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Yield performance and responses studies of chickpea (*Cicer arietinum* L.) genotypes under drought stress

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Abstract

Drought is a major abiotic constraint limiting the chickpea yield up to a greater level in Pakistan. The yield level remain very low under prolong moisture deficit conditions. A set of 40 chickpea lines including some approved varieties were assessed for drought tolerance under glasshouse conditions. The crop was given an artificial drought stress at pre-flowering stage for a period of 30 days and then re-irrigated regularly till harvesting. The observations were recorded on plant wilting-I, plant wilting-II, crop recovery percentage and grain yield. The results revealed a relatively divergent response of various chickpea lines/varieties for all the studied parameters. Genotypes SL-05-30 NCS950219 and F-97-112 C remained superior while observing plant wilting-I by scoring 1, 1.67 and 2.00 at 1-9 rating scale and produced higher yield of 18.43, 18.33 and 18.23 grams per plant respectively. The plant recovery response revealed that more than 50% of studied lines could not properly recover after termination of moisture stress suggesting that moisture stress at pre-flowering has usually lethal effect on chickpea plants. Kabuli type chickpea lines were more sensitive to moisture stress and high temperature and produced lower yields as compared to desi type chickpea.

Key words: Chickpea germ plasm screening, Drought stress, Plant wilting, Plant recovery and grain yield

Introduction

Chickpea is the major pulse crop of Pakistan, which is grown on about one million hectare in the country each year (MINFAL, 2009). More than 95% production of chickpea comes from rainfed areas where the crop is sown on residual moisture after monsoon. Among various factors minimizing the crop yield, the terminal drought stress is most often, which reduces the crop yield up to greater extent. Field screening of chickpea germplasm against drought stress is usually not reliable because of uncertain rainfall at critical stage of artificial moisture stress imposed to the crop.

Chickpea with indeterminate habit grows well under favourable conditions. The crop needs variable temperature during its various growth phases. If grown under favourable moisture, it produces higher pods and grain yield under heat and drought in the later part of it reproductive stage. A significant pod abortion has been observed under sever moisture stress especially during commencement of pod set (Leport et al., 1999). The drought tolerance in their case was found to be directly proportional to deep root system and high leaf water potential (LWP). High temperature stress also causes yield losses because of damage to reproductive organs (Anyia and Herzy, 2000) and had reduced total dry matter and grain yield during drought (Leport et al., 2006). Singh et al. (1997), Kashiwagi et al. (2005) and Lopez et al. (2006) have screened out some pulses germ plasm accessions with greater genetic variability in various traits. They also identified some drought tolerant related characteristics in the chickpea plant. A multipinnate chickpea lines reduce amount of energy stored in leaf due to high level of reflection Moisture stress to chickpea is more important at pre-flowering stag, because it is the most damaging stage to yield and yield parameters and plant needs abundant availability of moisture in the root zone. Therefore, artificial stress at this stage will lead to screening of drought resistant genotypes in chickpea (Leport, 2006). Aslam et al. (2008) evaluated the performance of 23 chickpea

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genotypes and reported significant variation in morphological, physiological, phonological characters and yield and yield components. In case of breeding drought and heat-resistant chickpea days to the first flowering and maturity should be evaluated ahead of many other phenological traits, harvest index, biological yield and pods per plant to escape terminal drought and heat stresses for increased yield (Canci and Tokar, 2009) Karadavut et al. (2010) studied the some fababean genotypes across the environments and reported significant variation in yield among genotypes and also over environments. Khan et al. (2010) studies genetic variability and correlation in wheat under water stress conditions. They reported significant genetic variability in various morphological and physiological traits. Shamsi et al. (2010) observed significant difference in most of the yield components when irrigated at flowering and pod filling stage in chickpea. They also suggested that pod-filling is the most sensitive stage to drought stress, and under water limitation conditions, that can considerably increase grain yield at this stage by one time irrigation

The present studies are actual screening of chickpea germ plasm based on tangible selection criterion being output of two different experiments under drought stress environment. The initial studies on development of field screening technique was carried out by Yaqoob et al. (2011) suggesting that moisture stress at pre-flowering stage being harmful and detrimental is the, most critical for screening chickpea germ plasm under drought prone conditions. These studies were further endorsed by Yaqoob et al. (2012) through their studies on root and shoot behaviors of chickpea genotypes under different moisture The hypothesis under consideration were: 1. Chickpea plant can survive well under one month moisture stress as it stores enough water in its tissues. 2. There is considerable drought recovery in chickpea due to indeterminate plant growth habits. 3. Drought stress at pre-flowering stage is more detrimental to chickpea plant. The drought screening nursery must experience severe drought during the critical stages of plant growth. Therefore, such experiments regarding screening of germ plasm are needed to conduct under the control environment to avoid the risk of rainfall interruption during the imposition of moisture stress at the specific plant growth stages.

Materials and Methods

The experiment was conducted in Glasshouse at research site of Centre of Arid Zone Studies (CAZS), Natural Resources, University of Wales, Bangor, United Kingdom during 2007. Forty chickpea breeding lines (24 desi and 12 kabuli type) including four approved varieties viz. Paidar-91, Karak-1, Sheenghar-2000, and C-44 were included in this screening. All the germ plasm accessions were procured from various pulses research institutions of Pakistan. The experiment was laid out in Randomized Complete Block Design with three replications. The seeds of each line were first germinated in P12 plug Tray. Seven day-old seedlings were then transferred to Bench Top Raised Bed (BTRB) measuring 50 × 50 × 30 cm. Each BTRB comprised of four plants of different lines. The data were recorded from four plants in in each replication for each treatment. The glasshouse temperature was maintained at 18°C (8 h) and 15°C (16 h) during day and night respectively. The crop was maintained well and regularly irrigated up to pre-stress period. The moisture stress was imposed to the crop at pre-flowering stage for a period of 30 days (Yaqoob et al., 2011). After the stress was terminated, the crop had been regularly irrigated till harvesting. The crop observations were recorded on following parameters. Plant Wilting, Plant Wilting-II, Plant Recovery Response, and Grain Yield per plant (g).

The observation regarding first and second wilting were respectively recorded 20 and 30 days after commencing of moisture stress on 1-9 rating scale whereas plant recovery response was noted 10 days after re-watering to the crop. The grain yield was recorded in grams on per plant basis. Plant wilting and plant recovery were recorded as shown in Table 1.

Table 1. Plant wilting and plant recovery.

Plant Wilting rating		Plant Recovery Rating	
Score	Symptom of pant wilting	Score	Symptom of pant Recovery
1	Healthy plants	1	100% plant recovered
3	Slight foliar damage(11-20% on leave)	3	61-80% plant recovered
5	41-60% withering/drying in plant	5	41-60% plant recovered
7	61-80% withering/drying in plant	7	21-40% plant recovered
9	100% plant killing	9	No plant recovery

Statistical Analysis

The data acquired were subjected to analysis of variance based on RCBD using SPSS software version 12.0.

Results and Discussion

The results of analysis of variance regarding Wilting-I and Wilting-II, Plant Recovery and grain yield are given in Table 2 while means for these traits are given in Table 3. A study of Table 2 revealed highly significant variation for all the traits due to various chickpea lines/varieties.

Plant wilting-I

The analysis of variance regarding plant wilting-I showed highly significantly different among various chickpea lines/varieties (Table 2). The plant Wilting-I data recorded 20 days after imposing moisture stress ranged from 1 to 5 at 1-9 rating scale. There found variable trend of chickpea genotypes against moisture stress. The lines including SL-05-30 and SL-05-68 were found the best among all the genotypes and remained unaffected due to moisture stress by scoring 1. These lines were very closely followed by NCS950219, NCS05017, SL-03-11, SL-03-25, and C44 each having score of 1.67 (Table 3). The genotypes NCS9906, NCS05012, NCS05016, Karak-1, SL-03-14, SL-03-15, F-98-96C, F-97-112C, Sheenghar-2000 and F-97-168-C were also slightly affected at initial stage and their wilting score hardly reached to 2.00. There also found some lines which scored 3.00 or even low, these were NCS0501, SL-03-16, SL-03-7, SL-03-8, SL-03-16, SL-03-21, F-97-171C, Paaidar-91 and NCS05018. Out of forty, three genotypes namely, NCS9917, 90261, and NCS05010 were found to be more sensitive to moisture stress and showed more than 50% plant wilting recorded 20 days after moisture stress. The response of most of the lines indicated that chickpea crop easily escaped through moisture stress conditions up to 20 days. Among the lines, Kabuli types were found more sensitive to moisture stress as compared the desi type. The plant wilting in both the types could not exceed score 5. The highest wilting score (5) was found in kabuli type. Results revealed that chickpea genotypes were found sensitive to temperature and also remained type specific. The studies further showed that desi and kabuli types had variable response to abiotic stresses. The kabuli type chickpea were found more sensitive to high temperature and moisture stress than desi chickpea. Wang et al. (2006) had also found significant variation in desi and kabuli type chickpea in response to moisture and high temperature stress. This was due to the reason that kabuli types are adapted to Mediterranean region and therefore is more sensitive to high temperature and drought as compared to desi type (Leport et al., 2006). Matsui and Singh (2003) and Anbessa and Bejiga (2002) have also selected drought tolerance genotypes among chickpea accessions and reported reduced water loss from plant and extensive extraction of soil moisture as the factor of adaptation in drought tolerant genotypes.

Plant wilting-II

The data provided in Table 3 revealed that plant wilting-II had linearly increased in chickpea with increasing days to moisture stress. The genotypic trend of wilting-II has been directly proportional to the Wilting-I as well as to moisture stress period. Although, plant-wilting rate was quite divergent in different genotypes but their drought tolerance trend remained consistent in Wilting-I and Wilting-II. The wilting-II ranged from 2 to 7 (at 1-9 rating scale). The line SL-05-30 has again showed resistance to drought as it was slightly affected by drought after 30 days scoring 1.67. Some other desirable lines followed it were, NCS05019, NCS05017, SL-05-68 and C-44 each scored 2. These lines had also shown resistance to drought at Wilting-I. The lines Bittle-98, CMC211S, NCS9914, NCS9917, 90261, NCS05010, and NCS05014 were badly stroked by drought stress after 30 days with maximum wilting score of 7 by Bittle-98 (7.00). The performance of these lines was also not encouraging in Wilting-I.

Table 2. Mean squares of chickpea genotypes as affected by moisture stress.

Source of Variation	D.F	Plant Wilting-I 1-9 Scale	Plant Wilting-II 1-9 Scale	Plant Recovery 1-9 Scale	Grain yield Per plant (g)
Variation	39	4.289	10.045	14.757	75.823
Replications	2	0.896**	0.362**	9.923**	8.842**
Error	78	0.550	1.375	4.421	6.712
Total	120	-	-	-	-

Table 3. Plant wilting-I, Plant wilting-II, plant recovery and grain yield of various chickpea genotypes as under moisture stress.

Genotypes	Wilting-I	Witling-II	Grain yield plan^{-1}	Plant Recovery	Genotypes	Wilting-I	Witling-II	Grain yield plan^{-1}	Plant Recovery
SL-05-30	1 H	1.67 N	18.43A	3 F	NCS05019	2.67CD	4.67FG	4.93 STU	7.33 CD
C-44	1.67G	2 LM	12.47K	4.67EF	SL-03-16	2.67CD	4.67FG	6.23 PQRST	8.67 AB
NCS05017	1.67G	2 LM	17.79ABCDE	3 F	Paidar-91	3 CD	4.67FG	7.19 NOPQ	4.33 F
SL-05-68	1 H	2 LM	17.82 ABCD	5.33EF	NCS05013	3.33CD	4.67FG	9.88 M	9 A
NCS950219	1.67G	2 LM	18.33 AB	5.67EF	SL-03-01	2.67CD	4.67FG	12.22KL	4.33 FG
SL-03-11	1.67G	2.67 JKL	5 STU	7.33CD	F-98-96C	2 FG	4.67FG	14.41FGHJ	4.67 EF
NCS05018	2.33 EF	2.67 JKL	5.76 QRST	4 F	SL-03-15	2 FG	4.67FG	15.01FGHI	6 DE
F-97-168-C	2 FG	3 JK	6.22 PQRST	3 F	SL-03-7	2.67CD	5 EF	4.03 UV	8 AC
SL-03-25	1.67G	3.33 IJ	6.33 PQRST	4 F	NCS50204	4 B	5 EF	6.52 PQRS	8 AC
NCS05016	2 FG	3.33 IJ	6.58 PQRS	4.33F	NCS0502	4.67A	5 EF	6.56 PQRS	7.67 AC
Sheenghar-2000	2 FG	3.33 IJ	7.06 OPQ	4.67EF	SL-03-13	4 B	5.33DEF	6.87 PQR	9 A
SL-03-14	2 FG	3.33 IJ	15.19FGH	7.67AC	NCS05015	4.67A	5.67CDE	4.74 TUV	8.67 AB
Karak-1	2 FG	3.33 IJ	15.3 FG	4.33F	NCS0501	4 B	5.67CDE	8.85 MNO	9 A
NCS05012	2 FG	3.33 IJ	15.71 F	7.33CD	CMC211S	4 B	6 CDE	3.2 V	9 A
F-97-112C	2 FG	3.33 IJ	18.23ABC	3 F	90261	5 A	6 BCD	6.53 PQRS	9 A
SL-03-8	2.33EF	3.67 I	4.91 STU	4.67EF	NCS9917	5 A	6.33BC	4.01 UV	8.67 AB
F-97-171C	3 CD	4G HI	7.03PQR	9 A	NCS05010	5 A	6.33AB	6.00 PQRST	9 A
NCS05011	3.67BC	4.33 GH	4.03 UV	7.33CD	NCS05014	3 CD	6.67AB	5.04 STU	9 A
NCS9906	2F G	4.33 GH	7.58 P	6.33D	NCS9914	4.67A	6.67AB	7.59 NO	9 A
SL-03-21	2.33EF	4.33 GH	8.98MN	5 EF	Bittle-98	4.67A	7:00 AM	5.39 RSTU	8 AC
Mean	2.84	4.28	6.50	9.10	-	-	-	-	-
Range	1-5	1.67-7	3-9	3.2-18.43	-	-	-	-	-
S.E.	0.354	0.553	0.991	1.22	-	-	-	-	

The genotypic means have been arranged in their merit of ascending order in plant wilting-II.

The moisture stress had significant effect on number of flowers, fruiting nodes, pods, seeds and harvest index (Anyia et al., 2004). Kabuli types chickpea were found more sensitive to moisture stress than desi type in wilting-I and Wilting-II. The Desi type had higher yield than kabuli type chickpea (Leport et al., 2006). Leaf moisture retention index (LMRI) is an easily measurable physiological trait reflecting leaf turger maintenance under moisture stress and may be related to drought tolerance (Gupta and Sharma, 2006). Kabuli types have greater pod abortion than desi type (Leport et al., 2005). Wang et al. (2006) also reported that moisture stress was more damaging to kabuli type as compared to desi chickpea.

Plant Recovery Response

Re-sprouting and recovery of crop plant after termination of drought or any other biotic or abiotic stress depends upon the capability of genotype. The efficient genotypes usually have enough Leaf Water Potential (LWP) and also retain water in shoot tissues. The plant, ultimately utilizes the stored water, when it experienced moisture stress. The extent of plants survival under stress conditions and magnitude of their recovery after termination of stress depend upon their genetic potential. The plant recovery response in present investigations revealed that more than 50% lines could not properly recover and scored 7. While other lines though showed some recovery but could neither re-produce properly nor did they develop flowers and/or pod after revitalization. The lines NCS05017, SL-05-30 and F-97-112C and F-97-16C showed great recovery and scored 3 while most of the lines could not properly heal or recover slightly. Leport et al. (1999) reported that declining in photosynthesis in chickpea due to drought stress follows linear trend. Decreases in photosynthesis in cowpea under drought are largely attributed to effect of senescence with the increase of water (Quarrie and Jones, 1979). The net photosynthetic assimilation rate after drought termination is generally higher and it increases the dry matter accumulations in some cowpea genotypes (Anyia and Herzy, 2000). Berger et al. (1989) reported higher degree of biomass reduction in leaves and stem under rainfed conditions. They further suggested that physiological mechanism in addition to rapid phenology development had major role in chickpea adaptation to drought conditions. Yadav et al. (2005) have identified ICC4958 and FLIP87-59C as drought tolerant chickpea lines. The plant recovered greatly, at early pre-flowering stress as compared to pod formation stage. They also observed the higher yield of kabuli chickpea as compared to desi variety. The decrease in Leaf Water Potential (LWP) was faster in kabuki type chickpea as compared to desi type (Nayyar et al. 2006). Aslam et al. (2008) have also reported significant variation in morphological, physiological, phonological characters and yield and yield components in chickpea. The studies of Karadavut et al. (2010) also revealed significant character variability in fababean genotypes under different environments.

Grain yield

There exists highly significant variation in grain yield of various chickpea lines (Table 2). The grain yield ranged from 3.20 to 18.43 grams per plant. It was observed that the lines that were least affected by drought had produced higher yield, but this rule was not common in all the genotypes because, some of the lines having low first wilting score showed poor yield and conversely, there identified some other lines showing high wilting score and low yield. Lines SL-05-30, NCS950219 and F-97-112C with 18.43, 18.33 and 18.23 grams per plant produced the highest yield respectively. Another high yielding group including SL-05-68, NCS05017, NCS05012 and Karak-1 with grain yield of 17.82, 17.79, 15.71 and 15.30 grams per plant respectively followed the above lines. The lines SL-03-14, SL-03-15 and F-98-96C had also produced reasonable yield with 15.19 and 15.01 and 14.41 gram per plant respectively. The lines CMC 211S, SL-03-07 and NCS05015 with highest wilting and poor recovery score remained at the bottom and produced very low yield of only 3.24 and 4.74 gram pr plant respectively. It was also noted that the higher yields were mostly produced by the lines belong to desi type while the kabuli type produced lower yield under moisture stress conditions (Table 3). Similarly, data regarding plant wilting at 1-9 rating scale recorded at two stages during moisture stress had also showed that desi type chickpea possess more resistance to drought than kabuli type. It was interestingly noted that a few lines namely, NCS05016, SL-03-11, C44, NCS05018 and F-97-168C also produced poor yield despite low wilting and good plant recovery score. Mid-season drought had considerable reduction in plant activities and losses in biomass as well as in grain yield (Anyia and Herzy, 2000). Wang et al. (2006) exposed various chickpea lines at pre-flowering and pod formation stage under higher temperature and observed maximum yield damage by 59% due to higher temperature at pod formation stage as compared to 34% yield reduction at pre-flowering stage. The results of Nayyar et al. (2006) revealed that 14 days water stress, to kabuli type chickpea exhibited 80% reduction in yield as compared with 64% reduction observed in desi chickpea and also noted that decrease in water leave potential was faster in kabuli as compared to desi. Singh et al. (1997) also confirmed that desi chickpea produces higher pods and yield than kabuli type. The chickpea lines with higher plant water status and high leaf water potential (LWP) produce higher number of seed per plant, seed/pod, harvest index and grain yield (Yadav et al., 2005). High temperature stress reduces the seed yield in desi as well as kabuli chickpea. They also have significant variation in various yield traits due to water stress. The lines having resistant to drought can be utilized in breeding programme for developing drought resistant lines. Desi types were found more tolerant to moisture stress coupled with high temperature as compared to kabuli type and ultimately produced higher yield. The pods abortion percentage was more sever in kabuli type chickpea as compared to Desi type under moisture stress and high temperature (Leport et al., 2006).

In present investigations, it has been observed that various chickpea lines had a quite divergent response to drought stress conditions. Out of 40 genotypes, ten had shown tolerance against drought prone conditions. These ten lines namely, SL-05-30, NCS950219, F-97-112-C, SL-05-68, NCS05017, NCS05012, Karak-1, SL-03-14, SL-03-15 and F-98-96-C remained superior all the time and gave higher yield of 18.43, 18.33, 18.23, 17.82, 17.79, 15.71, 15.30, 15.19, 15.01 and 14.41 grams per plant respectively. Similarly, plant recovery response revealed that more than 50% lines could not properly convalesce after termination of drought stress. This showed greater variability in chickpea lines in response to drought stress. The sensitivity of remaining 30 lines also suggests that moisture stress at pre-flowering is quite dangerous to chickpea plants. Kabuli type proved to be the more sensitive to moisture stress conditions as compared to desi type chickpea. These lines may therefore, be involved in screening/breeding for drought tolerance chickpea. In our present discussion, it has been observed that chickpea screening against drought environment is only possible under control environment. Moreover, among the various drought stresses at different crop growth stages, the stress at pre-flowering stage has been established to be the more fatal (Yaqoob et al., 2011). It is also suggested that chickpea lines should be given moisture stress at pre-flowering stage while screening against drought stress conditions.

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