	14.78
BC_1F_3-8-7	22.5	14.6	18.30	1.6	-7.9	18.55	64.89	1.80	0.35	18.12	17.71
BC_1F_3-11-3	24.3	13.2	17.10	2.08	-11.1	18.75	54.32	1.62	0.46	17.91	17.11
BC_1F_3-18-8	22.3	12.4	14.90	2.02	-9.9	17.35	55.61	1.53	0.44	16.63	15.94
BC_1F_3-34-4	17.1	15.5	16.97	0.44	-1.6	16.33	90.38	1.91	0.1	16.3	16.28
BC_1F_3-37-4	16.5	14.6	15.30	0.52	-1.9	15.55	88.48	1.80	0.12	15.52	15.49
BC_1F_3-39-1	16.0	14.0	14.22	0.56	-1.9	15.02	87.78	1.73	0.12	14.99	14.96
JG-11 (LC)	15.4	13.1	12.57	0.67	-2.2	14.27	85.35	1.62	0.15	14.23	14.19
BGD 103 (LC)	14.5	11.9	10.38	0.8	-2.5	13.26	82.43	1.47	0.18	13.19	13.13
ICC13124 (P1)	15.4	14.8	15.15	0.18	-0.6	15.15	96.12	1.83	0.04	15.15	15.14
WR315 (P2)	12.7	7.5	2.82	1.85	-5.1	10.13	59.28	0.93	0.41	9.79	9.47
Mean	18.56	13.98	15.41	1.06	-4.58	16.27	76.68	1.72	0.23	16.01	15.76
S.Em.	1.03	0.85	1.57	0.20	1.01	0.79	4.35	0.10	0.04	0.79	0.79

rather than the irrigated, similar results were reported by Rehman (2009) and Win (2011) in Chickpea. Whereas the families like BC_1F_3-6-3, BC_1F_3-4-1 and BC_1F_3-8-7 were found superior for DPI and most productive under both environments. Even though families BC_1F_3-11-3 and BC_1F_3-18-8 showed higher DSI, TDS and RR but superior with respect to DPI, hence these families can also be selected as most productive and drought tolerant ones. Families BC_1F_3-4-1 and BC_1F_3-11-3 showed similar MP (18.75) but superiority of these families can be differentiated based on DPI values. BC_1F_3-4-1 was found superior for DPI(22.10) compared to BC_1F_3-11-3(17.10).

Screening of large number of genotypes for root related traits to identify drought tolerant lines will be very difficult and cumbersome. Hence, to get idea about the performance of line under irrigated and rainfed and its drought tolerance ability, drought tolerance indices are computed based on yield under irrigated and rainfed. Strong correlation between YIR and YRF and with drought indices indicates that indirect selection could be effective for drought tolerance. There is a positive and strong correlations exist between DPI, MP, GMP, HM and YI with YIR and YRF. Mere selection based on the mean performance of genotype may not give clear idea about the genotype under drought. Therefore, the parameters like DPI, MP, DTE, GMP, HM and YI can be suggested to select high yielding drought tolerant genotypes along with lower values of DSI and RR. Based on the drought tolerances indices 10 superior families were identified in BC_1F_3 population. Among the selected entries BC_1F_3-6-3 was found very superior transgressive segregant followed by BC_1F_3-4-1 and BC_1F_3-8-7 with respect all the drought tolerance indices as well as DPI. Hence, these genotypes can be used in the future breeding programmes as tolerant sources. Continuous selfing of these families gives stable genotypes and may be released as drought tolerant varieties.

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