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Screening of Chickpea (*Cicer arietinum* L.) Genotypes for Germination and Early Seedling Growth under PEG 6000 Induced Drought Stress

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ABSTRACT

Background: Drought stress at germination and early growth stages hinders the seedling establishment in chickpea which ultimately affects the economic yield. Such adverse affects of drought can be mitigated by screening and identifying the tolerant genotypes of chickpea which is commonly cultivated under rain-fed conditions during *post-rainy* season.
Methods: Effect of drought stress on germination and early seedling growth of thirty three chickpea genotypes was studied under four different concentrations of PEG 6000 (-0.3, -0.6, -0.9 and -1.2 MPa) along with control and hydration under laboratory conditions during 2018-19.
Result: Significant variation was observed among the genotypes for germination, root length, shoot length and seedling vigour index under different concentrations of PEG 6000. Complete inhibition of germination was observed in most of the genotypes at -1.2 MPa. Based on the results obtained, JG 11 and NBeG 3 were considered as tolerant since they showed comparatively higher germination, root length, shoot length and seedling vigour even at -1.2 MPa, while NBeG 723 and NBeG 833 were considered as susceptible genotypes because of their poor germination and seedling growth even at lower levels of drought stress.

Key words: Chickpea, Drought stress, Germination, PEG-6000, Seedling length, Seedling vigour.

INTRODUCTION

Drought stress is one of the prime abiotic constraints limiting the crop growth and productivity under the present scenario of climate change across the world. Chickpea being a *post-rainy* season crop is mostly grown in arid and marginal lands as a rainfed crop where it faces drought stress at different growth stages. When water stress occurs at early stages the first and foremost consequence is impaired germination and poor stand establishment (Harris *et al*. 2002). Drought reduces soil osmotic potential that inhibits the germination which was found to halt completely at -0.8 MPa (Yucel *et al*. 2010; Sleimi *et al*. 2013). Germination initiation is delayed under limited water availability due to prolonged imbibition time (Vessal *et al*. 2012). Lack of sufficient soil moisture effects the establishment of the seedlings leading to seedling mortality. Knowledge on the genotypical differences in tolerance to drought within the crop is essential to identify the elite genotype which can be recommended for cultivation under water deficit areas. Genotypic differences in response to osmotic stress was earlier noticed in chickpea (Macar *et al*. 2009; Awari and Mate, 2015; Dharanguttikar *et al*. 2015).

Screening of the genotypes for drought tolerance can be done both in field as well as laboratory. But field experiments related to water stress are labour intensive, time consuming and difficult to handle due to uncontrolled atmospheric conditions, soil heterogeneity and significant interaction with biotic, abiotic and other environmental factors. Moreover creation and maintenance of a pure and uniform water potential in the field is a difficult job. Hence, *in vitro* screening method by creation of water stress using different osmotic materials is considered as one of the best methods to study the effects of drought stress during early seedling growth and select drought tolerant genotypes. The osmotically active substances or osmolytes increases the solute concentration, thereby decreases the water potential in the substrate making it unavailable to the plant. Various osmolytes that are used to induce drought stress include sugars, sodium chloride, mannitol, sorbitol, polyethylene glycol *etc*. However to obtain accurate results and inter-experimental compatibility, special importance should be given to biologically inert polymeric osmolytes. Polyethylene glycol (PEG) is considered as non-toxic, non-permeable and most commonly used as drought simulator. PEG solutions mimic dry soil moisture more closely than solutions of low molecular osmotic compounds, which infiltrate the cell wall with solutes (Verslues *et al.* 1998). The present investigation was carried out to screen the chickpea genotypes and

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identify elite genotypes that could withstand different levels of PEG induced water deficit conditions during germination and early seedling growth.

MATERIALS AND METHODS

The present study was conducted in the Department of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur andhra Pradesh, India during 2018-19 with the seed of thirty three chickpea genotypes procured from Regional Agricultural Research Station, Nandyal. Initially the seed was surface sterilized with 0.1% sodium hypochlorite solution for 5 minutes followed by thorough washing with distilled water for three times. Hydration treatment was given by soaking the seed in distilled water with 1:5 (w/v) seed weight to volume ratio for 8 hrs and then air dried under shade till they reach to safe moisture content. Seed of all the genotypes were exposed to different levels of (-0.3, -0.6, -0.9 and -1.2 MPa) PEG 6000 induced drought stress. Osmotic potentiality of PEG at different concentrations was calculated by the method described by Michel and Kaufmann (1973).

Four replicates of 100 seed from each PEG-induced drought stress treatment along with hydrated and control seed were sown in sand with uniform spacing. Equal volume of different concentrations of polyethylene glycol (PEG) 6000 solution was used to moisten the sand in respective treatments. For hydration treatment and control equal volume of distilled water was used to moisten the sand. All the samples were incubated at 25 ± 2°C for 8 days. Data on germination and seedling vigour index were recorded/ computed as per the details mentioned below:

Normal seedlings were counted and expressed as germination (%) as per the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seed sown}} \times 100$$

Root and shoot lengths were measured at the end of test period by randomly selecting ten normal seedlings from every replication in each treatment. The root length was measured from the tip of the primary root to the base of the hypocotyl and the mean root length was expressed in centimeters. Shoot length was measured from the tip of the primary leaf to the base of the hypocotyl and the mean shoot length was expressed in centimeters. The root length and shoot length were added to calculate the seedling length (cm).

Seedling vigour index was computed by adopting the following formula suggested by Abdul-Baki and Anderson (1973) and was expressed in whole number.

Seedling Vigour Index =

$$\text{Germination (\%)} \times \text{Seedling length (cm)}$$

Data were analyzed in factorial completely randomized design (FCRD) with four replications by using SPSS (version 16.0) software after subjecting the obtained data to proper transformations. The differences among the genotypes and treatment means were compared by using Duncan's multiple range test at 5% level of probability.

RESULTS AND DISCUSSION

Better germination is a key factor for the fast establishment and uniform growth of crop plants. Drought stress had significant negative impact on germination and other seedling quality parameters of chickpea genotypes. Analysis of variance (Table 1) showed highly significant differences among the genotypes, treatments and their interactions for all the seedling quality parameters *viz.,* germination, root length, shoot length, seedling length and seedling vigour index. This indicates the existence of genetic variability among the chickpea genotypes under study, which could be exploited for the identification of drought tolerant genotypes. The significant impact of interaction effects clearly revealed the differential response of the chickpea genotypes to various levels of osmotic potential.

Mean germination of chickpea genotypes ranged from 71.58% (JG 11) to 29.00% (NBeG 723) with an overall mean of 47.42% (Table 2). Increase in PEG concentration caused a gradual and highly significant decline in germination. Untreated seed (control) recorded significantly highest mean germination (93.77%). The reduction in mean germination upon hydration (90.35%) over control might be due to differential response of the chickpea genotypes. PEG induced drought stress drastically reduced the germination at all the levels. However, the per cent decrease in germination over control was highest (98.12%) and lowest (41.12%) at -1.2 MPa and -0.3 MPa, respectively (Fig 1). Germination potential diminished gradually with increase in water stress and was completely inhibited in majority of the

Table 1: Mean sum of squares for seedling quality parameters of different chickpea genotypes under drought stress conditions.

Source	d.f.	Sum of squares				
		Germination (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling vigour index
Genotypes	32	2173.522**	0.390**	0.414**	0.665**	4.791**
Treatments	5	112027.056**	13.786**	21.083**	26.982**	186.664 **
G × T	160	336.456**	0.121**	0.069**	0.160**	0.963**
Error	594	0.853	0.003	0.002	0.004	0.008

**Significant difference at 1% probability level.

*Significant difference at 5% probability level.

genotypes at -1.2 MPa. NBeG 3, NBeG 738, JG 11, KAK 2, NBeG 119, NBeG 399 and NBeG 829 exhibited germination even at -1.2 MPa while, NBeG 723 and NBeG 833 showed lowest germination even at -0.3 MPa. In addition to these two genotypes, NBeG 785 and NBeG 805 did not show germination at -0.6 Mpa.

The reduction in germination with decrease in osmotic potential was earlier reported by Yucel *et al*. (2010) and Awari and Mate (2015) in chickpea. The decline in germination under different stress levels may be due to reduced imbibition by seed (Rauf *et al*. 2006). Pratap and Sharma (2010) reported that during water deficit condition seed forces themselves to undergo dormancy as an adaptive strategy to prevent germination under stressful conditions. The decrease in water potential gradient between seed and media will prevent the seeds to absorb the desired amount of water (Achakzai, 2009). Shamim *et al.* (2016) earlier pointed out that PEG creates an osmotic barrier, hinders water uptake leading to reduction in cell division and cell enlargement and ultimately effects the protein synthesis

Table 2: Variation among the chickpea genotypes for germination (%) under PEG 6000 induced drought stress.

Genotype	Treatments						Mean
	Control	Hydration	-0.3 MPa	-0.6 MPa	-0.9 MPa	-1.2 MPa	
NBeG 3	97.50(83.03)*	97.00(81.84)	80.75(64.69)	68.00(56.15)	45.50(42.98)	20.50(27.61)	68.21(59.38)^{b}
NBeG 47	97.25(83.41)	90.25(72.81)	71.00(58.03)	38.25(38.78)	9.25(18.66)	0(5.74)	51.00(46.24)^{j}
NBeG 49	97.50(83.03)	93.00(75.81)	75.00(60.64)	62.25(52.66)	11.75(20.91)	0(5.74)	56.58(49.80)^{h}
NBeG 452	100.00(89.96)	96.00(79.99)	92.25(74.92)	32.25(35.20)	17.50(25.46)	0(5.74)	56.33(51.88)^{g}
NBeG 506	100.00(89.96)	96.75(81.38)	93.75(76.73)	47.00(43.84)	9.00(18.43)	0(5.74)	57.75(52.68)^{f}
NBeG 738	91.50(74.08)	93.75(76.73)	90.00(72.51)	60.50(51.63)	23.00(29.32)	1.50(8.63)	60.04(52.15)^{fg}
NBeG 753	90.25(72.77)	88.50(71.07)	25.75(31.13)	19.00(26.55)	0(5.74)	0(5.74)	37.25(35.50)^{r}
NBeG 773	100.00(89.96)	94.75(78.09)	74.75(60.48)	75.00(60.64)	9.25(18.66)	0(5.74)	58.92(52.26)^{fg}
NBeG 778	97.25(82.43)	85.50(68.42)	81.25(65.06)	75.50(60.98)	9.25(18.66)	0(5.74)	58.13(50.21)^{h}
NBeG 779	97.25(82.43)	81.00(64.88)	60.50(51.63)	23.50(29.66)	12.00(21.13)	0(5.74)	45.71(42.58)^{m}
NBeG 785	87.75(70.38)	91.75(74.36)	13.00(21.96)	0(5.74)	0(5.74)	0(5.74)	32.08(30.65)^{v}
NBeG 786	93.25(76.11)	93.50(76.42)	33.00(35.65)	14.25(22.98)	0(5.74)	0(5.74)	39.00(37.10)^{p}
NBeG 798	90.00(72.51)	92.00(74.63)	60.00(51.34)	32.75(35.5)	0(5.74)	0(5.74)	45.79(40.91)^{n}
NBeG 806	93.25(76.13)	76.25(61.49)	50.75(45.98)	20.50(27.61)	0(5.74)	0(5.74)	40.13(37.12)^{p}
NBeG 857	90.75(73.30)	90.50(73.03)	58.50(50.46)	8.00(17.45)	0(5.74)	0(5.74)	41.29(37.62)^{p}
NBeG 864	97.00(82.11)	93.00(75.81)	69.25(56.92)	26.00(31.29)	4.50(13.54)	0(5.74)	48.29(44.24)^{k}
NBeG 868	97.25(82.43)	98.25(85.66)	57.50(49.87)	20.50(27.61)	5.50(14.75)	0(5.74)	46.50(44.35)^{k}
NBeG 1004	100.00(89.96)	88.25(70.84)	41.25(40.53)	14.75(23.37)	0(5.74)	0(5.74)	40.71(39.36)^{o}
JG 11	98.75(88.53)	90.75(73.28)	90.75(73.28)	81.50(65.25)	55.75(48.86)	12.00(21.13)	71.58(61.72)^{a}
KAK 2	98.00(84.47)	95.75(79.60)	78.50(63.05)	76.00(61.32)	27.00(31.94)	1.50(8.63)	62.79(54.84)^{d}
NBeG 119	90.25(72.77)	88.00(70.60)	86.75(69.49)	71.25(58.19)	37.00(38.04)	6.00(15.3)	63.21(54.06)^{e}
NBeG 399	89.25(71.78)	90.75(73.28)	75.25(60.81)	54.00(47.85)	16.00(24.30)	1.50(8.63)	54.46(47.78)^{i}
NBeG 471	92.00(74.63)	93.50(76.44)	62.50(52.81)	34.00(36.26)	10.50(19.77)	0(5.74)	48.75(44.28)^{k}
NBeG 529	88.50(71.07)	90.00(72.51)	12.75(21.75)	4.25(13.23)	0(5.74)	0(5.74)	32.58(31.67)^{u}
NBeG 723	85.75(68.68)	80.25(64.32)	8.00(17.45)	0(5.74)	0(5.74)	0(5.74)	29.00(27.94)^{w}
NBeG 789	85.75(68.68)	72.50(58.99)	50.75(45.98)	11.25(20.48)	0(5.74)	0(5.74)	36.71(34.26)^{s}
NBeG 801	96.00(79.99)	84.00(67.19)	59.00(50.75)	37.00(38.04)	9.00(18.43)	0(5.74)	47.50(43.36)^{l}
NBeG 805	88.00(70.60)	92.00(74.63)	13.00(21.96)	0(5.74)	0(5.74)	0(5.74)	32.17(30.73)^{v}
NBeG 829	97.25(83.41)	95.75(79.60)	88.75(71.30)	51.25(46.27)	44.00(42.11)	15.00(23.57)	65.33(57.71)^{c}
NBeG 833	91.50(74.08)	92.00(74.63)	8.00(17.45)	0(5.74)	0(5.74)	0(5.74)	31.92(30.56)^{v}
NBeG 835	93.25(76.11)	93.25(76.11)	15.00(23.57)	4.00(12.92)	0(5.74)	0(5.74)	34.25(33.36)^{t}
NBeG 837	89.00(71.54)	91.00(73.57)	12.75(21.75)	4.00(12.92)	0(5.74)	0(5.74)	32.79(31.87)^{u}
NBeG 839	93.50(76.42)	92.00(74.65)	32.00(35.05)	11.25(20.48)	0(5.74)	0(5.74)	38.13(36.34)^{q}
Mean	93.77(78.39)^{A}	90.35 (73.72)^{B}	55.21(48.94)^{C}	32.66(33.27)^{D}	10.78(16.73)^{E}	1.76(7.96)^{F}	47.42(43.17)
			G	T	G x T		
		S Em ±	0.189	0.080	0.462		
		CD (5%)	0.524	0.223	1.283		
		CV (%)		2.140			

*Values in the parenthesis indicate arc-sine transformed values.

The mean values in the same column / row with the same alphabet are not significantly different as per DMRT (P < 0.05).

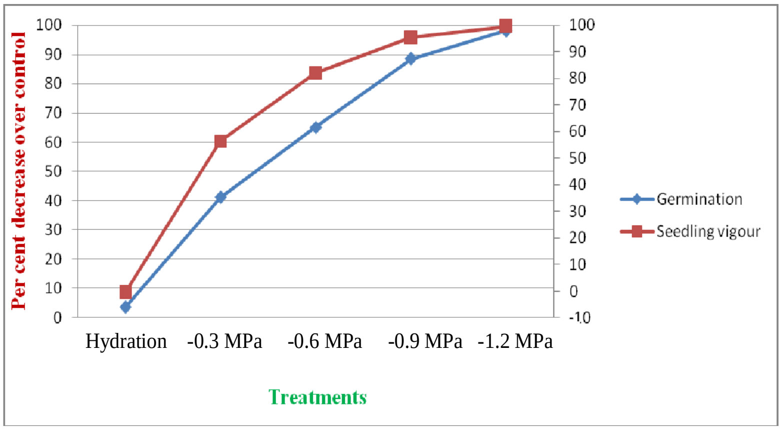

Fig 1: Per cent decrease in germination and seedling vigour over control in chickpea genotypes under different levels of PEG induced drought stress.

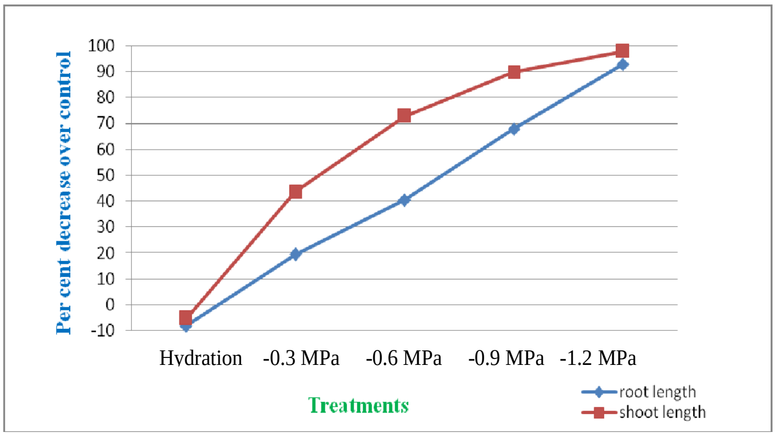

Fig 2: Per cent decrease in root length and shoot length over control in chickpea genotypes under different levels of PEG induced drought stress.

along with mobilization of reserved resources (Farooq *et al.* 2009; Osorio *et al.* 2014) due to the activation of stress inducible genes which expresses themselves under specific stress conditions (Foolad *et al.* 2003).

Plants with better growth of root system under stress conditions can be considered as tolerant genotypes (Allah *et al*. 2010; Basha *et al.* 2015) since they can explore moisture and nutrients from the deeper layers of the soil. Significantly superior root growth was noticed in JG 11 (12.87 cm) followed by NBeG 3 (11.66 cm). In contrast lowest mean root length was recorded in NBeG 723 (4.26 cm) and NBeG 833 (4.82 cm). Increased levels of drought stress showed repressing effect on root length. Highest mean root length was expressed for hydration treatment (14.64 cm) followed by control (13.54 cm) (Table 3). The per cent decrease in mean root length over control was more (92.76%) at -1.2 MPa (Fig. 2). Reduction in root growth is a good indicator of drought susceptibility of cultivars (Macar *et al*. 2009). Smita and Nayyar (2005) earlier observed reduction in root length of chickpea seedlings under water stress and opined that detrimental effects could be due to distortion and reduction in root hair diameter and plasmolysis. Root growth inhibition under PEG induced drought stress is the result of less turgor pressure created on the cell wall by the vacuole which ultimately inhibits cell division and/or elongation (Awari and Mate, 2015). Shahriari and Hassan (2005) attributed the decrease in root length under stress conditions to the decreased divisions in meristematic cells which ultimately affect the cell growth.

Highest mean shoot length was recorded by JG 11 (13.55 cm) followed by NBeG 3 (12.35 cm) and lowest was observed in NBeG 723 (4.47 cm) followed by NBeG 833 (5.23 cm). Progressive decrease in shoot length was observed with increase in PEG concentration. Hydration treatment showed highest mean shoot length (18.52 cm) when compared to control (17.62 cm) (Table 4). At lower PEG concentration (-0.3 MPa) 43.47% decrease in shoot length was observed over control, while at -1.2 MPa, 97.78% decrease was observed (Fig 2). Severe effect of drought on shoot length was also reported by Macar *et al.* (2009) in chickpea. Kravic *et al*. (2012) earlier reported that decline in shoot length in response to drought might be due to decrease in cell elongation resulting from the inhibitory effect of water shortage on growth promoting hormones which in turn led to decrease in cell turgor, cell volume and eventually cell growth (Banon *et al*. 2006). Fathi and Tari (2016) found that the prevention of shoot growth during drought stress was due to modification of biochemical changes occurring in cell wall during growth.

For testing drought tolerance under laboratory conditions, seedling development can be taken as an advisable parameter (Bayoumi *et al.* 2008). Effect of drought stress was observed more in seedling length when compared to germination (Macar *et al*. 2009; Petrovic *et al*. 2016). Lack of sufficient soil moisture effects the establishment of the seedlings leading to seedling mortality. Seedling growth varied significantly among the genotypes with highest in JG 11 (26.43 cm) followed by NBeG 3 (24.01 cm) and lowest in NBeG 723 (8.74 cm) followed by NBeG 833 (10.05 cm) (Table 5). Similar variation among the genotypes for seedling growth was earlier reported by Dharanguttikar *et al*. (2015) in chickpea. Gradual decrease in seedling growth was observed with increase in PEG concentration. Seed subjected to hydration recorded better

Table 3: Variation among the chickpea genotypes for root length (cm) under PEG 6000 induced drought stress.

Genotype	Treatments						Mean
	Control	Hydration	-0.3 MPa	-0.6 MPa	-0.9 MPa	-1.2 MPa	
NBeG 3	17.85(1.29)*	14.35(1.21)	12.77(1.17)	10.27(1.09)	8.77(1.03)	5.95(0.90)	11.66(1.12)^{b}
NBeG 47	15.39(1.24)	15.31(1.24)	6.71(0.94)	10.47(1.09)	7.24(0.96)	0(0.30)	9.18(0.96)^{efg}
NBeG 49	12.30(1.15)	14.01(1.20)	11.77(1.14)	10.28(1.09)	9.76(1.07)	0(0.30)	9.69(0.99)^{def}
NBeG 452	16.33(1.26)	15.47(1.24)	13.77(1.20)	10.30(1.09)	8.38(1.02)	0(0.30)	10.72(1.02)^{d}
NBeG 506	11.15(1.12)	14.33(1.21)	11.45(1.13)	7.45(0.97)	8.96(1.04)	0(0.30)	8.89(0.96)^{efg}
NBeG 738	14.91(1.23)	17.09(1.28)	11.95(1.14)	8.96(1.04)	8.90(1.04)	3.63(0.63)	10.91(1.06)^{c}
NBeG 753	15.32(1.24)	14.59(1.22)	12.96(1.17)	6.11(0.91)	0(0.30)	0(0.30)	9.16(0.86)^{mnop}
NBeG 773	14.75(1.22)	14.43(1.22)	12.95(1.17)	10.54(1.10)	6.80(0.94)	0(0.30)	9.91(0.99)^{def}
NBeG 778	14.61(1.22)	15.57(1.24)	12.93(1.17)	9.42(1.06)	8(1.00)	0(0.30)	10.08(1.00)^{de}
NBeG 779	10.02(1.08)	15.12(1.23)	6.11(0.89)	9.13(1.05)	7.89(0.99)	0(0.30)	8.05(0.92)^{hij}
NBeG 785	9.48(1.06)	16.11(1.26)	8.53(1.02)	0(0.30)	0(0.30)	0(0.30)	5.67(0.71)^{r}
NBeG 786	13.24(1.18)	13.33(1.19)	13.63(1.19)	9.48(1.06)	0(0.30)	0(0.30)	8.28(0.87)^{lmn}
NBeG 798	15.68(1.25)	15.68(1.25)	13.05(1.18)	11.09(1.12)	0(0.30)	0(0.30)	9.25(0.90)^{jkl}
NBeG 806	14.60(1.22)	13.22(1.18)	13.98(1.20)	7.89(0.99)	0(0.30)	0(0.30)	8.28(0.87)^{lmno}
NBeG 857	17.54(1.29)	16.80(1.27)	13.71(1.20)	10.56(1.10)	0(0.30)	0(0.30)	9.77(0.91)^{ijk}
NBeG 864	13.92(1.20)	17.70(1.29)	12.66(1.17)	9.20(1.03)	7.58(0.95)	0(0.30)	10.18(0.99)^{def}
NBeG 868	14.09(1.21)	15.38(1.24)	6.18(0.91)	7.71(0.98)	8.19(1.00)	0(0.30)	8.59(0.94)^{ghi}
NBeG 1004	15.61(1.25)	16.06(1.26)	14.03(1.20)	7.74(0.98)	0(0.30)	0(0.30)	8.91(0.88)^{klm}
JG 11	18.17(1.30)	13.51(1.19)	14.36(1.21)	12.54(1.16)	11.15(1.12)	7.51(0.98)	12.87(1.16)^{a}
KAK 2	15.29(1.24)	14.92(1.23)	14.19(1.21)	10.55(1.10)	7.52(0.97)	3.43(0.62)	10.98(1.06)^{c}
NBeG 119	14.32(1.21)	14.61(1.22)	12.81(1.17)	10.96(1.11)	8.96(1.04)	5.39(0.87)	11.75(1.10)^{b}
NBeG 399	9.99(1.08)	14.12(1.21)	9.64(1.07)	7.89(0.99)	6.22(0.91)	2.48(0.57)	8.39(0.97)^{efg}
NBeG 471	15.26(1.24)	15.11(1.23)	11.05(1.11)	8.09(1.00)	5.82(0.89)	0(0.30)	9.22(0.96)^{efg}
NBeG 529	7.92(0.99)	14.52(1.22)	8.48(1.02)	7.98(0.99)	0(0.30)	0(0.30)	6.48(0.80)^{q}
NBeG 723	8.61(1.03)	12.45(1.16)	4.51(0.81)	0(0.30)	0(0.30)	0(0.30)	4.26(0.65)^{s}
NBeG 789	9.94(1.08)	14.14(1.21)	9.60(1.06)	8.38(1.02)	0(0.30)	0(0.30)	7.01(0.83)^{pq}
NBeG 801	13.47(1.19)	14.11(1.21)	12.06(1.14)	9.46(1.06)	4.93(0.84)	0(0.30)	9.01(0.96)^{efgh}
NBeG 805	10.55(1.10)	13.33(1.19)	9.66(1.07)	0(0.30)	0(0.30)	0(0.30)	5.59(0.71)^{r}
NBeG 829	16.15(1.26)	15.43(1.24)	13.39(1.19)	9.91(1.07)	8.67(1.03)	4.05(0.78)	11.27(1.09)^{b}
NBeG 833	11.14(1.12)	11.48(1.13)	6.30(0.91)	0(0.30)	0(0.30)	0(0.30)	4.82(0.68)^{rs}
NBeG 835	13.98(1.20)	12.74(1.17)	8.15(1.01)	6.93(0.95)	0(0.30)	0(0.30)	6.97(0.82)^{pq}
NBeG 837	11.67(1.13)	13.35(1.19)	8.49(1.02)	9.50(1.06)	0(0.30)	0(0.30)	7.17(0.83)^{opq}
NBeG 839	13.46(1.19)	14.88(1.23)	8.78(1.03)	7.34(0.97)	0(0.30)	0(0.30)	7.41(0.84)^{nopq}
Mean	13.54(1.18)^{B}	14.64(1.22)^{A}	10.92(1.10)^{C}	8.06(0.95)^{D}	4.35(0.68)^{E}	0.98(0.40)^{F}	8.75(0.92)
			G	T	G x T		
		S Em ±	0.012	0.005	0.029		
		CD (5%)	0.033	0.014	0.081		
		CV (%)		6.291			

*Values in the parenthesis indicate log transformed values.

The mean values in the same column / row with the same alphabet are not significantly different as per DMRT ($P < 0.05$).

mean seedling growth (33.16 cm) compared to control (31.70 cm). The per cent decrease in seedling growth was highest at -1.2 MPa (95.62%) whereas lowest decrease was noticed at -0.3 MPa (12.50%). Amador *et al.* (2002) earlier reported that decrease in seedling growth was due to reduction in uptake of water which inhibits mobilization of cotyledon reserves to the growing embryonic axis. The inhibition of growth under stress condition is due to inhibition of cell division and/or cell elongation (Farooq *et al*. 2009). In the present study, shoot length of chickpea genotypes under drought stress was more inhibited when compared to root length (Fig 2), which could be due to the fact that root emerges first from the seed and hence exhibit faster growth than shoot (Awari and Mate, 2015). Seedling growth is impaired due to decline in growth rate (Soltani *et al*. 2006). Suboptimal moisture availability drastically affects the seedling dry weight, plumule length and radicle length (Ajirloo *et al*. 2011).

Seedling vigour being sensitive to the availability of moisture reflects better response of genotypes to drought

Table 4: Variation among the chickpea genotypes for shoot length (cm) under PEG 6000 induced drought stress.

Genotype	Treatments						Mean
	Control	Hydration	-0.3 MPa	-0.6 MPa	-0.9 MPa	-1.2 MPa	
NBeG 3	20.10(1.34)*	19.46(1.33)	17.73(1.29)	10.62(1.10)	4.47(0.81)	1.74(0.57)	12.35(1.07)^{b}
NBeG 47	18.32(1.31)	19.81(1.34)	11.38(1.13)	6.80(0.94)	2.59(0.66)	0(0.30)	9.81(0.95)^{gh}
NBeG 49	20.35(1.35)	19.94(1.34)	13.65(1.19)	5.50(0.87)	2.84(0.68)	0(0.30)	10.38(0.96)^{fg}
NBeG 452	20.08(1.34)	20.01(1.34)	13.73(1.20)	5.52(0.87)	2.80(0.68)	0(0.30)	10.36(0.96)^{fg}
NBeG 506	15.25(1.24)	17.52(1.29)	9.61(1.06)	9.41(1.06)	3.05(0.70)	0(0.30)	9.14(0.94)^{gh}
NBeG 738	22.77(1.39)	21.60(1.37)	10.38(1.09)	5.14(0.85)	2.84(0.68)	1.54(0.49)	10.71(0.98)^{e}
NBeG 753	19.17(1.32)	18.78(1.32)	14.44(1.22)	2.92(0.69)	0(0.30)	0(0.30)	9.22(0.86)^{m}
NBeG 773	18.10(1.30)	20.11(1.34)	15.40(1.24)	10.63(1.10)	1.71(0.57)	0(0.30)	10.99(0.98)^{ef}
NBeG 778	22.36(1.39)	20.53(1.35)	14.51(1.22)	6.32(0.92)	1.55(0.55)	0(0.30)	10.88(0.95)^{fg}
NBeG 779	18.13(1.30)	18.20(1.31)	7.83(0.99)	7.03(0.95)	4.26(0.79)	0(0.30)	9.24(0.94)^{gh}
NBeG 785	14.04(1.20)	15.61(1.25)	1.97(0.59)	0(0.30)	0(0.30)	0(0.30)	5.27(0.66)^{q}
NBeG 786	17.64(1.29)	18.97(1.32)	11.15(1.12)	2.72(0.67)	0(0.30)	0(0.30)	8.41(0.83)^{n}
NBeG 798	18.54(1.31)	20.30(1.35)	13.13(1.18)	8.55(1.02)	0(0.30)	0(0.30)	10.09(0.91)^{ijk}
NBeG 806	19.95(1.34)	19.45(1.33)	12.21(1.15)	3.37(0.73)	0(0.30)	0(0.30)	9.16(0.86)^{m}
NBeG 857	19.01(1.32)	15.83(1.25)	13.42(1.19)	7.54(0.98)	0(0.30)	0(0.30)	9.30(0.89)^{kl}
NBeG 864	19.29(1.33)	19.73(1.34)	8.14(1.01)	3.98(0.77)	2.44(0.65)	0(0.30)	8.93(0.90)^{jkl}
NBeG 868	20.38(1.35)	19.13(1.32)	10.59(1.10)	3.68(0.75)	3.04(0.70)	0(0.30)	9.47(0.92)^{hij}
NBeG 1004	19.62(1.33)	19.95(1.34)	16.03(1.26)	3.48(0.74)	0(0.30)	0(0.30)	9.85(0.88)^{lm}
JG 11	20.72(1.36)	18.80(1.32)	15.69(1.25)	10.95(1.11)	10.01(1.08)	5.16(0.85)	13.55(1.16)^{a}
KAK 2	19.66(1.34)	18.46(1.31)	12.44(1.16)	5.66(0.88)	2.73(0.67)	0.83(0.43)	9.96(0.96)^{efg}
NBeG 119	18.66(1.31)	20.02(1.34)	13.35(1.19)	6.67(0.94)	3.38(0.73)	1.78(0.57)	10.64(1.01)^{d}
NBeG 399	21.41(1.37)	19.27(1.33)	8.98(1.04)	4.41(0.80)	2.87(0.68)	1.10(0.46)	9.67(0.95)^{gh}
NBeG 471	19.32(1.33)	18.92(1.32)	12.40(1.16)	6.40(0.92)	1.49(0.54)	0(0.30)	9.75(0.93)^{hi}
NBeG 529	15.10(1.23)	16.19(1.26)	2.11(0.61)	1.11(0.49)	0(0.30)	0(0.30)	5.75(0.70)^{p}
NBeG 723	10.42(1.09)	14.79(1.23)	1.63(0.56)	0(0.30)	0(0.30)	0(0.30)	4.47(0.63)^{r}
NBeG 789	14.46(1.22)	16.91(1.28)	8.18(1.01)	2.63(0.66)	0(0.30)	0(0.30)	7.03(0.79)^{o}
NBeG 801	20.31(1.35)	18.09(1.30)	10.05(1.08)	3.48(0.73)	3.20(0.70)	0(0.30)	9.19(0.91)^{ijk}
NBeG 805	14.03(1.20)	15.73(1.25)	1.94(0.59)	0(0.30)	0(0.30)	0(0.30)	5.28(0.66)^{q}
NBeG 829	19.77(1.34)	18.99(1.32)	15.47(1.24)	9.40(1.06)	4.29(0.80)	1.33(0.52)	11.54(1.05)^{c}
NBeG 833	13.80(1.20)	15.58(1.24)	1.98(0.60)	0(0.30)	0(0.30)	0(0.30)	5.23(0.66)^{q}
NBeG 835	15.54(1.24)	16.93(1.28)	1.94(0.59)	1.10(0.49)	0(0.30)	0(0.30)	5.92(0.70)^{p}
NBeG 837	14.23(1.21)	17.99(1.30)	2.52(0.65)	1.20(0.50)	0(0.30)	0(0.30)	5.99(0.71)^{p}
NBeG 839	18.99(1.32)	19.72(1.34)	4.64(0.82)	1.93(0.59)	0(0.30)	0(0.30)	7.55(0.78)^{o}
Mean	17.62(1.30)^{B}	18.52(1.31)^{A}	9.96(1.02)^{C}	4.79(0.77)^{D}	1.81(0.52)^{E}	0.39(0.36)^{F}	8.84(0.88)
			G	T	G x T		
		S Em ±	0.008	0.003	0.020		
		CD (5%)	0.022	0.010	0.055		
		CV (%)		4.506			

*Values in the parenthesis indicate log transformed values.

The mean values in the same column / row with the same alphabet are not significantly different as per DMRT ($P < 0.05$).

Table 5: Variation among the chickpea genotypes for seedling length (cm) under PEG 6000 induced drought stress.

Genotype	Treatments						Mean
	Control	Hydration	-0.3 MPa	-0.6 MPa	-0.9 MPa	-1.2 MPa	
NBeG 3	37.94(1.60)*	33.81(1.55)	30.50(1.51)	20.89(1.36)	13.24(1.18)	7.69(0.98)	24.01(1.36)^{b}
NBeG 47	33.71(1.55)	35.12(1.57)	18.09(1.30)	17.27(1.28)	9.83(1.07)	0(0.30)	19.00(1.18)^{efgh}
NBeG 49	32.64(1.54)	33.94(1.56)	25.42(1.44)	15.78(1.25)	12.60(1.16)	0(0.30)	20.06(1.21)^{efg}
NBeG 452	36.41(1.58)	35.48(1.57)	27.50(1.47)	15.82(1.25)	11.18(1.12)	0(0.30)	21.06(1.22)^{e}
NBeG 506	26.40(1.45)	31.84(1.53)	21.05(1.36)	16.86(1.28)	12.00(1.14)	0(0.30)	18.03(1.18)^{efgh}
NBeG 738	37.68(1.60)	38.68(1.61)	22.32(1.39)	14.10(1.21)	11.74(1.14)	5.16(0.69)	21.61(1.27)^{d}
NBeG 753	34.49(1.56)	33.37(1.55)	27.39(1.47)	9.02(1.04)	0(0.30)	0(0.30)	17.38(1.04)^{k}
NBeG 773	32.85(1.54)	34.54(1.56)	28.34(1.48)	21.17(1.36)	8.51(1.02)	0(0.30)	20.90(1.21)^{e}
NBeG 778	36.97(1.59)	36.10(1.58)	27.43(1.47)	15.74(1.25)	9.55(1.06)	0(0.30)	20.96(1.21)^{ef}
NBeG 779	28.14(1.48)	33.32(1.55)	13.94(1.20)	16.16(1.26)	12.15(1.14)	0(0.30)	17.28(1.15)^{h}
NBeG 785	23.51(1.41)	31.72(1.53)	10.51(1.10)	0(0.30)	0(0.30)	0(0.30)	10.96(0.82)^{n}
NBeG 786	30.88(1.52)	32.30(1.54)	24.78(1.43)	12.20(1.15)	0(0.30)	0(0.30)	16.69(1.04)^{k}
NBeG 798	34.21(1.56)	35.98(1.58)	26.18(1.45)	19.64(1.34)	0(0.30)	0(0.30)	19.34(1.09)^{i}
NBeG 806	34.56(1.56)	32.68(1.54)	26.19(1.45)	19.64(1.12)	0(0.30)	0(0.30)	17.45(1.05)^{jk}
NBeG 857	36.55(1.59)	32.63(1.54)	27.13(1.46)	18.10(1.30)	0(0.30)	0(0.30)	19.07(1.08)^{ij}
NBeG 864	33.21(1.55)	37.43(1.60)	20.80(1.36)	13.18(1.17)	10.01(1.05)	0(0.30)	19.11(1.17)^{fgh}
NBeG 868	34.46(1.56)	34.51(1.56)	16.77(1.27)	11.39(1.12)	11.23(1.12)	0(0.30)	18.06(1.16)^{h}
NBeG 1004	35.23(1.57)	36.01(1.58)	30.06(1.51)	11.22(1.12)	0(0.30)	0(0.30)	18.75(1.06)^{ijk}
JG 11	38.89(1.61)	32.31(1.54)	30.05(1.51)	23.49(1.41)	21.16(1.36)	12.66(1.17)	26.43(1.43)^{a}
KAK 2	34.95(1.57)	33.39(1.55)	26.63(1.46)	16.22(1.26)	10.25(1.08)	4.25(0.66)	20.95(1.26)^{d}
NBeG 119	32.98(1.54)	34.63(1.56)	26.16(1.45)	17.63(1.29)	12.34(1.15)	7.16(0.96)	21.81(1.33)^{c}
NBeG 399	31.40(1.52)	33.39(1.55)	18.61(1.31)	12.30(1.16)	9.08(1.04)	3.58(0.63)	18.06(1.20)^{efg}
NBeG 471	34.58(1.56)	34.03(1.56)	23.44(1.41)	14.49(1.22)	7.31(0.96)	0(0.30)	18.98(1.17)^{gh}
NBeG 529	23.02(1.40)	30.72(1.51)	10.59(1.10)	9.09(1.04)	0(0.30)	0(0.30)	12.23(0.94)^{m}
NBeG 723	19.03(1.32)	27.24(1.47)	6.14(0.91)	0(0.30)	0(0.30)	0(0.30)	8.74(0.77)^{o}
NBeG 789	24.40(1.42)	31.04(1.52)	17.78(1.30)	11.01(1.11)	0(0.30)	0(0.30)	14.04(0.99)^{l}
NBeG 801	33.78(1.55)	32.20(1.53)	22.11(1.38)	12.94(1.17)	8.13(1.00)	0(0.30)	18.19(1.16)^{h}
NBeG 805	24.57(1.42)	29.06(1.49)	11.59(1.13)	0(0.30)	0(0.30)	0(0.30)	10.87(0.83)^{n}
NBeG 829	35.92(1.58)	34.42(1.56)	28.86(1.49)	19.31(1.33)	12.95(1.17)	5.38(0.87)	22.80(1.33)^{bc}
NBeG 833	24.94(1.43)	27.06(1.46)	8.28(1.01)	0(0.30)	0(0.30)	0(0.30)	10.05(0.80)^{n}
NBeG 835	29.52(1.50)	29.67(1.50)	10.09(1.08)	8.03(1.00)	0(0.30)	0(0.30)	12.88(0.95)^{m}
NBeG 837	25.91(1.44)	31.34(1.52)	11.01(1.11)	10.70(1.10)	0(0.30)	0(0.30)	13.16(0.96)^{lm}
NBeG 839	32.45(1.54)	34.59(1.56)	13.42(1.19)	9.27(1.05)	0(0.30)	0(0.30)	14.95(0.99)^{l}
Mean	31.70(1.52)^{B}	33.16(1.54)^{A}	20.88(1.33)^{C}	13.11(1.10)^{D}	6.16(0.74)^{E}	1.39(0.42)^{F}	17.73(1.11)
		G	T	G x T			
	S Em ±	0.012	0.005	0.030			
	CD (5%)	0.034	0.015	0.084			
	CV (%)	5.435					

*Values in the parenthesis indicate log transformed values.

The mean values in the same column / row with the same alphabet are not significantly different as per DMRT ($P < 0.05$).

Table 6: **V**ariation among the chickpea genotypes for seedling vigour index under PEG 6000 induced drought stress.

Genotype	Treatments						Mean
	Control	Hydration	-0.3 MPa	-0.6 MPa	-0.9 MPa	-1.2 MPa	
NBeG 3	3699(3.57)*	3280(3.52)	2463(3.39)	1423(3.15)	602(2.78)	158(2.20)	1937(3.10)^{b}
NBeG 47	3278(3.52)	3169(3.50)	1284(3.11)	661(2.82)	91(1.97)	0(0.30)	1414(2.54)^{hi}
NBeG 49	3182(3.50)	3156(3.50)	1906(3.28)	982(2.99)	148(2.17)	0(0.30)	1562(2.62)^{fg}
NBeG 452	3641(3.56)	3406(3.53)	2537(3.40)	510(2.71)	195(2.30)	0(0.30)	1715(2.63)^{f}
NBeG 506	2640(3.42)	3081(3.49)	1974(3.30)	792(2.90)	108(2.04)	0(0.30)	1432(2.57)^{gh}

Table 6: Continue...

Table 6: Continue...

NBeG 738	3448(3.54)	3626(3.56)	2009(3.30)	852(2.93)	270(2.43)	15(0.91)	1704(2.78)^{e}
NBeG 753	3114(3.49)	2953(3.47)	706(2.85)	171(2.24)	0(0.30)	0(0.30)	1157(2.11)^{o}
NBeG 773	3285(3.52)	3272(3.52)	2119(3.33)	1588(3.20)	79(1.91)	0(0.30)	1724(2.63)^{fg}
NBeG 778	3594(3.56)	3086(3.49)	2229(3.35)	1188(3.08)	89(1.95)	0(0.30)	1698(2.62)^{fg}
NBeG 779	2737(3.44)	2698(3.43)	844(2.92)	380(2.58)	146(2.16)	0(0.30)	1134(2.47)^{jkl}
NBeG 785	2063(3.31)	2909(3.46)	137(2.14)	0(0.30)	0(0.30)	0(0.30)	852(1.64)^{r}
NBeG 786	2879(3.46)	3020(3.48)	819(2.91)	174(2.24)	0(0.30)	0(0.30)	1149(2.12)^{no}
NBeG 798	3079(3.49)	3310(3.52)	1571(3.20)	643(2.81)	0(0.30)	0(0.30)	1434(2.27)^{m}
NBeG 806	3222(3.51)	2491(3.40)	1329(3.12)	231(2.37)	0(0.30)	0(0.30)	1212(2.17)^{n}
NBeG 857	3317(3.52)	2953(3.47)	1587(3.20)	145(2.17)	0(0.30)	0(0.30)	1334(2.16)^{no}
NBeG 864	3223(3.51)	3481(3.54)	1441(3.16)	344(2.54)	44(1.67)	0(0.30)	1422(2.44)^{kl}
NBeG 868	3351(3.53)	3390(3.53)	964(2.98)	234(2.37)	61(1.80)	0(0.30)	1333(2.42)^{l}
NBeG 1004	3523(3.55)	3178(3.50)	1240(3.09)	166(2.22)	0(0.30)	0(0.30)	1351(2.16)^{no}
JG 11	3841(3.58)	2932(3.47)	2727(3.44)	1915(3.28)	1180(3.07)	152(2.19)	2125(3.17)^{a}
KAK 2	3424(3.53)	3197(3.50)	2091(3.32)	1232(3.09)	277(2.45)	13(1.17)	1706(2.85)^{e}
NBeG 119	2976(3.47)	3047(3.48)	2269(3.36)	1256(3.10)	456(2.66)	43(1.65)	1675(2.95)^{d}
NBeG 399	2802(3.45)	3031(3.48)	1400(3.15)	664(2.82)	146(2.16)	11(1.10)	1342(2.69)^{f}
NBeG 471	3182(3.50)	3182(3.50)	1465(3.17)	493(2.69)	76(1.88)	0(0.30)	1399(2.51)^{ij}
NBeG 529	2037(3.31)	2764(3.44)	135(2.13)	39(1.60)	0(0.30)	0(0.30)	829(1.85)^{q}
NBeG 723	1631(3.21)	2186(3.34)	49(1.70)	0(0.30)	0(0.30)	0(0.30)	644(1.52)^{t}
NBeG 789	2093(3.32)	2250(3.35)	902(2.96)	124(2.10)	0(0.30)	0(0.30)	895(2.05)^{p}
NBeG 801	3243(3.51)	2704(3.43)	1305(3.11)	479(2.68)	73(1.87)	0(0.30)	1301(2.49)^{ijk}
NBeG 805	2162(3.33)	2673(3.43)	151(2.18)	0(0.30)	0(0.30)	0(0.30)	831(1.64)^{r}
NBeG 829	3494(3.54)	3295(3.52)	2561(3.41)	989(3.00)	571(2.75)	81(1.91)	1832(3.02)^{c}
NBeG 833	2282(3.36)	2490(3.40)	66(1.83)	0(0.30)	0(0.30)	0(0.30)	806(1.58)^{s}
NBeG 835	2753(3.44)	2767(3.44)	151(2.18)	32(1.53)	0(0.30)	0(0.30)	951(1.87)^{q}
NBeG 837	2306(3.36)	2852(3.46)	140(2.15)	43(1.65)	0(0.30)	0(0.30)	890(1.87)^{q}
NBeG 839	3034(3.48)	3182(3.50)	429(2.63)	105(2.02)	0(0.30)	0(0.300	1125(2.04)^{p}
Mean	2986(3.47)^{A}	3000(3.47)^{A}	1303(2.93)^{B}	541(2.30)^{C}	140(1.35)^{D}	14(0.56)^{E}	1331(2.35)
			G	T	G x T		
		S Em ±	0.018	0.008	0.045		
		CD (5%)	0.051	0.022	0.124		
		CV (%)		3.812			

*Values in the parenthesis indicate log transformed values.

The mean values in the same column / row with the same alphabet are not significantly different as per DMRT ($P < 0.05$).

during germination and early seedling growth. Seedling vigour index of all the genotypes in the present study ranged from 644 (NBeG 723) to 2125 (JG 11) (Table 6). NBeG 3 (1937) exhibited superior seedling vigour next to JG 11. NBeG 833 (806) recorded slightly more seedling vigour than NBeG 723. With the increase in drought stress, seedling vigour index decreased drastically. Highest seedling vigour index was observed in hydration (3000) which was at par with control (2986). Even at lower concentration of PEG (-0.3 MPa) 56.36% of decrease in seedling vigour over control was observed. Highest percent reduction (99.53%) in seedling vigour index over control was observed at -1.2 MPa (Fig 1). Gong *et al.* (2000) suggested that improvement of the seedling vigour index was associated with the enhancement of activated oxygen metabolism in seedlings.

CONCLUSION

The chickpea genotypes under study showed differential response to PEG induced drought stress that had an inhibitory effect on germination and seedling growth parameters. Based on the results obtained at various levels of PEG induced drought stress, JG 11 and NBeG 3 were considered as drought tolerant genotypes, because of their better germination and seedling growth even at -1.2 MPa. NBeG 723 and NBeG 833 were categorized as drought sensitive since their germination and seedling performance was severely affected even at -0.3 MPa. These genotypes need to be further tested tor their response to water stress conditions at different growth stages under field conditions in different locations.

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