Evaluation of Chickpea (*Cicer arietinum* L.) Genotypes for Yield and Drought Tolerance under Rain Fed and Irrigated Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. Author RDM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors VJ and MSP managed the analyses of the study. All authors read and approved the final manuscript.

Short Research Article

ABSTRACT

In Southern India, drought stress is a major constraint to chickpea production and yield stability. Drought tolerant index (DTI) that provides a measure of drought based on yield loss under drought condition in comparison to normal condition was used for screening drought-tolerant genotypes. This study was conducted to determine drought tolerant genotypes with high yield in stress and non-stress conditions utilising physiological traits. Thirty chickpea genotypes were tested in a randomized complete block design with three replications under rain fed and irrigated conditions at Regional Agricultural Research Station, Nandyal, Andhra Pradesh, India during rabi, 2018-2019. The analysis of variance carried out for yield and drought tolerant traits revealed highly significant differences among the genotypes for all characters under rain fed as well as irrigated conditions. NBeG 776, NBeG 779, NBeG 868, ICCV 181606, MH 13 and MH 14 are drought tolerant. NBeG 776, NBeG 779 and NBeG 868 are suitable under both rain fed and irrigated conditions with significantly higher yields over their respective means. ICCV 181606, MH 13 and MH 14 are suitable exclusively for rain fed condition with significantly superior yields over the mean.

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1. INTRODUCTION

Grains legumes play an important nutritional role in the diet of millions of people in the developing countries and thus sometimes referred to as poor man's meat. Legumes are vital sources of protein, calcium, iron, phosphorus and other minerals. Chickpea is considered to be unique because of its high level of protein content that accounts for almost 40% of its weight. India is the largest producer of chickpea in the world with annual production of 9.07 million tons from an area of 9.54 m ha. with productivity of 951.4 kgha^{-1} [1]. In India, chickpea area is mainly contributed by six states *viz*., Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Andhra Pradesh and Karnataka. In Andhra Pradesh, the area under chickpea has increased from less than one lakh ha (1993-94) to more than 6.0 lakh ha by 2007-08 registering the highest productivity of 1449 kg ha^{-1}. In Southern India, drought stress particularly at the end of the growing season is a major constraint to chickpea production and yield stability. This problem is more serious in Andhra Pradesh where chickpea is traditionally planted towards the end of the rainy season and generally grown on progressively declined residual soil moisture. With predicted climate change scenarios and continuous population explosion, there is a great need to develop high-yielding chickpea varieties with improved drought tolerance [2]. Therefore, study of chickpea genotypes utilising physiological traits to be utilised in breeding for drought along with seed yield will be useful for planning suitable breeding strategies to develop chickpea genotypes with increased drought tolerance.

2. MATERIALS AND METHODS

The investigation was carried out during *rabi* 2018-19 at Regional Agricultural Research Station, Nandyal, situated at 15^{0}29' North latitude and 78^{0}29' East longitude at an altitude of 211.76 m above mean sea level. The research station comes under scarce rainfall agro-climatic zone of Andhra Pradesh. The experimental material comprised of 25 *desi* chickpea genotypes and five checks *viz*., NBeG 47, NBeG 49, JG 11, GBM 2 and HC 5 which were sown on 24th October *rabi,* 2018 in a Randomized Block Design (RBD) with three replications under both rain fed and irrigated situations. Since very meagre rainfall was received during *rabi* season, a pre sowing irrigation was given to take up the

sowing of experiments. In rain fed condition genotypes were grown on receding soil moisture where as in irrigated condition two supplemental irrigations were given at 35 and 55 days after sowing through sprinklers. Each genotype was sown in two rows in a plot of 3m row length at spacing of 30 cm between rows and 10 cm between plants within the row. Data was recorded on following traits *viz*.,

SPAD Chlorophyll Meter Reading (SCMR): SCMR was measured randomly on five plants on leaflets of the third leaf from the apex on the main axis at 60 DAS under normal sunlight using SPAD chlorophyll meter of Minolta Company, New Jersey, USA (SPAD-502) and the average was recorded.

Specific leaf area (SLA) (cm^{2}g^{-1}): The SLA was calculated as per the following equation at 60 DAS and expressed as cm^2 g^{-1}.

$$SLA = \frac{\text{Leaf area (cm)}^2}{\text{Leaf dry weight (g)}}$$

Relative water content (RWC) (%) at 30 DAS and 60 DAS: The RWC was calculated based on the formula mentioned by Gonzalez and Gonzalez-Vilar [3] as follows:

$$RWC\ (\%) = \frac{FW-DW}{TW-DW}\ x\ 100$$

FW = Fresh weight of the leaf; TW = Turgid weight; DW = Dry weight of the leaf

Proline (μ mole g^{-1}): Proline concentrations were determined using the rapid colorimetric method of Bates et al. [4]. Proline was extracted from 0.5 g of each leaf by grinding in 10 ml 3% (v/v) sulphosalicylic acid. The mixtures were then centrifuged at 10,000 × g for 10 min. Two ml of the supernatant was placed in a test-tube, to which 2 ml of a freshly prepared ninhydrin solution was added. The tubes were incubated in a water bath at 90°C for 30 min and the reaction was terminated in an ice bath. Each reaction mixture was extracted with 5 ml toluene and vortex-mixed for 15 s. The tubes were allowed to stand for at least 20 min in the dark at room temperature to allow separation of the toluene and aqueous phases. Each toluene phase was then carefully collected into a clean test-tube and its absorbance was read at 520 nm using UV-visible spectrophotometer. The free proline content in each sample was determined from a

standard curve using analytical grade proline. Same procedure was followed for thirty genotypes under both rain fed and irrigated conditions.

Seed yield (g): The seed obtained from all the plants in the plot (2.8 m x 0.6 m) of each genotype were weighed and mean seed yield was recorded.

Drought tolerance Index (DTI): According to Fernandez [5]

$$DTI = \frac{(Y_P)\,(Y_S)}{(\overline{Y_P})^2}$$

where,

$(\overline{Y_P})$ = mean seed yield of all genotypes under irrigated condition,
(Y_P) and (Y_S) = seed yield of genotypes under irrigated and rain fed conditions, respectively.

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The analysis of variance was performed for each character separately under rain fed and irrigated conditions and the total variation was partitioned into different sources of variation. The mean squares due to treatments were significant for all traits under rain fed and irrigated conditions. This indicated genetic variation among genotypes of the present investigation for traits under study. The results are presented in the Table 1.

The mean performance of thirty chickpea genotypes evaluated under rain fed and irrigated conditions is presented in Table 2.

3.2 SPAD Chlorophyll Meter Reading (SCMR)

The chlorophyll density in the leaves reflects the photosynthetically active light-transmittance features of the leaf which was measured by the SCMR [6]. The ability to maintain high chlorophyll density under water deficit conditions has been suggested as a measure of drought tolerance [7]. The general mean of genotypes under rain fed condition was 54.9 ranging from 47.1 (MH 22) to 63.7 (MH 14). MH 1 (63.0), MH 14 (63.7) and MH 21 (61.9) showed significantly higher SCMR values under rain fed condition. Under irrigated condition SCMR ranged from 43.6 (MH 21) to ICCV 181602 (70.7) with a general mean of 56.3

where it was slightly greater than the mean value of rain fed (54.9). ICCV 181607 (62.8), ICCV 181610 (62.9), ICCV 181664 (62.3), MH 4 (63.9) and MH 22 (61.5) showed significantly higher values under irrigated condition. NBeG 865 (rain fed = 63.6, irrigated = 62.5) and ICCV 181602 (rain fed = 61.3, irrigated = 70.7) showed significantly higher values when compared to their respective means under both rain fed as well as irrigated conditions.

3.3 Specific Leaf Area (SLA) ($cm^2\,g^{-1}$)

Reduction of leaf area is an important adaptive mechanism for drought stress and is usually the first strategy a plant adopts under moisture stress [8]. There was a significant reduction in SLA under rain fed (170.8 $cm^2\,g^{-1}$) compared to irrigated condition (201.1 $cm^2\,g^{-1}$). Under rain fed condition, SLA ranged from 107.9 $cm^2\,g^{-1}$ (ICCV 181602) to 232.2 $cm^2\,g^{-1}$ (MH 21) and from 130.3 $cm^2\,g^{-1}$ (ICCV 181612) to 279.8 $cm^2\,g^{-1}$ (NBeG 868) under irrigated condition. ICCV 181602 (rain fed = 107.9 $cm^2\,g^{-1}$, irrigated = 144.3 $cm^2\,g^{-1}$), ICCV 181606 (rain fed = 114.9 $cm^2\,g^{-1}$, irrigated = 145.3 $cm^2\,g^{-1}$), ICCV 181607 (rain fed = 121.3 $cm^2\,g^{-1}$, irrigated = 159.8 $cm^2\,g^{-1}$), ICCV 181612 (rain fed = 118.8 $cm^2\,g^{-1}$, irrigated = 130.3 $cm^2\,g^{-1}$) and MH 14 (rain fed = 138.4 $cm^2\,g^{-1}$, irrigated = 147.9 $cm^2\,g^{-1}$) had significantly lesser SLA under both rain fed and irrigated conditions. ICCV 181608 (157.6 $cm^2\,g^{-1}$) and MH 4 (170.0 $cm^2\,g^{-1}$) recorded significantly lesser SLA exclusively under irrigated condition.

3.4 Relative Water Content (%) at 30 DAS, 60 DAS (Gonzalez and Gonzalez-Vilar, 2001)

Under moisture stress treatment, relative water content is an important physiological trait that determines leaf water potential and survival ability of plant. RWC was measured at 30 and 60 DAS. RWC at 30 DAS ranged from 67.3% (MH 22) to 87.7% (NBeG 47) with a general mean of 76.4% under rain fed condition where as under irrigated condition it ranged from 64.0% (MH 1) to 91.7% (MH 11) with a general mean of 80.7%. Under rain fed conditions, ICCV 181606 (87.3%), MH 13 (87.0 %) and NBeG 47 (87.7%) showed significantly higher RWC values over the mean value where as under irrigated conditions MH 5 (90.3%), MH 11 (91.7%), MH 12 (89.7%), and HC 5 (90.0%) showed significantly higher RWC values over the mean value.

Table 1. Analysis of variance in 30 chickpea genotypes under rain fed and irrigated condition during *rabi* 2018-19

S. no.	Character	Mean squares					
		Replications (df :2)		Treatments (df :29)		Error (df :58)	
		Rain fed	Irrigated	Rain fed	Irrigated	Rain fed	Irrigated
1	SCMR	2.13	1.52	67.89**	113.37**	9.00	9.30
2	SLA ($cm^2 g^{-1}$)	157.95	372.93	3632.97**	4712.36**	308.28	221.98
3	RWC at 30 DAS (%)	25.01	26.99	91.58**	147.08**	23.95	20.63
4	RWC at 60 DAS (%)	7.86	14.40	69.76**	42.81**	27.24	20.19
5	Proline (µ mole g^{-1})	0.08	0.10	4.11**	2.23**	0.25	0.20
6	Seed yield plot^{-1}(2.8 m x 0.6m) (g)	520.81	870.18	15793.39**	15145.75**	512.82	1537.97

* Significant at P ≤ 0.05, ** Significant at P ≤ 0.01

Table 2. *Per se* performance of 30 chickpea genotypes for drought tolerant traits under rain fed and irrigated condition during *rabi* 2018-19

S. no.	Genotypes	RWC at 30 DAS (%)		SCMR		SLA ($cm^2 g^{-1}$)		RWC at 60 DAS (%)		Proline (µ mole g^{-1})	
		RF	IR	RF	IR	RF	IR	RF	IR	RF	IR
1	NBeG 776	69.0	79.3	52.0	55.6	162.8	186.9	60.4	59.9	4.6*	3.3
2	NBeG 779	74.0	80.7	49.8	55.3	160.5	205.8	68.3	62.0	5.2**	3.8**
3	NBeG 780	78.3	79.3	54.4	57.3	192.7	260.7	66.5	59.3	5.2**	3.0
4	NBeG 865	80.3	84.7	63.6**	62.5*	164.1	224.1	62.9	69.0	5.4**	2.8
5	NBeG 868	78.0	73.7	57.0	51.6	232.0	279.8	58.3	64.7	4.6*	2.8
6	PG 08108	74.3	78.3	58.1	60.3	193.5	240.8	62.7	68.0	4.8*	3.2
7	ICCV 08102	76.7	85.6	53.3	55.7	169.9	176.8	64.4	63.7	2.4	2.3
8	ICCV 181602	70.9	76.0	61.3*	70.7**	107.9**	144.3**	49.0	61.3	2.0	1.7
9	ICCV 181606	87.3**	87.7	48.7	49.9	114.9**	145.3**	55.0	56.7	3.4	1.3
10	ICCV 181607	80.7	75.0	56.8	62.8*	121.3**	159.8**	64.7	63.3	5.6**	4.8**
11	ICCV 181608	81.0	81.7	52.0	54.5	147.7	157.6**	51.3	61.0	3.2	2.7
12	ICCV 181610	76.8	79.0	59.5	62.9*	143.5	177.3	63.7	59.7	4.3	2.5
13	ICCV 181612	70.1	70.0	51.5	54.8	118.8**	130.3**	61.3	61.7	4.0	2.4
14	ICCV 181664	73.3	80.7	57.8	62.3*	156.0	183.0	65.7	61.3	4.5	2.4
15	ICCV 181667	69.0	71.0	51.1	57.1	195.2	211.5	65.0	60.0	4.8*	3.7*
16	MH 1	75.7	64.0	63.0**	60.6	231.0	257.2	61.0	65.0	3.36	2.6

17	MH 4	82.7	77.7	56.1	63.9**	168.8	170.0*	65.8	64.0	3.96	3.1
18	MH 5	78.7	90.3*	55.2	51.4	212.0	237.1	62.3	68.3	2.13	2.1
19	MH 11	74.0	91.7**	53.7	55.2	214.0	226.2	64.7	69.7	4.6 *	3.5*
20	MH 12	75.0	89.7*	47.5	49.2	153.4	244.3	62.3	61.0	4.6*	2.5
21	MH 13	87.0*	83.0	54.6	60.2	176.0	197.0	61.3	64.0	4.3	4.1**
22	MH 14	78.3	66.0	63.7**	59.3	138.4*	147.9**	56.0	63.3	2.3	2.2
23	MH 15	71.7	81.0	54.7	49.0	183.9	195.3	66.3	69.7	3.8	2.8
24	MH 21	69.0	79.7	61.9**	43.6	232.2	241.0	65.9	70.0	3.2	2.9
25	MH 22	67.3	83.0	47.1	*61.5	153.6	224.8	59.8	61.7	2.3	1.9
26	NBeG 47	87.7**	87.5	55.4	57.7	168.4	203.0	72.1*	62.3	4.2	3.9**
27	NBeG 49	72.3	83.7	56.4	48.1	143.8	185.6	60.0	56.7	1.4	0.9
28	JG 11	74.7	87.3	50.8	46.0	171.6	161.0	65.5	63.0	2.4	2.1
29	GBM 2	82.0	84.3	48.4	50.4	218.3	246.0	59.1	69.3	2.6	1.2
30	HC 5	76.3	90.0*	51.7	60.1	177.2	211.7	64.0	64.3	2.5	2.4
General Mean		**76.4**	**80.7**	**54.9**	**56.3**	**170.8**	**201.1**	**62.2**	**63.5**	**3.7**	**2.7**
CV (%)		6.4	5.6	5.5	5.4	10.3	7.4	8.4	7.1	13.4	16.8
SE (m)		2.8	2.6	1.7	1.8	10.1	8.6	3.0	2.6	0.3	0.3
CD (P ≤ 0.05)		8.0	7.4	4.9	5.0	28.7	24.4	8.5	7.3	0.8	0.7
CD (P ≤ 0.01)		10.6	9.9	6.5	6.6	38.2	32.4	11.3	9.8	1.1	1.0

*** significant at 1 % and * significant at 5 % (RF = Rain fed; IR = Irrigated)*

RWC at 60 DAS ranged from 49.0 % (ICCV 181602) to 72.1 % (NBeG 47) under rain fed condition with a general mean of 62.2 %. NBeG 47 (72.1 %) performed significantly superior to the mean exclusively under rain fed condition. Under irrigated condition it ranged from 56.7 % (ICCV 181606 and NBeG 49) to 70.0 % (MH 21) with a general mean of 63.5 %.

3.5 Proline (µ mole g^{-1})

Proline is one of the important osmolytes which accumulates during moisture stress condition. Proline accumulation helps to maintain turgor and promotes continued growth under moisture stress condition [9]. Under rain fed and irrigated conditions proline content was lowest in NBeG 49 (rain fed = 1.4 µ mole g^{-1}, irrigated = 0.9 µ mole g^{-1}) and the highest value in ICCV 181607 (rain fed = 5.6 µ mole g^{-1}, irrigated = 4.8 µ mole g^{-1}). Kumar et al. [10] reported that the the proline content in leaves was significantly higher under rain fed condition in eight chickpea genotypes as compared to irrigated condition. Under rain fed condition NBeG 776 (4.6 µ mole g^{-1}), NBeG 780 (5.2 µ mole g^{-1}), NBeG 865 (5.4 µ mole g^{-1}), NBeG 868 (4.6 µ mole g^{-1}), PG 08108 (4.8 µ mole g^{-1}) and MH 12 (4.6 µ mole g^{-1}) had significantly more proline content where as under irrigated condition MH 13 (4.1 µ mole g^{-1}) and NBeG 47 (3.9 µ mole g^{-1}) had significantly more proline content. NBeG 779 (rain fed = 5.2 µ mole g^{-1}, irrigated = 3.8 µ mole g^{-1}), ICCV 181607 (rain fed = 5.6 µ mole g^{-1}, irrigated = 4.8 µ mole g^{-1}), ICCV 181667 (rain fed = 4.8 µ mole g^{-1}, irrigated = 3.7 µ mole g^{-1}) and MH 11 (rain fed = 4.6 µ mole g^{-1}, irrigated = 3.5 µ mole g^{-1}) had significantly more proline when compared to their mean values under both rain fed (3.7 µ mole g^{-1}) and irrigated (2.7 µ mole g^{-1}) conditions.

3.6 Seed Yield (g/plot)

In Andhra Pradesh more than 80 per cent of chickpea area is under rain fed cultivation and very little rainfall received during crop season. Therefore, the crop is subjected to increased intensity of water deficit which imposes a ceiling on crop duration demanding selection for matching duration varieties for best adaptability and productivity [11,12]. In the present study during current crop season dry weather prevailed in Andhra Pradesh, rainfall was not received for taking up rain fed sowings. Therefore a pre sowing irrigation was given for sowing rain fed and irrigated crops. Subsequently the irrigated crop was provided with two light irrigations at 35 and 55 DAS through sprinklers. The mean seed yield of the genotypes was high under irrigated conditions. Though different genotypes have shown differences in their ability to respond to irrigation, the overall improvement in mean performance under irrigated conditions is clearly visible for traits SCMR, SLA and RWC at 30 DAS.

The general mean of seed yield per plot under rain fed conditions was 237.2 (g) ranging from 139.0 g (ICCV 181664) to 403.3 g (MH 14). Under irrigated condition seed yield ranged from 141.7 g (ICCV 181664) to 426.7 g (NBeG 868) with a general mean of 308.3 g. Seed yields were high under irrigated condition for all the tested genotypes except NBeG 780, ICCV 181607 and MH 14 (Table 3). Genotypes varied in their ability to respond to irrigation. The increase of seed yield in genotypes under irrigated condition ranged from 1.9 % (MH 13 and ICCV 181664) to 145.4 % (ICCV 08102). 15 genotypes showed more than 20 per cent yield advantage under irrigated condition. Turner et al. [13], Rao et al. [14], Khamssi et al. [15], Khamssi et al. [16] and Meena and Kumar [17] also reported that the genotypes of their study responded well to irrigation in terms of yield.

NBeG 776 (rain fed = 318.3 g, irrigated = 383.7 g), NBeG 779 (rain fed = 305.0 g, irrigated = 391.3 g), NBeG 868 (rain fed = 361.7 g, irrigated = 426.7 g) and NBeG 49 (rain fed = 340.0 g, irrigated = 373.3 g) produced significantly superior yield over their respective mean values under both rain fed and irrigated conditions. Genotypes ICCV 181606 (303.3 g), ICCV 181607 (300.0 g), MH 1 (315.0 g), MH 13 (316.7 g), MH 14 (403.3 g) and JG 11 (295.3 g) produced significantly superior yield over the mean under rain fed. NBeG 865 (380.0 g), MH 4 (383.3 g) and MH 15 (386.7 g) produced significantly superior yield over the mean value under irrigated condition.

Under rain fed condition, among check genotypes NBeG 49 (340.0 g) and JG 11 (295.3 g) were high yielding and MH 14 (403.3 g) recorded highly significant yield than the checks NBeG 49 and JG 11. NBeG 776, NBeG 779, NBeG 868, ICCV 181606, ICCV 181607, MH 1 and MH 13 were on par with the checks NBeG 49 and JG 11 under rain fed condition. Under irrigated condition, 17 genotypes were on par with the yield of the check NBeG 49. NBeG 868 recorded significantly high yield than the check JG 11 and nearly 22 genotypes were on par with the yield of the check JG 11.

Table 3. Seed Yield and drought tolerance index of 30 chickpea genotypes under rain fed and irrigated condition during *rabi* 2018-19

S. no.	Genotypes	Seed yield plot^{-1} (g) (2.8 m*0.6m)		Drought Tolerance Index (DTI)
		RF	IR	
1	NBeG 776	318.3**	383.7*	1.29**
2	NBeG 779	305.0**	391.3*	1.26**
3	NBeG 780	241.3	226.7	0.57
4	NBeG 865	180.3	380.0*	0.72
5	NBeG 868	361.7**	426.7**	1.62**
6	PG 08108	213.3	266.7	0.61
7	ICCV 08102	141.3	346.7	0.51
8	ICCV 181602	156.7	163.3	0.27
9	ICCV 181606	303.3**	323.3	1.03*
10	ICCV 181607	300.0**	284.7	0.90
11	ICCV 181608	233.3	263.3	0.65
12	ICCV 181610	220.0	230.0	0.54
13	ICCV 181612	233.3	247.3	0.61
14	ICCV 181664	139.0	141.7	0.21
15	ICCV 181667	179.3	196.7	0.37
16	MH 1	315.0**	243.3	0.81
17	MH 4	203.3	383.3*	0.82
18	MH 5	141.7	320.0	0.47
19	MH 11	217.3	353.3	0.81
20	MH 12	227.0	343.0	0.82
21	MH 13	316.7**	322.7	1.07*
22	MH 14	403.3**	353.3	1.50*
23	MH 15	211.7	386.7*	0.85
24	MH 21	181.7	341.7	0.65
25	MH 22	150.0	325.0	0.52
26	NBeG 47	185.3	264.0	0.51
27	NBeG 49	340.0**	373.3*	1.33**
28	JG 11	295.3**	330.0	1.02*
29	GBM 2	243.0	341.7	0.87
30	HC 5	159.0	296.0	0.49
General Mean		**237.2**	**308.3**	**0.79**
CV (%)		9.5	12.7	15.9
SE **(m)**		13.1	22.6	0.07
CD (P ≤ 0.05)		37.0	64.1	0.2
CD (P ≤ 0.01)		49.2	85.3	0.3

*** significant at 1 % and * significant at 5 % (RF = Rain fed; IR = Irrigated)*

3.7 Drought Tolerance Index

Drought tolerance index provides a measure of drought based on yield loss under drought condition in comparison to normal condition and used for screening drought-tolerant genotypes [18]. The genotypes with high values of DTI can be selected as tolerant genotypes to water stress [19] and Zare [20]. The general mean value of DTI was 0.79 ranging from 0.21 (ICCV 181664) to 1.62 (NBeG 868). NBeG 776 (1.29), NBeG 779 (1.26), NBeG 868 (1.62), ICCV 181606 (1.03), MH 13 (1.07), MH 14 (1.50), NBeG 49 (1.33) and JG 11 (1.02) had significantly superior DTI values.

Table 4. Significantly superior genotypes based on the mean performance for yield, yield components and drought tolerant traits under rain fed and irrigated conditions

S. no	Characters	Genotypes		Rain fed and Irrigated
		Rain fed	**Irrigated**	
1	SCMR	MH 14, NBeG 865, MH 1, MH 21and ICCV 181602	ICCV 181602, MH 4, ICCV 181610, ICCV 181607, NBeG 865, ICCV 181664 and MH 22	ICCV 181602 and NBeG 865
2	SLA	ICCV 181602, ICCV 181606, ICCV 181607, ICCV 181612 and MH 14	ICCV 181602, ICCV 181606, ICCV 181607, ICCV 181608, ICCV 181612, MH 4 and MH 14	ICCV 181602, ICCV 181606, ICCV 181607, ICCV 181612 and MH 14
3	RWC at 30 DAS	NBeG 47, ICCV 181606 and MH 13	MH 11, MH 5, HC 5 and MH 12	-
4	RWC at 60 DAS	NBeG 47	-	-
5	Proline	ICCV 181607, NBeG 865, NBeG 780, NBeG 779, ICCV 181667, PG 08108, MH 11, MH 12, NBeG 776 and NBeG 868	ICCV 181607, MH 13, NBeG 47, NBeG 779, ICCV 181667 and MH 11	NBeG 779, ICCV 181607, ICCV 181667 and MH 11
6	Seed yield plot[-1]	MH 14, NBeG 868, NBeG 49, NBeG 776, MH 13, MH 1, NBeG 779, ICCV 181606, ICCV 181607 and JG 11	NBeG 868, NBeG 779, MH 15, NBeG 776, MH 4, NBeG 865 and NBeG 49	NBeG 868, NBeG 776, NBeG 779 and NBeG 49
7	Drought Tolerance Index	-	-	NBeG 868, MH 14, NBeG 49, NBeG 776, NBeG 779, MH 13, ICCV 181606 and JG 11

Test genotypes, NBeG 776, NBeG 779, NBeG 868, ICCV 181606, MH 13 and MH 14 are drought tolerant. NBeG 776, NBeG 779 and NBeG 868 are suitable under both rain fed and irrigated conditions with significantly higher yields over their respective means (Tabe 4). ICCV 181606, MH 13 and MH 14 are suitable exclusively for rain fed condition with significantly superior yields over the mean. Ludlow and Muchow [12] have indicated that to achieve a stable and consistent drought tolerance across the environments, constitutive traits that are closely associated with drought tolerance need to be considered as selection criterion rather than grain yield itself. Some of genotypes of present study with high DTI also possessed other desirable traits. NBeG 776 and NBeG 779 with higher yield under rain fed and irrigated conditions also had higher proline under rain fed condition. NBeG 868 possessed traits like high proline under rain fed conditions, along with higher yield under rain fed and irrigated conditions.

However, ICCV 181606 with high DTI had significantly higher yield under rain fed conditions with significantly lesser SLA. MH 13 apart from high DTI, had significantly higher yield under rain fed condition. MH 14 possessed desirable physiological traits like SCMR, besides lesser SLA and higher yield under rain fed condition. Apart from test genotypes, check variety NBeG 49 had higher yield under rain fed and irrigated conditions. JG 11, the most popular variety had higher yield under rain fed.

4. CONCLUSION

The genotypes ICCV 181606, MH 13 and MH 14 with high DTI and desirable associated traits should be utilised in chickpea breeding programmes aimed at improving drought tolerance in rain fed areas because trait based breeding improves the probability of crosses resulting in high additive gene action [21,22].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/62805