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Characterization of drought tolerant accessions identified from the minicore of chickpea (*Cicer arietinum* L.)

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Abstract

Terminal drought is one of the major causes of yield losses in chickpea (*Cicer arietinum* L.) and there is scope for recovery of major part of this loss through genetic improvement. The progress in breeding for drought tolerance is slow due to the quantitative and temporal variability of available moisture across years and the low genotypic variance in yield under drought. Deep and prolific root system is a high priority trait that can improve drought tolerance in chickpea. Ten accessions which were identified as drought tolerant based on drought susceptible index (DSI) and drought tolerant efficiency per cent (DTE %) were evaluated during *rabi* 2006-07 along with stanadred check Annigeri-1 and drought tolerant checks ICC 4958 and ICC 10448 under irrigated and rainfed condition for seed yield and root traits. Wide range of genetic variability, moderate to high heritability and high genetic advance for yield and its component traits was observed in drought tolerant accessions evaluated under moisture stress and irrigated situations during 2006-07. Among the drought tolerant genotypes evaluated, ICC 13124 showed maximum yield levels under irrigated (1220 kg/ha) as well as rainfed condition (990 kg/ha). The per cent reduction in yield was minimum (18.9 %) as compared to checks under moisture stress for this genotype. Observations on root length, root weight and root volume showed that ICC 13124 was equally good in respect of root traits which can be used in the breeding programme aimed at drought tolerance.

Key words: Chickpea, drought tolerance, drought susceptible index, DTE, MII

Introduction

Chickpea (*Cicer arietinum* L.) is the world's third largest legume crop with a total annual production of 8.8 million tonnes from a cultivated area of over 10 million hectare [1]. Major chickpea production worldwide is predominantly under rainfed conditions, grown on residual, progressively declining soil moisture. Terminal drought is a primary constraint to chickpea productivity. Thus, there is a need to improve tolerance to drought in chickpea. It is critical that both agronomic and genetic management strategies should focus on maximum extraction of available soil moisture and its efficient use in crop establishment, growth and seed yield. Chickpea improvement with early-maturity to escape terminal drought and heat stress can be one option [2] although drought escape carries the penalty of decreasing potential yield through inability to utilize the extended growing periods, when available. Therefore, for achieving high and stable yields under drought, it is necessary to develop drought tolerant/ avoiding varieties.

Breeding for enhanced yield stability and/or potential under drought stress has been quite successful in some crops [3]. The progress in breeding for drought tolerance is slow due to the quantitative and temporal variability of available moisture across years, the low genotypic variance in yield under these conditions and inherent methodological difficulties in evaluating component traits together with the highly complex genetic nature of this character [4].

Several physiological, morphological and phenological traits may play a significant role in crop adaptation to drought stress during soil drying [4]. Root traits play a major role in drought tolerance under terminal drought environments. In terms of root architecture, more prolific root systems extracting more of the water in upper soil layers and longer root systems extracting soil moisture from deeper soil layers are

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important for maintaining yield under terminal drought [4]. Association of deep root morphology and root thickness with increased water extraction during progressive water stress [5] and a high ratio of deep root weight to shoot weight with maintenance of good plant water potential and positive effect on yield under stress [6] has been documented in upland rice. Contribution of root traits to drought tolerance particularly in chickpea is also well established [7, 8].

Efforts made at ICRISAT and ICARDA during the past decade to identify chickpea germplasm accessions that possess large and deep root systems and to incorporate these traits into a well-adapted cultivars, have resulted in identification of a germplasm accession ICC 4958 as one of the most drought- tolerant lines by improving the root system [7]. The objective of this study was to quantify the genetic variation for seed yield amongst the drought tolerant lines selected from minicore accessions for variation in root traits under moisture stress and irrigated situation and to study the relationship between the seed yield and root biomass at each of these situations.

Materials and methods

During *rabi* 2005-06, chickpea minicore comprising 203 germplasm accessions were evaluated under irrigated and rainfed condition for seed yield and yield components. Based on this evaluation, drought susceptible index (DSI) and drought tolerant efficiency per cent (DTE %) were computed for the minicore of chickpea .Based on DSI and DTE (%), ten accessions were characterized as drought tolerant. These were further evaluated during *rabi* 2006-07 along with stanadred check A-1 and drought tolerant checks ICC 4958 and ICC 10448 under irrigated (E1) and rainfed (E2) conditions. The field experiments were conducted in plot number 121 of 'E' block of Genetics and Plant Breeding at College of Agriculture, Dharwad. The experiments were laid out in medium black soils. The soils are rich in available nitrogen, potash and poor in available phosphorous. The soil pH is 7.6 and contains high amount of clay, silt and sand with a bulk density of 1.33 g/cc. The field experiments were carried out in a Randomized Complete Block Design with two replications. Each genotype was grown in four rows of 4 m length with 30 cm spacing between rows and 10cm within the row. Same set of genotypes were sown in PVC pipes of 110 cm length x 20 cm diameter dimention in two replications for studying root traits of all these genotypes. Each PVC pipe was filled with a mixture of soil, sand and compost in 2:1:1 proportion and was watered to get sufficient soil moisture for dibbling five seeds per each pipe. One pipe was used for one genotype in each replication. Recommended agronomic practices were followed during the period of crop growth in both the situations. The crop was maintained free from weeds, diseases and pests by adopting appropriate plant protection measures. In irrigated situation, two irrigations were provided one at flowering and the other at pod formation stage.

The following observations were recorded on each of the five plants selected at random per treatment or genotype in each replication and averaged separately in all the experiments.

1. Days to 50 per cent flowering (DFF) 2. Plant height (PLHT) in cms. 3. Primary branches per plant (PB) 4. Secondary branches per plant (SB) 5. Tertiary branches per plant (TB) 6. Pods per plant (PPP) 7. 100- Seed weight (SDWT) in g. 8. Yield per plant (YPP) in g.

9. Relative leaf water content (RLWC%) : Three leaflets on top, middle and lower part of plant from five plants in each plot were taken for measuring relative leaf water content (RLWC%) at flowering and poding stage. RLWC (%) was calculated by the following formula given by Blum and Ebercon [9].

RLWC (%) = F_w-D_w / T_w-D_w x 100

where, F_w = Fresh weight, T_w = Turgid weight, D_w = Dry weight

10. Membrane injury index (MII) : Two gram fresh weight of leaf sample was taken to record membrane injury index (MII) at 50% flowering stage. MII was calculated by the following formula given by Blum and Ebercon [9].

MII = C_1/C_2

where, C_1 = Electrical conductivity at 40^0C for 30 minutes

C_2 = Electrical conductivity at 100^0C for 10 minutes

11. Drought susceptibility index (DSI) : Drought susceptibility index was calculated by the following formula given by Fischer and Maurer [10].

DSI = (1-Y_d / Y_p) / D

where, Y_d = Grain yield of the genotype under moisture condition.

Y_p = Grain yield of the genotypes under irrigated condition.

$$D = \frac{\text{Mean yield of all strains under moisture stress condition}}{\text{Mean yield of all strains under irrigated condition}}$$

12. Drought tolerance efficiency (DTE %): Drought tolerance efficiency was estimated by using the following formula given by Fischer and Wood [11].

$$DTE(\%) = \frac{\text{Yield under stress}}{\text{Yield under non-stress}} \times 100$$

13. Root length (cm): It was measured in cm from root collar to the tip of the main root.

14. Root weight (g) : Roots of plants sampled at maturity were dried to the constant weight and expressed in grams per plant

15. Root volume (mm^3): Roots of plants sampled at maturity were immersed in 100 ml volumetric flask filled with water and the rise in level of water measured in cubic milimeter. The analysis of variance for different characters were carried out using the mean data in order to partition variability due to different sources by following Panse and Sukhatme [12]. In order to assess and quantify the genetic variability among the genotypes for the characters under study, the GCV, PCV, heritability, genetic advance and GAM were estimated following standard statistical procedures.

Results and discussion

This study was carried out to quantify the genetic variation for seed yield and it's component traits amongst the drought tolerant accessions of minicore collections of chickpea. The genetic variability, heritability and genetic advance of eight quantitative traits are given in Table 1. Data showed wide range of genetic variability, moderate to high heritability and high genetic advance for yield and its component traits in drought tolerant accessions evaluated under moisture stress and irrigated situations during 2006-07. The coefficient of variability were high for days to 50 per cent flowering, number of secondary branches per plant, number of pods per plant, seed weight and seed yield per plant at phenotypic and genotypic levels, respectively in 2006-07 both in irrigated and rainfed experiments. Moderate level of coefficient of variability was observed for plant height, number of primary branches and tertiary branches per plant in 2006-07 irrigated experiment, whereas moderate level of coefficient of variability was noticed only for plant height in 2006-07 rainfed experiment both at genotypic and phenotypic levels. The heritability estimate was high in both moisture stress as well as irrigated situations for days to 50 per cent flowering, number of secondary branches per plant, number of pods per plant, seed weight and seed yield per plant, while moderate heritability was observed for number of primary branches per plant in both moisture stress and irrigated situations. High genetic advance in per cent mean was noticed for all the characters in irrigated experiment. Moderate per cent genetic advance was observed for plant height and number of primary branches per plant in moisture stress experiment, while high genetic advance in per cent mean was recorded for the remaining characters in 2006-07.

The performance of promising drought tolerant chickpea accessions evaluated under irrigated (E_1) and rainfed (E_2) condition during 2006-07 (Table 2) indicated

Table 1. Genetic variability, heritability and genetic advance for seed yield and its component traits in drought tolerant chickpea accessions evaluated under under irrigated (E_1) and rainfed (E_2) conditions

S.No.	Characters	E_1				E_2			
		GCV (%)	PCV (%)	h^2 (%)	GAM (%)	GCV (%)	PCV (%)	h^2 (%)	GAM (%)
1.	DFF	23.74	23.91	98.59	48.57	24.48	24.55	99.42	21.50
2.	PLHT (cm)	11.34	11.51	97.02	23.00	9.24	13.23	48.73	10.93
3.	PB	13.49	18.39	53.80	22.76	13.59	23.77	32.67	15.45
4.	SB	25.87	28.00	85.34	49.24	22.65	24.56	85.07	41.13
5.	TB	18.56	19.03	95.16	37.32	20.59	20.70	98.97	61.36
6.	PPP	30.49	34.59	77.67	55.36	31.17	39.04	63.74	20.38
7.	SDWT (g)	36.58	36.69	99.35	75.12	33.91	35.31	96.04	67.79
8.	YPP (g)	38.05	39.24	93.98	75.96	41.04	41.16	99.44	44.37

that, among the 10 accessions for days to 50 per cent flowering ICC 13124 recorded 38.4 days followed by ICC 1422 (39.9 days) compared to the checks A-1 (42 days), ICC 4958 (42.3 days) and ICC 10448 (42 days) under irrigated conditions. Under rainfed situation, ICC 13124 recorded 36.3 days followed by ICC 1422 (40 days) and ICC 867 (38.3 days) as compared to resistant checks ICC 4958 (40.4 days), ICC 10448 (40.1 days) and standared check A-1 (40.2 days). The genotype ICC 867 recorded lowest height of 35.6 cm and the genotype ICC 9848 recorded the highest height of 52.5cm under irrigated condition, while the genotype ICC 13124 (47.8 cm) recorded similar height as that of check ICC 4958 (47.6 cm). Among the accessions, ICC 867 was the dwarf with 30 cm height and the genotype ICC 9848 was the tall with 40.3 cm height under rainfed condition.

The genotype ICC 13124 had less number of primaries (2.4) while the genotype ICC 9848 had more number of primaries (3.6) in irrigated situation. Observed reductions in number of primary branches per plant for all the genotypes tested under rainfed condition. Under irrigated condition, the range for number of secondary branches was 6.4 (ICC 1422) to 12.5 (ICC 5504) whereas, this trait ranged from 5.1 (ICC 12654) to 8.0 (ICC 13124) under rainfed condition. The genotype ICC 13124 recorded similar number of tertiary branches (19.5) as compared to check ICC 4958 (21.4) followed by the genotype ICC 9848 which recorded similar number of tertiary branches (19.10) under rainfed condition.

Under irrigated condition, ICC 1205 recorded highest number of pods per plant (87.0) followed by ICC 13124 (77.5), ICC 2969 (75.1) than the resistant check ICC 4958 (72.0) In rainfed experiment, ICC 13124 recorded highest number of pods per plant (58.2) followed by the check ICC 4958 (57.0) and ICC 1205 (50.2).Among the genotypes tested ICC 13124 recorded highest seed weight of 36.4 g compared to the check ICC 4958 (31.2 g) under irrigated condition. Whereas under rainfed condition

Table 2. Performance of promising drought tolerant chickpea accessions evaluated under irrigated (E_1) and rainfed (E_2) condition during 2006-07

S.No.	Germplasm accessions	DFF		PLHT (cm)		PB		SB		TB		PPP		SDWT (g)		YPP (g)	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	ICC 13124	38.4	36.3	47.8	32.6	2.4	2.0	8.5	8.0	19.5	12.3	77.5	58.2	36.4	32.2	30.6	24.7
2	ICC 12654	46.2	40.3	45.6	35.2	2.6	2.2	6.4	5.1	17.2	13.4	62.3	49.2	15.4	14.2	14.5	11.3
3	ICC 1205	44.3	44.0	39.6	31.2	2.7	2.3	9.6	5.2	17.6	15.1	87.0	50.2	20.6	19.5	20.6	16.3
4	ICC 867	40.7	38.3	35.6	30.0	2.4	2.1	9.4	5.5	17.6	13.4	48.0	43.2	16.3	15.2	12.4	11.2
5	ICC 4182	48.5	43.2	45.8	34.5	3.6	2.4	7.8	6.2	13.4	12.0	52.0	34.4	14.5	12.3	9.9	7.5
6	ICC 5504	68.4	64.2	47.5	40.1	2.4	2.0	12.5	7.6	16.2	14.3	43.0	18.8	15.6	14.5	12.4	10.4
7	ICC 1422	39.9	40.0	39.2	32.6	3.7	2.1	6.4	6.0	19.0	14.0	53.2	40.0	18.1	18.0	16.5	12.8
8	ICC 2969	46.4	40.2	47.5	31.4	2.8	2.1	6.6	5.4	15.3	12.4	75.1	40.2	18.3	15.5	16.6	14.5
9	ICC 11121	46.7	42.1	46.0	32.5	2.6	2.0	8.0	6.2	17.5	16.0	57.5	39.2	14.3	14.1	12.5	8.3
10	ICC 9848	48.4	46.3	52.5	40.3	3.6	2.4	8.8	5.5	19.1	19.0	63.5	37.0	25.1	22.4	20.4	18.8
11	ICC 4958(RC)	42.3	40.4	47.6	36.4	2.6	2.2	11.5	7.2	21.4	13.8	72.0	57.0	31.2	27.0	21.0	18.2
12	ICC10448(RC)	42.0	40.1	41.2	30.5	3.6	2.4	12.4	6.5	21.5	15.6	59.0	41.2	26.0	24.5	19.5	17.4
13	A-1 (c)	42.0	40.2	39.8	35.6	2.9	2.5	9.7	6,9	16.7	13.9	43.7	38.5	19.8	17.8	23.5	16.8
	CD at 5 %	1.1	1.2	3.1	3.7	0.4	0.5	1.2	1.8	1.8	1.4	8.0	13.4	0.8	0.4	1.7	2.3
	CV %	7.0	8.3	8.4	5.7	8.3	12.5	6.4	6.3	8.3	9.6	8.9	17.1	8.9	8.2	9.3	9.2

the same genotype recorded highest seed weight of 32.2 g. ICC 13124 recorded highest yield of 30.6 g followed by ICC 4958 (21.0 g), ICC 1205 (20.6 g), ICC 9848 (20.4 g) and ICC 10448 (10.5 g) under irrigated condition. Under rainfed situation, ICC 13124 recorded highest yield of 24.7 g followed by ICC 9848 (18.8 g), the resistant check ICC 4958 (18.2 g) and standard check A-1 (16.8 g). The early maturing genotypes are giving more yield under moisture stress because the crop grows and matures on depleting soil moisture profile, early types are extracting moisture very quickly and gives highest yield. There is high probability that a genotype performing well under non-stress conditions will also perform well under drought, even if the relative yield reduction is large because of spillover effects of yield potential [13]. However stable genotypes which perform better under stress as well as under non- stress conditions are desirable for sustainable chickpea production in rainfed condition.

Among the 10 drought tolerant genotypes evaluated, ICC 13124 showed maximum yield potentiality under irrigated (1220 kg/ha) as well as rainfed condition (990 kg/ha) (Table 3). The per cent reduction in yield was minimum (18.9 %) under moisture stress for this genotype. It was followed by ICC 9848 which recorded 980 kg/ha and 770 kg/ha under irrigated and rainfed situation respectively and the per cent reduction in yield was 21.4 per cent. The drought tolerant checks ICC 4958 and ICC 10448 recorded 1342 kg/ha and 981 kg/ha and 849 kg/ha and 620 kg/ha under irrigated and moisture stress condition, respectively. The per cent reduction in yield was 26.9 and 27.0 per cent for these checks, respectively under moisture stress condition. Similar observations were reported in chickpea [9]. Further, ICC 13124 showed highest drought tolerance efficiency (72.46 %), least drought susceptibility index (0.76) and minimum injury (0.16) due to moisture stress compared to the check ICC 4958 which recorded 70.2 % drought tolerance efficiency, 0.79 drought susceptible index and 0.18 membrane injury. The effect of stress on RLWC of genotypes did not show any particular trend. However, ICC 13124 showed maximum difference in RLWC under moisture stress and irrigated conditions at flowering and poding stage. ICC 9848 showed no difference in RLWC under moisture stress and irrigated conditions. The maximum difference in RLWC value due to moisture stress and irrigated condition was shown by ICC 5504 (36.3 and 39.3) followed ICC 1422 (38.4 and 39.4) and ICC 2969 (39.2 and 40.3) as compared to the checks ICC 4958 (31.2 and 33.2) and ICC 10448 (30.0 and 31.8). This indicated genotypes ICC 5504, ICC 1422 and ICC 2969 were good in respect of RLWC and should be utilised as drought source in the breeding programme. The reduction of available water in chickpea caused a

Table 3. Seed yield (kg/ha) and drought tolerance related charecters infuenced by different chickpea germplasm accessions under irrigated (E_1) and Rainfed (E_2) condition during 2006-07

Genotypes	Yield kg/ha		% reduction in yield	DTE %	DSI	MII		RWC at flow.	RWC at pod.
	E_1	E_2				E_1	E_2		
ICC 13124	1220	990	18.9	72.46	0.76	0.14	0.16	31.8	32.2
ICC 12654	984	767	22.1	69.21	0.78	0.24	0.21	33.1	35.2
ICC 1205	958	734	23.4	63.21	0.86	0.16	0.19	35.5	32.2
ICC 4182	924	615	33.4	60.10	0.98	0.26	0.23	32.9	36.7
ICC 5504	1213	912	24.8	58.79	0.88	0.36	0.32	36.3	39.3
ICC 1422	1158	940	18.8	62.40	0.79	0.30	0.28	38.4	39.4
ICC 2969	1090	681	37.5	67.30	0.83	0.35	0.32	39.2	40.3
ICC 11121	1120	870	22.3	69.70	0.86	0.32	0.28	36.2	39.6
ICC 9848	980	770	21.4	68.90	0.84	0.28	0.26	33.4	33.4
ICC 4958 (RC)	1342	981	26.9	70.20	0.79	0.16	0.18	31.2	33.2
ICC10448 (RC)	849	620	27.0	69.40	0.82	0.22	0.20	30.0	31.8
A-1 (c)	985	765	22.3	68.7	0.84	0.28	0.26	33.7	34.7
CD at 5 %	109	87	-	-	-	-	-	5.7	4.9
CV %	11.6	9.8	-	-	-	-	-	6.8	7.2

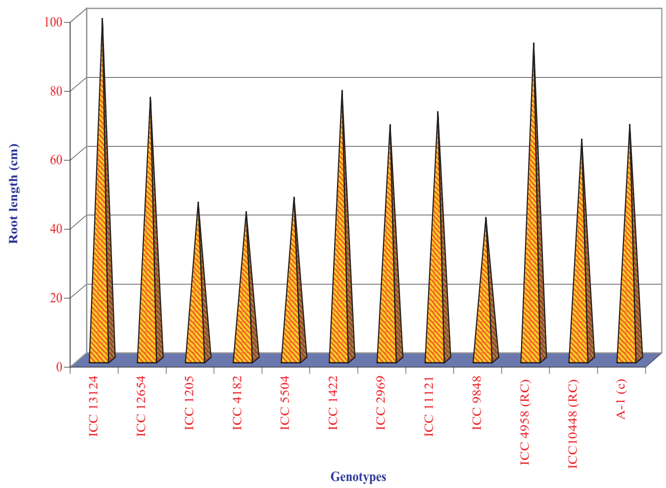

Fig. 1. Comparison of drought tolerant chickpea minicore for root length

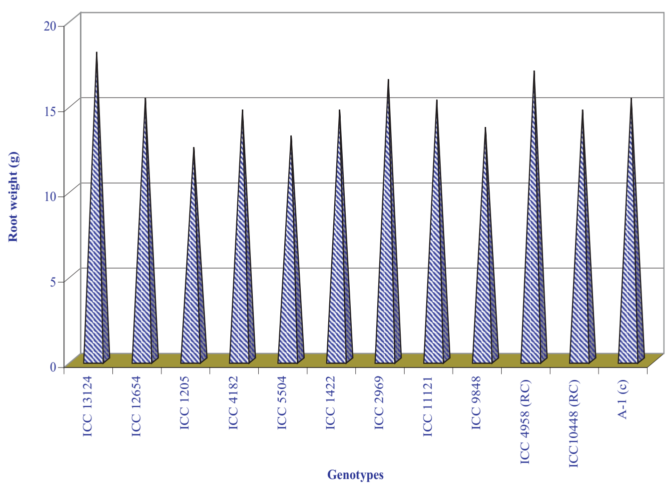

Fig. 2. Comparison of drought tolerant chickpea minicore for root weight

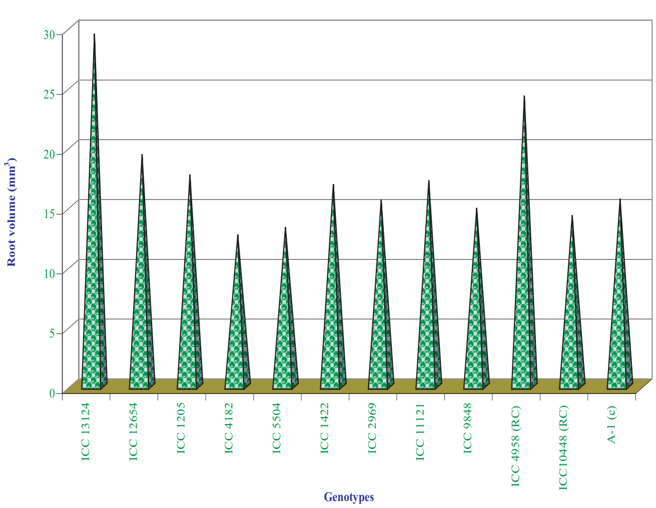

Fig. 3. Comparison of drought tolerant chickpea minicore for root volume

reduction in canopy growth and biomass production [14]. Genotypes with deep and dense root system display better drought tolerance by extracting water from deeper layers. Observations on root length, root weight and root volume showed that ICC 13124 was equally good in respect of root traits as compared to ICC 4958 (Figs. 1-3). In addition to drought tolerance, ICC 13124 is high yielding, early maturing and bold seeded desi variety. Therefore, ICC 13124 is identified as another new source for drought tolerance which can be used in the breeding programme in addition to ICC 4958 ensuring diversification of drought tolerant genes. Similar reports were made by many researchers [15-17] and hence it could be used in the breeding programme for improving drought tolerance of the agronomically superior cultivars.

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