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Differential Response of Elite Chickpea Genotypes under Moisture Stress Conditions

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Abstract | Drought is a severe constraint for chickpea productivity across the globe. In Pakistan, it is primarily cultivated in drought-prone regions and marginal lands where moisture stress is a major limiting factor for chickpea production. In order to identify drought resilient chickpea genotypes, a field experiment consisting of 16 elite genotypes was carried out in two environments i.e. under moisture stress and non-stress environment following randomized complete block design at Gram Breeding Research Station, Kallurkot, Punjab, Pakistan during rabi season of 2018-19. Under moisture stress conditions, highly significant positive correlation was exhibited by drought tolerance efficiency (DTE) with final grain yield followed by seed weight (SW) and pods plant^{-1}(NPP), while significant negative correlation was expressed by drought susceptibility index (DSI) to grain yield. Study of drought indices revealed that the highest DTE was presented by Punjab-2008 (84.13) followed by CH12/12, D-16004, CH-09/12, TG-1218 and TG-1221 (83.84, 80.10, 72.27, 69.93 and 69.31 % respectively) coupled with least DSI (0.39, 0.40, 0.49, 0.69, 0.75 and 0.76 respectively). Results indicated that the genotypes Punjab-2008, CH12/12, D-16004, CH-09/12, TG-1218 and TG-1221 possess high drought tolerance and higher yield potential under moisture stress environment. Therefore, these genotypes may be included in chickpea breeding program for development of stress tolerant varieties for drought prone areas of the country.

Introduction

Chickpea is one of the leading pulse legume crop providing nutritious food to ever expanding global population. It is extensively grown as major winter crop in arid and semi-arid tropical countries around the world (Varshney et al., 2019). In Pakistan, it is leading pulse legume crop with an average production of 444 kg ha^{-1} which is far below than the average world production of 969 kg ha^{-1}

(Nadeem et al., 2019). This gap in production per unit area is attributed to various biotic and abiotic stresses. Among abiotic stresses, moisture stress is the primary limiting factor for chickpea production in Pakistan because of its cultivation on marginal land and sand dunes of Thal where it faces terminal drought (Mahmood et al., 2018). In Pakistan, Thal shares more than 80 percent area under chickpea crop where the crop is exposed to arid to hyper-arid climatic conditions. Geographically, Thal lies between

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30°59´-32°6´ N and 71°14´-72°16´ E (Figure 1). comprising Bhakkar, Khushab, Layyah, Muzafargarh and Mianwali districts of Punjab, Pakistan (Shaheen and Baig, 2011).

Figure 1: *Location map of Chickpea Moisture Stress Tract, Thal, Punjab, Pakistan.*

Drought is generally unpredictable in its severity, occurrence and duration depending upon the inadequate and uneven rainfalls during the crop period. It is considered as the most adverse environment, limiting the chickpea production and demands immediate attention of the researchers to explore the drought tolerant germplasm (Merga and Haji, 2019; Nadeem et al., 2019; Varshney et al., 2019). Chickpea productivity is severely affected by moisture stress and such yield losses range from 15-60% (Pandey et al., 2017).

Various species of crop plants usually adapt to moisture stress conditions through tolerance mechanisms (Yadev et al., 2005). Chickpea productivity in drought prone regions is greatly dependent on efficient employment of available soil moisture. Therefore, systematic breeding efforts are required to evolve a large number of drought tolerant chickpea varieties (Devasirvatham et al., 2018).

Exploration of drought indices and the association analysis of various morpho-agronomic traits have been extensively utilized by several researchers to sort out the drought resilient chickpea genotypes. For this purpose, field screening has been found a powerful tool to screen out the drought tolerant germplasm (Hussain et al., 2015; Ghasemi and Farshadfar, 2015). The present study was planned to identify the efficient and superior drought tolerant

genotypes of chickpea adaptable to drought prone regions of the country.

Material and Methods

The present investigation was carried out at Gram Breeding Research Station, Kallurkot (71.153^{o}E and 32.923^{o}N), Punjab, Pakistan during rabi 2018-19 in two different environments i.e. moisture stress (I_0) and non-stress conditions. The experimental material consisting of 14 elite chickpea genotypes (CH09/12, CH12/12, CH40/12, CH44/12, D-16003, D-16004, D-16007, D-16017, D-16032, D-16011, TG1415, TG1218, TG1221 TGX228) along with two commercial varieties (Bittle-16 and Punjab-2008) developed by different breeding centers (Table 1) was laid down in split plot under randomized complete block design (RCBD) with three replications. Sowing was done by dibbler by maintaining 10 cm plant-plant and 30 cm row-row distance during last week of October, 2018. Only one irrigation was applied to I_0 set to create necessary moisture for germination and no supplementary irrigation was done. Whereas, two supplementary irrigations were applied to I_1 set. Around 78 mm rainfall was recorded during the crop period. All the recommended agronomic practices were performed throughout the cropping season.
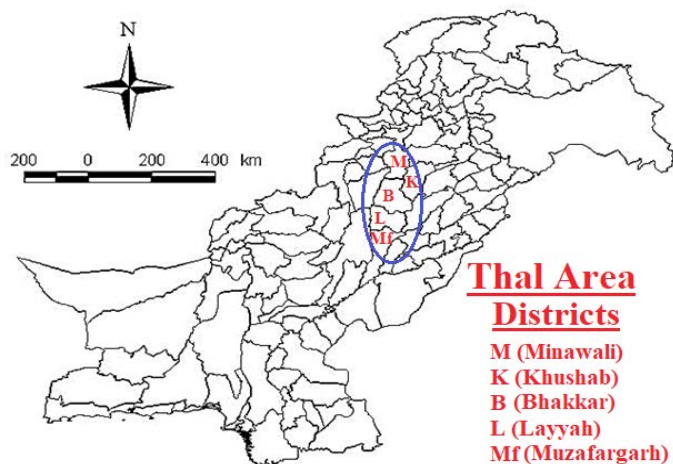
Table 1: *List of breeding centers of chickpea genotypes.*

Genotypes	Status	Breeding Center
CH09/12	Elite advance line	NIAB, Faisalabad, Pakistan
CH12/12	Elite advance line	NIAB, Faisalabad, Pakistan
CH40/12	Elite advance line	NIAB, Faisalabad, Pakistan
CH44/12	Elite advance line	NIAB, Faisalabad, Pakistan
D-16003	Elite advance line	PRI, AARI, Faisalabad, Pakistan
D-16004	Elite advance line	PRI, AARI, Faisalabad, Pakistan
D-16007	Elite advance line	PRI, AARI, Faisalabad, Pakistan
D-16017	Elite advance line	PRI, AARI, Faisalabad, Pakistan
D-16032	Elite advance line	PRI, AARI, Faisalabad, Pakistan
D-16011	Elite advance line	PRI, AARI, Faisalabad, Pakistan
TG1415	Elite advance line	AZRI, Bhakkar, Pakistan
TG1218	Elite advance line	AZRI, Bhakkar, Pakistan
TG1221	Elite advance line	AZRI, Bhakkar, Pakistan
TGX228	Elite advance line	AZRI, Bhakkar, Pakistan
Punjab-08	Drought tolerant variety	PRI, AARI, Faisalabad, Pakistan
Bittle-2016	Drought tolerant variety	PRI, AARI, Faisalabad, Pakistan

Data were recorded for days to flowering (DF), primary branches (PB), secondary branches (SB), pods plant^{-1}

(NPP), days taken to maturity (DM), plant height (PH), 100 seed weight (SW) and yield (YLD kg hectare^{-1}) under moisture stress and non-stress conditions.

Statistical analysis

Data was subjected to analysis of variances following Steel et al., 1997. While correlation coefficient analysis was performed following Singh and Chaudhry (1979).

Drought indices

Yield reduction percentage and drought susceptibility index were calculated by the formula suggested by Fischer and Maurer (1978) and used by Sabaghpour et al., 2006, Hussain et al., 2015.

$$(i). \text{Reduction Percentage} = \frac{\text{Yield in non stress (Yp)} - \text{Yield in stress (Yd)}}{\text{Yield in non stress(Yp)}} \times 100$$

$$(ii). \text{DSI} = (1 - Yd/Yp)/D$$

$$\text{Drought index(D)} = \frac{\text{Mean Yield of all genotypes in moisture stress}}{\text{Mean Yield of all genotypes in non stress}}$$

$$\text{Mean Productivity (MP)} = \frac{(Yd + Yp)}{2}$$

Yd= Yield in stress condition, Yp= Yield in non-stress condition and D= Drought index.

While, Drought tolerance efficiency (DTE) was calculated following the formula suggested by Fischer and Wood (1981).

$$\text{DTE (in percentage)} = \frac{\text{Yield in stress}}{\text{Yield in non stress}} \times 100$$

Results and Discussion

Days to flowering (DF) ranged from 83-102 days under water stress conditions (I_0) and 90-105 days under irrigated conditions (I_1). Primary branches (PB) were counted between 2-6 under stress and 3-7 in non stress conditions. Secondary branches (SB) 4-10 were recorded under stress while 6-12 under non stress conditions. Similarly, under stress environment 37-58 number of pods plant^{-1}(NPP) were found while 51-72 were recorded in irrigated conditions. Days to maturity ranged between 156-176 under stress and 160-178 under irrigated conditions. Plant height under stress conditions was recorded between 39-59 cm and 50-79 cm in non stress. Under stress environment 100 seed weight (SW) was recorded between 24-31 gram and 25-31 grams under non stress conditions. Under stress environment maximum grain yield (Yld) 774 kg ha^{-1} was recorded in Punjab-2008 followed by CH12/12 (773), D-16004 (753), TG 1218 (649),

D-16017 (604) and TG1221(603) while minimum 378 kg ha^{-1} was found in D-16032 (Table 4). In non stress conditions D-16004 showed maximum grain yield 940 kg ha^{-1}followed by D-16007 (938), TG1415 (930), TG1218 (928), Punjab-2008 (920) and D-16017 (880) while minimum 646 kg ha^{-1} was recorded in TGX228 (Table 2). In agreement to this study Deshmukh et al., 2004; Ghasemi and Farshadfar (2015) also reported delayed flowering, more branches, maximum number of pods, more seed weight and higher grain yield under non stress environments.

Data revealed that number of days to flowering have significant and positive association (0.536) with DM and non significant with all other morpho-yield traits and drought indices (Table 3). Yadev et al., 2005 and Hussain et al., 2015 narrated similar findings that the genotypes taking more numbers of days to 50% flowering are late maturing. Primary branches significantly correlated with SB (0.604) followed by DM (0.574) while all other studied traits were non significantly correlated. These results agree with the findings of Hussain et al., 2015. Secondary branches exhibited significant association with DTE (0.514) followed by PH (0.422) and NPP (0.401) while negatively correlated with yield reduction% (-0.514) and DSI (-0.511). Islam et al., 2008 also reported that SB have positive and significant correlation with PH and NPP. Number of pods plant^{-1}were positively associated with SW (0.778) and DTE (0.770) while showed negative correlation with yield reduction percentage. Days to maturity showed non-significant correlation with most of the studied traits. Seed weight exhibited significant positive correlation with DTE (0.774) but negative correlation was noted in DSI (-0.777) and yield reduction percentage (-0.775). Similar results were reported by Sabaghpour et al., 2006. Correlation studies also revealed that grain yield showed significant and positive association with 100 SW (87%) and NPP (79%). Similarly, drought indices; DTE exhibited highly significant positive correlation (0.948) in determination of grain yield while significantly negative correlation was exhibited by DSI (-0.949) and yield reduction percentage (-0.948). Findings of this study agree with the studies of Parameshwarappa et al., 2012 and Ghasemi and Farshadfar (2015) who reported that yield is positively associated with number of pods, drought tolerance and drought susceptibility index.

Table 2: *Mean performance of chickpea genotypes under stress and non-stress conditions.*

Genotypes	DF		PB		SB		NPP		DM		PH		SW	
	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1
Bittle-16	86	95	2	3	6	8	39	55	156	160	47	58	25	27
CH09/12	99	103	4	6	11	12	50	68	167	178	53	62	30	31
CH12/12	96	100	3	4	8	10	56	72	161	166	56	68	30	30
CH40/12	98	102	4	4	4	7	46	61	162	169	39	50	26	28
CH44/12	101	106	3	3	4	6	44	58	164	172	45	54	26	26
D-16003	94	99	3	4	7	8	47	60	165	168	42	49	29	30
D-16004	102	103	4	4	7	7	57	71	173	175	46	59	30	30
D-16007	97	99	3	5	6	8	50	64	163	171	51	68	29	29
D-16017	84	94	3	7	7	9	43	62	160	168	56	75	28	30
D-16032	96	100	3	4	5	6	33	49	167	169	52	64	26	27
D-16011	93	99	6	7	10	10	41	59	168	172	57	75	25	27
Punjab-08	90	98	4	5	10	10	58	66	166	169	52	57	30	30
TG1415	92	99	3	4	4	6	27	46	168	143	49	60	27	28
TG1218	102	105	4	4	8	10	58	72	158	166	56	70	31	31
TG1221	83	90	3	5	7	9	47	63	157	160	59	79	29	30
TGX228	102	105	5	6	10	14	37	51	175	166	45	77	24	25
CV	2.27	5.02	8.17	8.44	10.09	5.82	5.16	7.25	6.50	8.70	7.20	7.35	1.17	2.81

I_0: Stress conditions; I_1: Non-stress conditions; DF: Days to flowering; PB: number of primary branches; SB: number of Secondary branches; NPP: Number of pods; DM: Maturity days; PH: Plant height; SW: 100 Seeds weight.

Table 3: *Correlation coefficients of various traits under moisture stress conditions.*

	DF	PB	SB	NPP	DM	PH	SW	DTE	DSI	Red%	Yld
DF	1.000	0.393	0.054	0.228	0.536*	-0.397	0.053	-0.025	0.021	0.025	-0.071
PB		1.000	0.604*	0.112	0.574*	0.085	-0.165	0.013	-0.011	-0.014	-0.381*
SB			1.000	0.401*	0.274	0.422*	0.255	0.514*	-0.511*	-0.514*	0.375
NPP				1.000	-0.193	0.183	0.778**	0.770**	-0.755**	-0.750**	0.796**
DM					1.000	-0.325	-0.222	0.001	-0.001	-0.001	-0.107
PH						1.000	0.367	0.291	-0.288	-0.291	0.309
SW							1.000	0.774**	-0.777**	-0.775**	0.877**
DTE								1.000	-1.000	-1.000	0.948**
DSI									1.000	1.000	-0.949**
Red%										1.000	-0.948**
Yld											1.000

Correlation coefficient analysis is revealed that the genotypes possessing elevated 100 seed weight, maximum pods and secondary branches exhibited higher grain yield, more DTE percentage and less DSI.

Therefore, the genotypes Punjab-2008, CH12/12, D-16004, CH-09/12, TG-1218 and TG-1221 possessing relatively higher seed weight, maximum number of pods and secondary branches proved more stress tolerant and less susceptible to drought coupled with high yield potential under moisture stress environment.

Drought indices of all included genotypes were calculated from grain yield data under stress and non stress conditions as shown in Table 4. Maximum DTE percentage was exhibited by Punjab-2008 (84.13%) followed by CH12/12 (83.84%), D-16004 (80.1%), CH09/12 (72.27%), TG1218 (69.93%) and TG1221 (69.21%). Similarly, least drought susceptibility values were also shown by Punjab-2008, CH12/12, D-16004, CH-09/12, TG-1218 andTG-1221 (0.39,

0.40, 0.49, 0.69, 0.75 and 0.76 respectively). Minimum yield reduction percentage was also calculated in Punjab-2008 (15.9%), CH12/12 (16.2%), D-16004 (19.9%), CH-09/12 (27.7%), TG-1218 (30%) and TG-1221 (30.7%). Fischer and Maurer (1978) suggested that the genotypes with <1 drought index (DSI) values with higher DTE% are more efficient and tolerant to moisture stress environments. Hussain et al., 2015 narrated that the genotypes with higher DTE%, less DSI and yield reduction percentage are more tolerant to stress environments. Genotypes with higher DTE percentage coupled with least DSI and lower yield reduction percentage are more superior and ideal for drought tolerance. Therefore, the genotypes Punjab-2008, CH12/12, D-16004, CH-09/12, TG-1218 and TG-1221 can be rated as drought tolerant.

Table 4: *Drought indices of chickpea genotypes.*

Genotypes	Yield (kg/ha)		MP	DTE %	DSI	Yield Red. %
	I_0	I_1				
Bittle-16	426	857	642	49.7	1.26	50.3
CH09/12	623	862	743	72.27	0.69	27.7
CH12/12	763	910	836	83.84	0.40	16.2
CH40/12	453	916	685	49.45	1.26	50.5
CH44/12	457	825	641	55.45	1.11	44.6
D-16003	634	917	776	69.13	0.77	30.9
D-16004	753	940	846	80.1	0.49	19.9
D-16007	507	938	723	54.05	1.14	46
D-16017	604	880	742	68.6	0.78	31.4
D-16032	378	851	615	44.41	1.39	55.6
D-16011	444	906	675	49	1.28	51
Punjab-08	774	920	847	84.13	0.39	15.9
TG1415	488	930	709	52.47	1.19	47.5
TG1218	649	928	789	69.93	0.75	30
TG1221	603	870	737	69.31	0.76	30.7
TGX228	393	646	520	60.83	0.98	39.2

I_0: Stress conditions; I_1: Non-stress conditions; DTE %: Drought tolerance efficiency; DSI: Drought susceptibility index.

Conclusions and Recommendations

From the study it was concluded that six genotypes Punjab-2008, CH12/12, D-16004, CH-09/12, TG-1218 and TG-1221 exhibited higher grain yield, more drought tolerance coupled with less drought susceptibility and minimum yield reduction percentage. Therefore, these genotypes are best drought tolerant and may be incorporated in chickpea breeding program for development of drought tolerant varieties.

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