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Effect of elevated temperature on seed germination and seedling growth indices of chickpea genotypes (*Cicer arietinum* L.)

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Abstract
Seeds of twenty chickpea genotypes were subjected to five levels (15/15 ºC, 20/20 ºC, 25/15 ºC, 25/20 ºC and 25/25 ºC) of elevated temperature. Daily germination count, seedling length, germination percentage, promptness index, seedling vigour and various germination stress indices were recorded two days after starting germination test. The elevated temperature stress reduced germination percentage, shoot length and root length of seedling in all genotypes. Among the various temperature regimes, the temperature 15/15 ºC and 20/20 ºC found better for all the recorded parameters with their index. The genotypes Digvijay, PG 96006 and PG 625 recorded highest germination percentage with maximum seedling length, promptness index (PI), germination stress index (GSI), vigour index (VI), coefficient velocity of germination (CVG) with minimum stress susceptibility index (STI). Results also indicated that different growth indices were found effective tool for early screening of heat tolerant and susceptible chickpea genotypes.

Keywords: Chickpea, genotypes, germination, index, temperature

Introduction
Chickpea (*Cicer arietinum* L.) is one of the important legume crops being rich in protein content and that can be grown under a wide range of environments. However, in current scenario productivity of chickpea decreases due to several abiotic stresses. Out of that, temperature is one of the most important determinants of crop growth over a range of environments and may limit chickpea yield.

Better seed germination and seedling emergence are important prerequisites for a successful crop. Germination is considered as a critical step in plants development cycle. In fact, it controls the onset of seedling, its connection to the environment and probably its subsequent productivity. Under optimum moisture and temperature conditions, chickpea seeds imbibe water quickly and germinate within a few days. But, at elevated temperature germination negatively affects on seed germination (Verma *et al*. 2010) [29]. In fact, the optimum temperature for maximum final germination is between 10 and 15 °C (Ellis *et al*. 1986) [7]. Clarke *et al*. (2004) [6] showed that low temperatures represent a major constraint for improving the yield of chickpea in numerous regions of the world.

Many of the researchers demonstrated that, the elevated temperatures causes' internal cell injury and even death may occur within few minutes and eventually could be attributed to collapse of cellular organization (Schoffl *et al*. 1999) [26]. Direct injuries due to high temperatures include protein denaturation, aggregation, and increased fluidity of membrane lipids. Indirect or slower heat injuries include inactivation of enzymes in chloroplast and mitochondria, inhibition of protein synthesis, protein degradation and loss of membrane integrity (Howarth, 2005) [14]. All the metabolic activity of plant affects on seedling growth and development finally leads to reduction in growth indices. Essemine *et al.* (2010) [9] reported that temperature inhibited growth of wheat seedling.

Considering all the above findings, screening of the germplasm in the controlled environments for temperature stress response has increased our knowledge of plant responses to stress, and this information has been used in crop improvement. This work aimed to undertake an effect of elevated temperature on seed germination and seedling growth indices on chickpea genotypes.

Materials and Methods

The experiment was conducted in 2014-15 at Phytotron facility, PGI, MPKV, Rahuri, Maharashtra, India. The experiment consisted of twenty chickpea genotypes (PG 12110, Virat, PG 405, PG 12107, PG 625, Vijay, PG 9758, PG 96006, PG 0625-9, PG 717, PG 08108, PG 11117, Digvijay, PG 0906-1, PG 719, Vihar, PG 611, Vishal, PG 609-15-2 and ICC 4958) with combination of five elevated temperatures (15/15 ºC, 20/20 ºC, 25/15 ºC, 25/20 ºC and 25/25 ºC) and two replications laid out in FCRD.

The thermo-treatments were given separately in different growth chambers as mentioned above. The seed surface was sterilized with 10% sodium hypo chloride solution for five minutes and washed three times with distilled water. For germination test, ten seeds of every genotype were sown separately in petri dish covering by Whatmann filter paper. The 5 ml of Hoagland solution was added in each petridish. Number of seeds germinated was counted from 2nd day and the data was recorded upto 8th day. Shoot length and root length of seedling were recorded 8th days after start of the experiment, by using these data calculated germination stress indices are as follows

1. Germination Percentage (GP): Percentage of germination stress tolerance index was measured on 8th day using formula given by Al-mudaris (1998) [2]

$$GP\ (\%) = \frac{\text{Total number of germinated seeds}}{\text{Total seeds sown}} \times 100$$

2. Promptness Index (PI): It was calculated from the data of percentage of seed germinated starting from 2nd day up to 8th day (George, 1967) [13].

$$PI = nd_2\ (1.00) + nd_4\ (0.75) + nd_6\ (0.50) + nd_8\ (0.25)$$

nd_2, nd_4, nd_6 and nd_8 = Percent of seeds observed for germination after 2, 4, 6 and 8th days after observation.

3. Vigour Index (VI): (Abdul-Baki and Anderson, 1970) [1]

$$VI\ \frac{\text{Total germination (\%) X Seedlings length (mm)}}{100}$$

4. Germination Stress Index (GSI): (Al-mudaris, 1998) [2]

$$GSI\ (\%) = \frac{\text{Promptness index of stressed seeds}}{\text{Promptness index of control seeds}} \times 100$$

5. Germination Rate Index (GRI): (Al-mudaris, 1998) [2]

$$GRI = \frac{G1}{1} + \frac{G2}{2} + \text{---} + \frac{Gx}{X}$$

Where, G_1, G_2…, G_x represents the percentage of germination in 1st, 2nd and xth day after sowing respectively

6. Mean Germination Time (MGT): (Ellis and Roberts, 1981) [8];

$$MGT = \Sigma\ (ni/di)$$

Where, ni: number of germinated seeds and di: day of counting

7. Coefficient of Germination Velocity (CVG): (Kader and Jutzi, 2004) [17]

$$CVg = \frac{\Sigma Ni}{100} \times \Sigma(Ti \times Ni)$$

Where, Ni is the number of seeds germinated every day and Ti is the number of days from seeding corresponding to Ni.

8. Stress Susceptibility Index (SSI): (Sammar Raza *et al*. 2012) [25]

$$SI = 1 - \frac{\text{Promptness index of stressed seeds } (PI_0)}{\text{Promptness index of control seeds } (PI_1)}$$

$$SSI = \frac{1-[PI_0/PI_1]}{D} \quad \text{Where, } D = 1 - \frac{\text{Population mean of } PI_0}{\text{Population mean of } PI_1}$$

The data were statistically analyzed separately for each parameter/index by a two-way ANOVA (by using IBM SPSS 25 software) according to the adopted experimental design combining temperature treatments and genotypes. The differences between the means were compared by the least significant difference (LSD) test ($p \leq 0.05$).

Results and Discussion

Seed germination is the most sensitive stage in the plant life cycle (Ashraf and Mehmood, 1990) [3] and unfavorable environmental conditions causes negative impact on the seed germination. Different seed germination test for stress tolerance determine the stress tolerance capacity of the chickpea genotypes.

Germination occurs when the embryo elongates and the radical protrudes from the seed coat. For many species, enzymes responsible to facilitate this process and chemical signaling regulates production of enzymes, which is in turn regulated by temperature (Finch-Savage and Leubner-Metzger, 2006) [11]. If the temperature rises, then these enzymes may become inactive (Peterson *et al*. 2007) [21]. Due to the temperature dependency of hormones and enzymes, a drastic change in temperature will significantly affect germination. In present study, germination significantly affected by elevated temperature levels, genotypes and their interaction (Table 1, Figure 1 and 5). The germination count and its percentage decreases with increasing temperature, diverse genetic differences were found among the genotypes. The maximum mean germination count (9.88) and percentage (98.75%) was recorded in 15/15 ºC temperature while lowest (7.83 and 78.25%, respectively) in temperature treatment of 25/25 ºC. Among the genotypes Digvijay and PG 96006 exhibited less sensitivity to temperature as they recorded maximum germination count and germination percentage (9.40 and 94%, respectively). These findings are in agreement with the outcomes Sleimi *et al*. (2013) [27] and Bankaji *et al*. (2008) [5] who reported optimum constant temperature for maximum final germination as between 10 and 15 °C in chickpea.

At molecular level, high temperatures adversely affect cell metabolism (Levitt, 1980) [20] and cause changes in the pattern of protein synthesis (Larkindale *et al*. 2005) [18]. Supra-

optimal temperature suppress the synthesis of the normal complement of cellular proteins and at the same time induce the synthesis and accumulation of many new proteins including heat shock proteins (Feder and Hofmann, 1999 and Law and Brandner, 2001) [10, 18] such changes under heat stress cause reduced plant growth to sustain under adverse condition. In present study shoot, root and total seeding length significantly differ among genotypes, temperature and their interaction (Table 1, Figure 2, 3 and 4). The shoot, root and total seeding length decreases with increase in the temperature levels. The mean shoot, root and total seedling length was higher at 15/15 ºC (6.02, 9.90 and 15.92 cm, respectively) and lower at 25/25 ºC (5.01, 8.50 and 13.50 cm, respectively). By increasing temperature levels a different behavior among the genotypes was observed. The genotype PG-625 and PG 08108 recorded the highest mean shoot length (6.03 and 5.94 cm, respectively). Whereas the genotype PG-625 and Digvijay reported the highest mean root length (10.19 and 10.09 cm, respectively). Similarly, PG-625 and Digvijay showed a maximum seedling length. Similar findings were reported by Tripathi *et al*. (2009) [28] that high temperature significantly decreased seedling shoot length in wheat.

Based on the data, promptness index and germination stress index were calculated to identify the sensitive and tolerant chickpea genotypes. The promptness index and germination stress index showed significant differences among the genotypes and temperature while non-significant among its interaction effect (Table 1 and 2). Both the index decrease with increase in the temperature (Figure 6 and 8). The mean PI and GSI were higher at 15/15 ºC (56.25 and 100, respectively) and lower at 25/25 ºC (37.32 and 66.41, respectively). The genotype Digvijay recorded the highest mean PI (54.59) and GSI (88.76) followed by genotype PG 96006 (52.95 and 89.89, respectively) whereas Vishal recorded the least mean PI (39.83) and GSI (78.58). In present study high temperature stress significantly extended days, for germination which is evident from their speediness to germination (PI). At high temperature with increase in the duration of exposure to heat stress PI much lowered among all cultivars. It may be due the fact that heat stress reduces the water content of seeds, leading to the reduced activity of hydrolytic enzymes essential for carbohydrate metabolism and ultimately delayed germination (Wahid *et al*. 2007) [30]. Similarly, George (1967) [13] reported highest promptness index shows better germination percentage.

Seed vigor index is main indicator of rapid germination and seedling growth. It is an important parameter to identify overall performance of genotypes in different temperature regimes. The data on vigour index showed significant differences among genotypes and temperature while non-significant among its interaction effect (Table 2 and Figure 7). The vigour index decreases with increase in the temperature. The mean vigour Index was higher at 15/15 ºC (157.31) and lower at 25/25 ºC (105.93). The genotype Digvijay recorded the highest mean vigour Index (150.29) followed by PG 96006 (148.92 and PG 625 (146.57) whereas Vishal recorded the lowest vigour index (110.44). The highest vigor index relates superiority of the genotype grow more appropriately at different temperature regimes. Abdul-Baki and Anderson (1970) [1] reported that genotypes with highest vigour index performing better. Robert *et al*. (2008) [23] reported that both temperature and varietal differences are important factors to understand germination behavior and vigor index in wheat cultivars, also support the present results.

Germination rate index calculations merely show the percentage of germination per day, so the higher the percentage and the shorter the duration, the higher the GRI. Whereas the mean germination time is an accurate measure of the time taken for a germinate (Kader, 2005) [16]. In present study, data regarding GRI and MGT showed non-significant interaction effect among the genotypes and temperature and they decrease with increasing temperature (Table 2, Figure 9 and 10). The mean GRI and MGT were higher at 15/15 ºC (23.68 and 2.37, respectively) and lower at 25/25 ºC (16.31 and 1.63, respectively). The genotype Digvijay and PG 96006 recorded the highest GRI (23.05 and 22.55, respectively) and MGT (2.30 and 2.26, respectively) while Vishal recorded the least GRI (17.30) and MGT (1.73). These findings are in confirmation with the outcomes of Bankaji et al. (2008) [5] and Salehi (2012) [24] who reported that germination rate index decreased at high temperature in chickpea.

The coefficient velocity of germination (Jones and Sanders, 1987) [15] gives an indication of the rapidity of germination and increases when the number of germinated seeds increases and the time required for germination decreases. The present data showed non-significant interaction effect among the genotypes and temperature (Table 2 and Figure 11). The mean coefficient velocity of germination decreased with increasing the temperature. The mean CVG was higher at 15/15 ºC (1.06) and lower at 25/25 ºC (0.63). The genotype Digvijay recorded the highest mean CVG (0.94) and Vishal and PG-12107 both recorded the least (0.71). Present results supported by Auld *et al*. (1982) [4] and Bankaji *et al*. (2008) [5], they noted delayed germination with rise in temperature from 15 ºC to 30 ºC in chickpea.

The stress susceptibility index (SSI) (Fisher and Maurer, 1978) [12] is a ratio of genotypic performance under stress and non-stress conditions. The data on stress susceptibility index showed non-significant interaction effect among the genotypes and temperature (Table 2 and Figure 12). The mean stress susceptibility index increases with increasing the temperature. The mean stress susceptibility index was higher at 15/15 ºC (0.00) and lower at 25/25 ºC (0.92). The genotype Digvijay recorded the minimum mean stress susceptibility index (0.40) and the genotypes Vishal and PG-9758 both recorded highest mean stress susceptibility index (0.80). Sammar Raza *et al*. (2012) [25] reported that genotypes with less stress susceptibility index show better germination. Porch (2006) [22] also identifies superior bean genotypes for heat tolerance based on their stress indices.

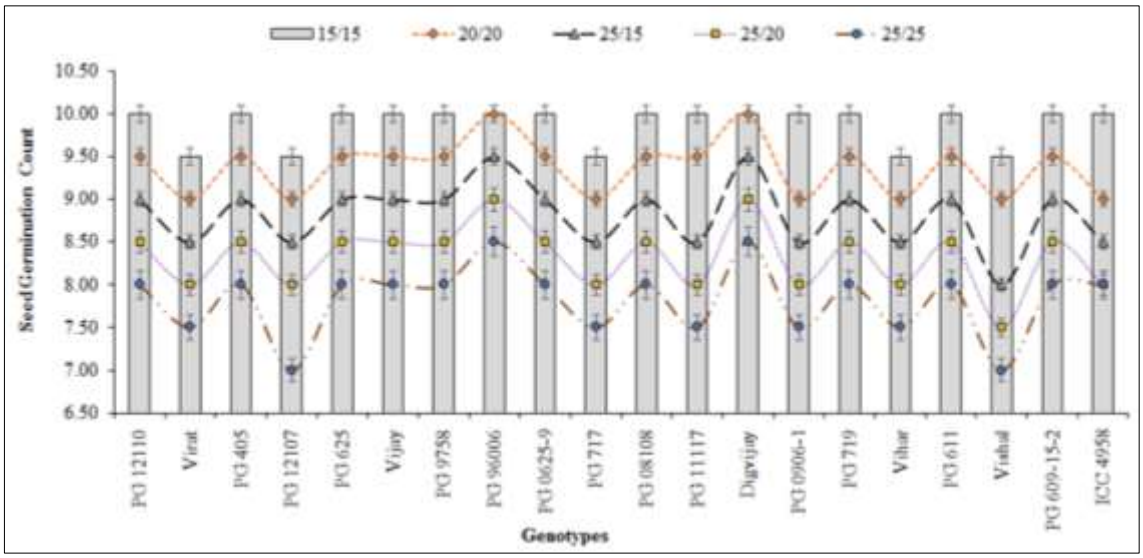

Fig 1: Seed germination count of chickpea genotypes influenced under varying temperatures

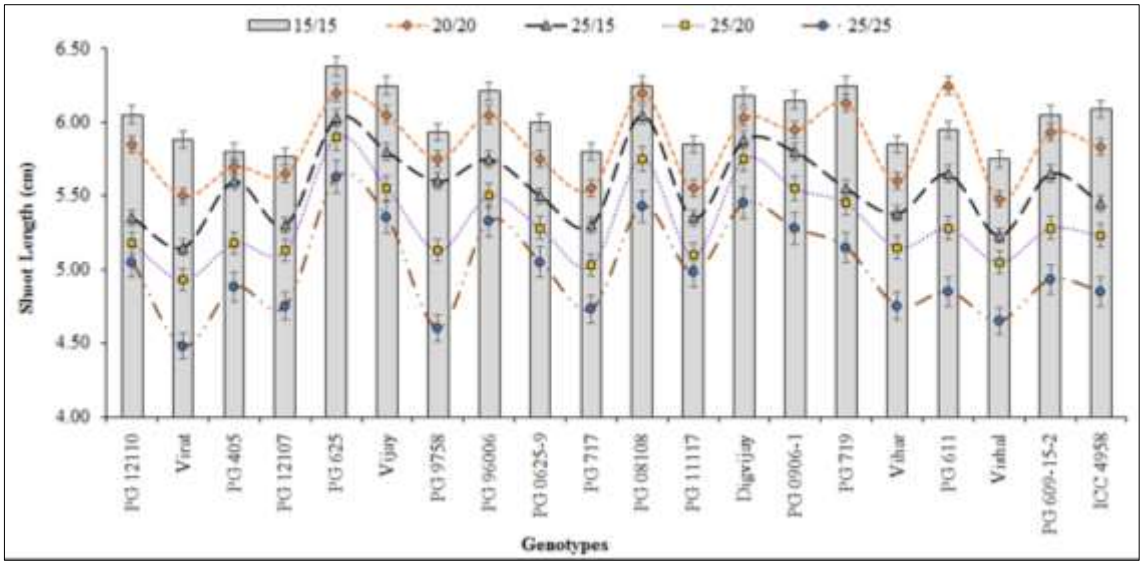

Fig 2: Shoot length of chickpea genotypes influenced under varying temperatures

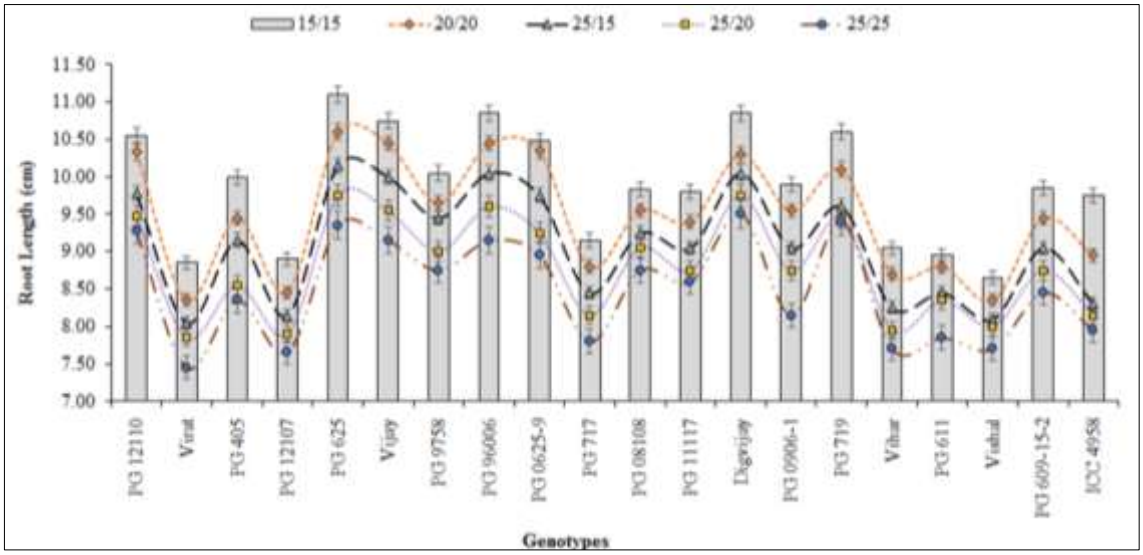

Fig 3: Root length of chickpea genotypes influenced under varying temperatures

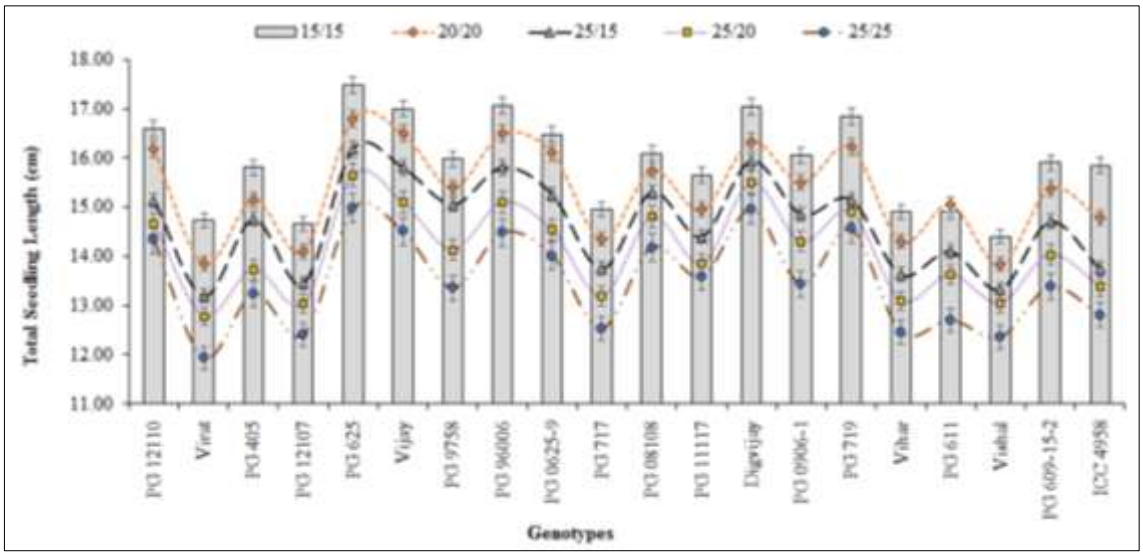

Fig 4: Total seedling length of chickpea genotypes influenced under varying temperatures

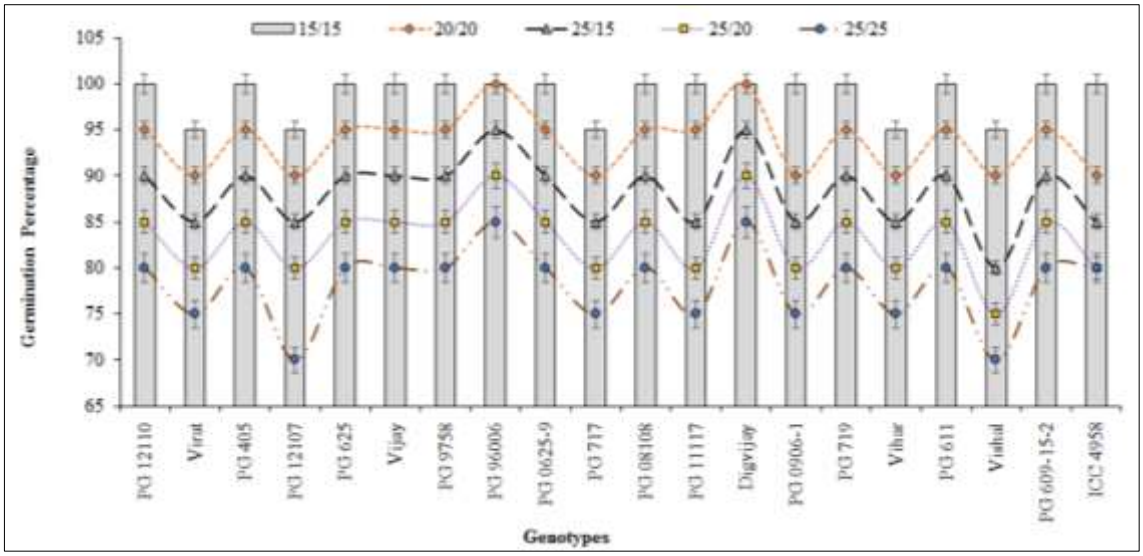

Fig 5: Germination percentage of chickpea genotypes influenced under varying temperatures

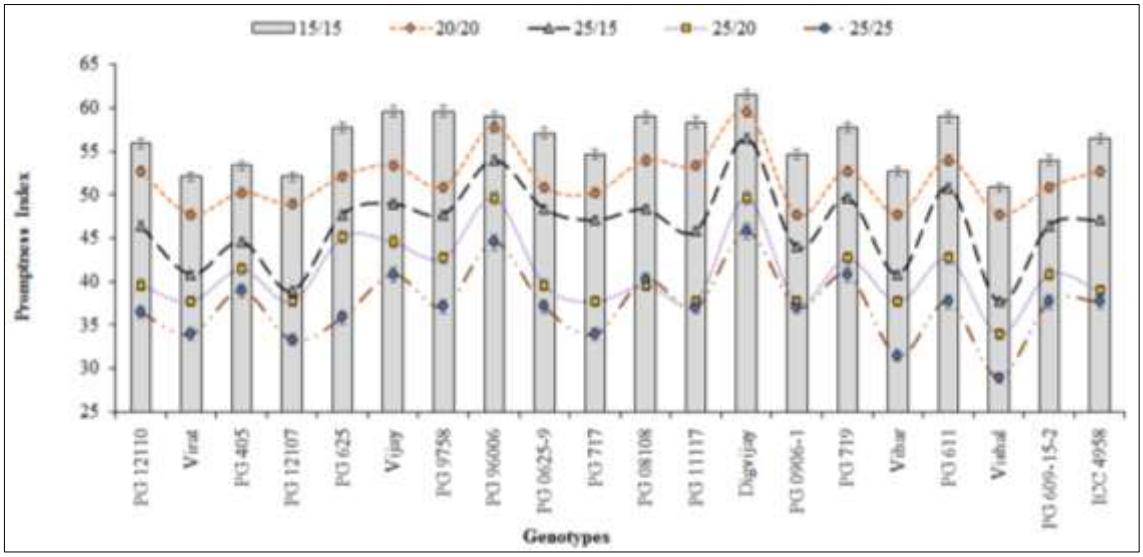

Fig 6: Promptness index of chickpea genotypes influenced under varying temperatures

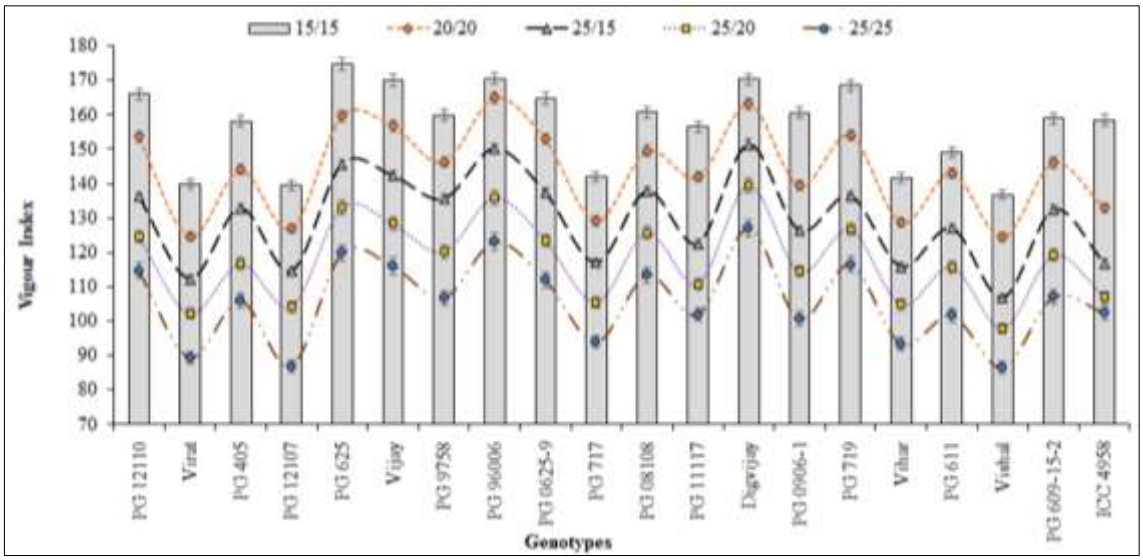

Fig 7: Vigour index of chickpea genotypes influenced under varying temperatures

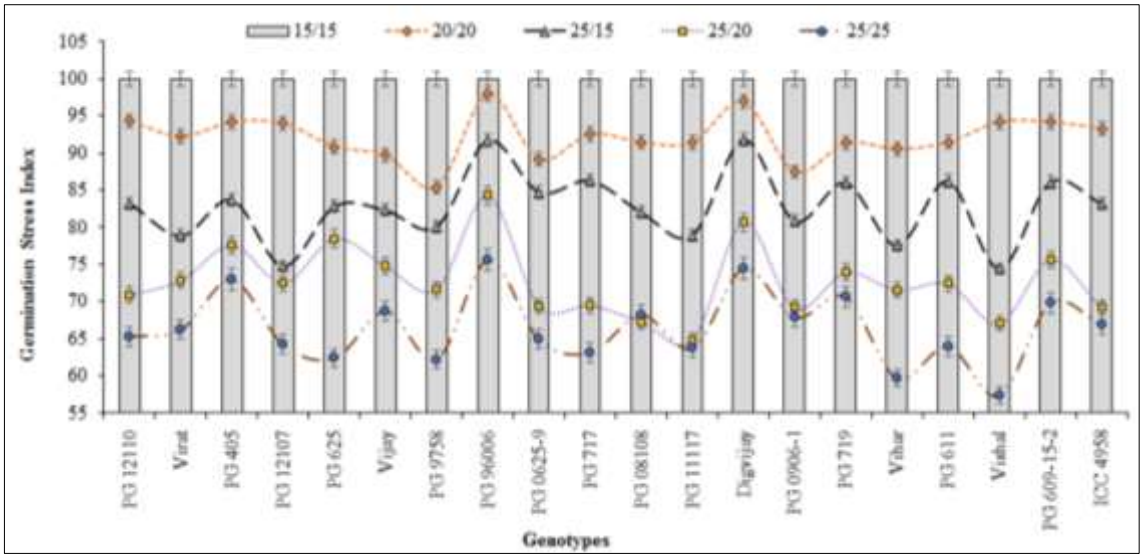

Fig 8: Germination stress index of chickpea genotypes influenced under varying temperatures

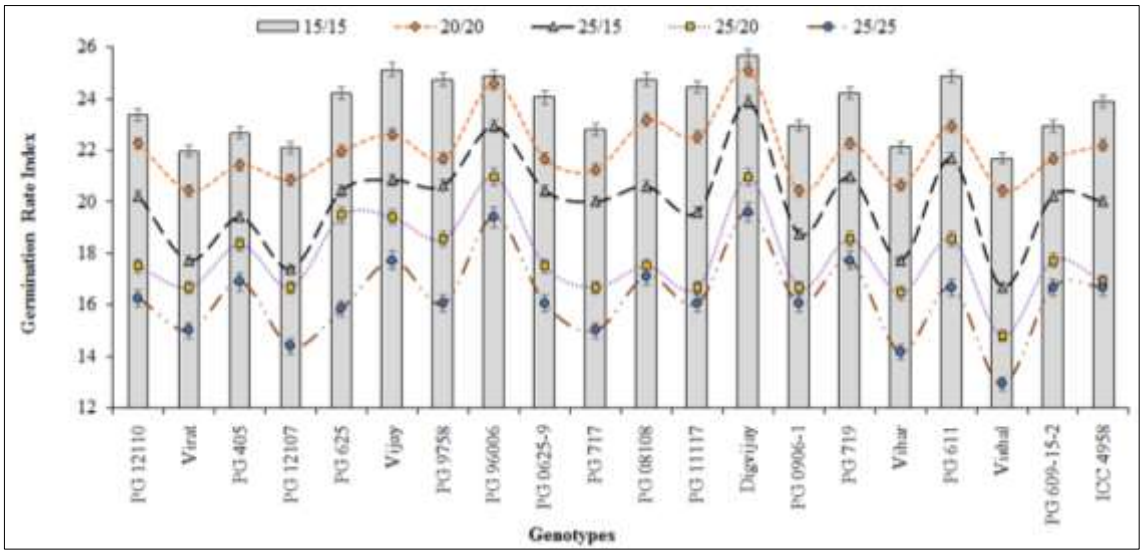

Fig 9: Germination rate index of chickpea genotypes influenced under varying temperatures

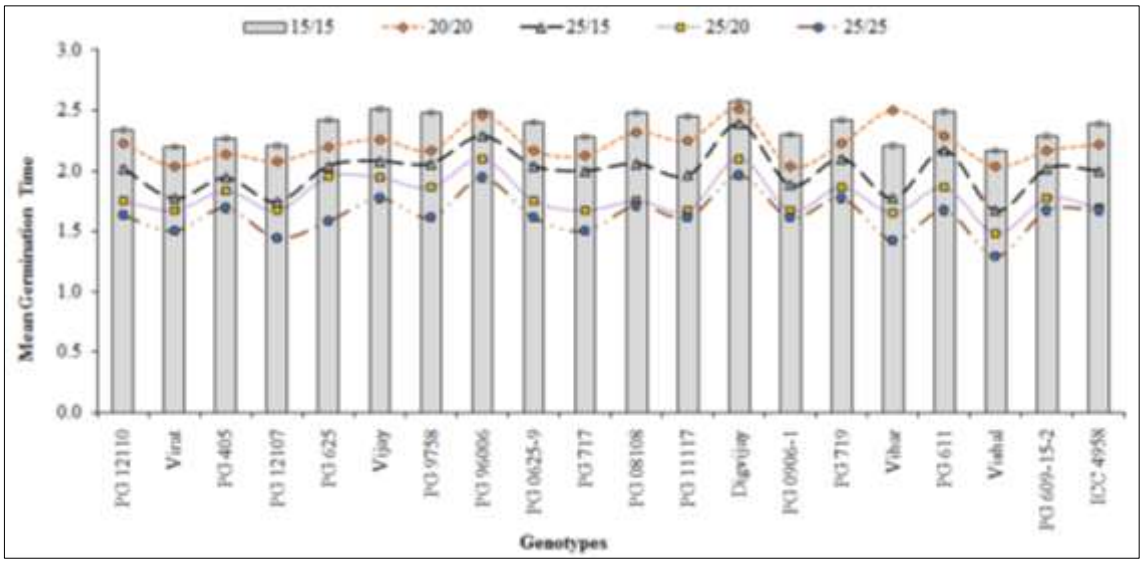

Fig 10: Mean germination time of chickpea genotypes influenced under varying temperatures

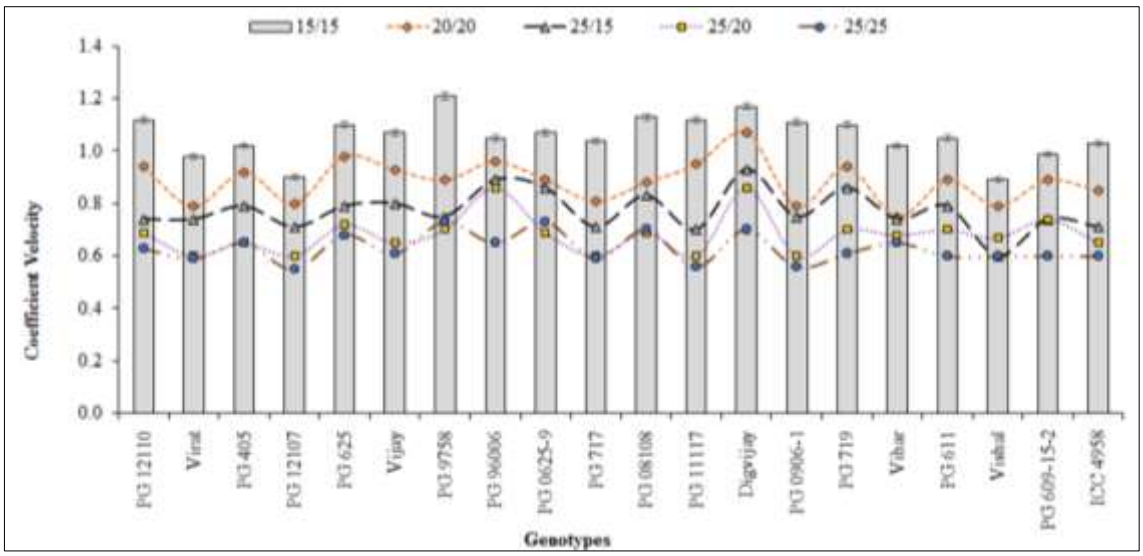

Fig 11: Coefficient velocity of chickpea genotypes influenced under varying temperatures

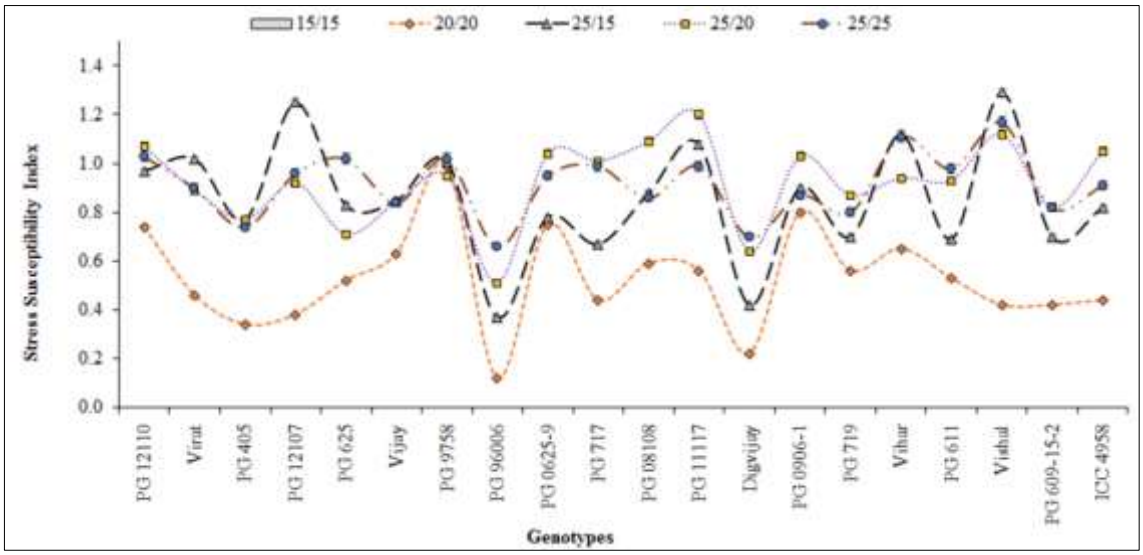

Fig 12: Stress susceptibility index of chickpea genotypes influenced under varying temperatures

Table 1: Mean values of studied indices for chickpea genotypes influenced under varying temperatures

	SGC	SL	RL	TSL	GP	PI
Temperature						
15/15 ºC	9.88±0.33^{a}	6.02±0.20^{a}	9.90±0.77^{a}	15.92±0.93^{a}	98.75±3.35^{a}	56.25±3.73^{a}
20/20 ºC	9.38±0.49^{b}	5.85±0.26^{b}	9.50±0.76^{b}	15.35±0.93^{b}	93.75±4.90^{b}	51.74±4.07^{b}
25/15 ºC	8.83±0.50^{c}	5.57±0.26^{c}	9.11±0.73^{c}	14.67±0.92^{c}	88.25±5.01^{c}	46.58±5.02^{c}
25/20 ºC	8.33±0.53^{d}	5.32±0.27^{d}	8.80±0.66^{d}	14.12±0.88^{d}	83.25±5.26^{d}	40.86±4.31^{d}
25/25 ºC	7.83±0.55^{e}	5.01±0.32^{e}	8.50±68^{e}	13.50±0.94^{e}	78.25±8.75^{e}	37.32±4.61^{e}
SE(m)±	0.108	0.018	0.032	0.035	1.08	0.682
p(LSD)	0.000	0.000	0.000	0.000	0.000	0.000
Genotypes						
PG 12110	9.00±0.82^{ab}	5.50±0.41^{f-i}	9.88±0.52^{b-d}	15.38±0.93^{cd}	90.00±8.16^{ab}	46.21±7.99^{c-f}
Virat	8.50±0.85 ^{b}	5.19±0.51^{m}	8.11±0.50^{i}	13.30±1.00^{i}	85.00±8.50^{b}	42.46±7.78^{d-g}
PG 405	9.00±0.94^{ab}	5.43±0.38^{g-j}	9.10±0.64^{f}	14.53±0.99^{f}	90.00±9.43^{ab}	45.71±6.33^{c-f}
PG 12107	8.40±0.97^{b}	5.32±0.39^{j-l}	8.21±0.46^{i}	13.53±0.84^{hi}	84.00±9.66^{b}	42.20±7.75^{e-g}
PG 625	9.00±0.82^{ab}	6.03±0.28^{a}	10.19±0.65^{a}	16.22±0.92^{a}	90.00±8.16^{ab}	47.70±8.12^{cd}
Vijay	9.00±0.82^{ab}	5.80±0.35^{cd}	9.98±0.62^{a-d}	15.78±0.96^{b}	90.00±8.16^{ab}	49.45±7.24^{bc}
PG 9758	9.00±0.82^{ab}	5.40±0.51^{h-k}	9.38±0.49^{e}	14.78±0.99^{e}	90.00±8.16^{ab}	47.59±8.39^{c-e}
PG 96006	9.40±0.70^{a}	5.77±0.35^{cd}	10.02±0.64^{a-c}	15.79±0.98^{b}	94.00±6.99^{a}	52.95±5.98^{ab}
PG 0625-9	9.00±0.82^{ab}	5.52±0.36^{f-h}	9.76±0.63^{d}	15.27±0.98^{d}	90.00±8.16^{ab}	46.60±8.13^{c-f}
PG 717	8.50±0.85^{b}	5.28±0.40^{k-m}	8.47±0.50^{gh}	13.75±0.90^{h}	85.00±8.50^{b}	44.70±8.71^{c-g}
PG 08108	9.00±0.82^{ab}	5.94±0.33^{ab}	9.29±0.40^{ef}	15.22±0.72^{d}	90.00±8.16^{ab}	48.20±8.25^{bc}
PG 11117	8.70±1.06^{ab}	5.37±0.34^{i-l}	9.12±0.58^{f}	14.49±0.86^{f}	87.00±10.49^{ab}	46.45±9.17^{c-f}
Digvijay	9.40±0.70^{a}	5.86±0.26^{bc}	10.09±0.50^{ab}	15.95±0.75^{b}	94.00±6.99^{a}	54.59±6.51^{a}
PG 0906-1	8.60±0.97^{ab}	5.75±0.33^{cd}	9.08±0.65^{f}	14.83±0.97^{e}	86.00±9.66^{ab}	44.20±7.18^{c-g}
PG 719	9.00±0.82^{ab}	5.71±0.44^{de}	9.83±0.49^{cd}	15.54±0.92^{c}	90.00±8.16^{ab}	48.70±7.12^{bc}
Vihar	8.50±0.85^{b}	5.35±0.41^{jkl}	8.33±0.52^{hi}	13.68±0.91^{h}	85.00±8.50^{b}	42.08±8.23^{fg}
PG 611	9.00±0.82^{ab}	5.60±0.52^{ef}	8.48±0.42^{gh}	14.08±0.92^{g}	90.00±8.16^{ab}	48.82±8.32^{bc}
Vishal	8.20±1.03^{b}	5.23±0.40^{lm}	8.16±0.35^{i}	13.39±0.74^{i}	82.00±10.33^{b}	39.83±8.85^{g}
PG 609-15-2	9.00±0.82^{ab}	5.57±0.44^{fg}	9.11±0.53^{f}	14.68±0.96^{ef}	90.00±8.16^{ab}	45.97±6.58^{c-f}
ICC 4958	8.70±0.82^{ab}	5.49±0.46^{f-i}	8.62±0.70^{g}	14.11±1.14^{g}	87.00±8.23^{ab}	46.58±8.13^{c-f}
SE(m)±	0.217	0.036	0.064	0.069	2.168	1.363
p(LSD)	0.343	0.039	0.045	0.021	0.343	0.172

SCG- Seed Germination Count; SL- Shoot Length; RL- Root Length; TSL-Total Seedling Length; GP- Germination Percentage; PI- Promptness Index

Table 2: Mean values of studied indices for chickpea genotypes influenced under varying temperatures

	VI	GSI	GRI	MGT	CVG	SSI
Temperature						
15/15	157.31±12.43^{a}	100.00±0.00^{a}	23.68±1.43^{a}	2.37±0.14^{a}	1.06±0.12^{a}	0.00±0.00^{a}
20/20	144.12±14.03^{b}	92.11±6.13^{b}	22.01±1.62^{b}	2.22±0.19^{b}	0.88±0.12^{b}	0.53±0.41^{b}
25/15	129.77±13.84^{c}	82.76±6.57^{c}	20.01±1.94^{c}	2.00±0.19^{c}	0.77±0.09^{c}	0.86±0.33^{c}
25/20	117.78±12.95^{d}	72.67±6.24^{d}	17.83±1.68^{d}	1.78±0.17^{d}	0.68±0.09^{d}	0.92±0.22^{c}
25/25	105.93±12.88^{e}	66.41±7.52^{e}	16.31±1.87^{e}	1.63±0.19^{e}	0.63±0.07^{d}	0.92±0.45^{c}
SE(m)±	1.61	1.41	0.273	0.30	0.023	0.067
p(LSD)	0.000	0.000	0.000	0.000	0.002	0.166
Genotypes						
PG 12110	138.97±20.29^{a-e}	82.74±14.26^{a}	19.93±2.93^{cd}	1.99±0.29^{cd}	0.82±0.21^{ab}	0.76±0.48^{a}
Virat	113.69±19.31^{hi}	82.04±15.35^{a}	18.36±2.88^{de}	1.84±0.29^{de}	0.74±0.18^{b}	0.65±0.48^{a}
PG 405	131.46±21.34^{c-f}	85.69±11.93^{a}	19.75±2.53^{cd}	1.97±0.25^{cd}	0.80±0.18^{ab}	0.53±0.41^{a}
PG 12107	114.34±19.85^{hi}	81.09±14.91^{a}	18.28±3.06^{de}	1.83±0.31^{de}	0.71±0.15^{b}	0.70±0.48^{a}
PG 625	146.57±21.18^{ab}	82.90±14.96^{a}	20.39±3.09^{cd}	2.04±0.31^{b-d}	0.85±0.20^{ab}	0.62±0.50^{a}
Vijay	142.66±21.02^{a-c}	83.09±12.66^{a}	21.14±2.84^{a-c}	2.11±0.28^{a-c}	0.81±0.19^{ab}	0.63±0.39^{a}
PG 9758	133.67±20.31^{c-f}	79.86±14.15^{a}	20.33±3.20^{cd}	2.03±0.32^{b-d}	0.85±0.21^{ab}	0.80±0.51^{a}
PG 96006	148.92±19.33^{ab}	89.89±10.66^{a}	22.55±2.40^{ab}	2.26±0.24^{ab}	0.88±0.16^{ab}	0.33±0.32^{a}
PG 0625-9	138.08±20.76^{a-e}	81.63±14.37^{a}	19.94±3.18^{cd}	1.99±0.32^{cd}	0.85±0.16^{ab}	0.71±0.49^{a}
PG 717	117.48±18.75^{g-i}	82.29±16.30^{a}	19.15±3.28^{c-e}	1.92±0.33^{c-e}	0.75±0.21^{b}	0.62±0.47^{a}
PG 08108	137.44±18.29^{b-e}	81.78±13.91^{a}	20.63±3.28^{bc}	2.06±0.33^{b-d}	0.84±0.18^{ab}	0.68±0.43^{a}
PG 11117	126.72±22.19^{e-g}	79.77±15.75^{a}	19.86±3.56^{cd}	1.99±0.36^{cd}	0.79±0.24^{ab}	0.77±0.53^{a}
Digvijay	150.29±17.39^{a}	88.76±10.59^{a}	23.05±2.58^{a}	2.30±0.26^{a}	0.94±0.19^{a}	0.40±0.31^{a}
PG 0906-1	128.26±22.22^{d-g}	81.07±13.54^{a}	18.98±2.80^{c-e}	1.90±0.28^{c-e}	0.76±0.21^{ab}	0.72±0.43^{a}
PG 719	140.40±20.40^{a-d}	84.37±11.55^{a}	20.74±2.74^{bc}	2.07±0.27^{bc}	0.84±0.20^{ab}	0.59±0.33^{a}
Vihar	116.83±18.63^{g-i}	79.85±15.62^{a}	18.23±3.15^{de}	1.91±0.46^{c-e}	0.77±0.14^{ab}	0.77±0.50^{a}
PG 611	127.26±19.04^{e-g}	82.80±13.87^{a}	20.94±3.23^{bc}	2.09±0.32^{a-c}	0.80±0.18^{ab}	0.63±0.39^{a}
Vishal	110.44±16.66^{i}	78.58±17.72^{a}	17.30±3.54^{e}	1.73±0.35^{e}	0.71±0.14^{b}	0.80±0.61^{a}
PG 609-15-2	132.72±20.12^{c-f}	85.13±12.19^{a}	19.85±2.56^{cd}	1.98±0.25^{cd}	0.79±0.15^{ab}	0.55±0.40^{a}

ICC 4958	123.52±21.67^{f-h}	82.50±14.02^{a}	19.93±3.13^{cd}	1.99±0.31^{cd}	0.77±0.17^{ab}	0.64±0.43^{a}
SE(m)±	3.221	2.817	0.545	0.059	0.045	0.134
p(LSD)	0.092	0.417	0.181	0.198	0.301	0.433

VI-Vigour Index: GSI- Germination Stress Index; GRI- Germination Rate Index; MGT- Mean Germination Time; CVG- Coefficient of Germination Velocity; SSI- Stress Susceptibility Index

Conclusion

The elevated temperature stress decreases all the recorded parameters in all genotypes. Among the various temperature regimes, the temperature 15/15 ºC and 20/20 ºC noted better germination percentage, seedling length and their indices as compared to other temperatures levels. The genotypes Digvijay, PG 96006 and PG 625 recorded highest germination percentage with maximum seedling length, promptness index (PI), germination stress index (GSI), vigour index (VI), mean germination rate (MGR) and coefficient velocity of germination (CVG) with minimum stress susceptibility index (STI). The results also indicated that different growth indices were found effective tool for early screening of heat tolerant and susceptible chickpea genotypes. Based on these seed germination, the genotypes PG 96006 and Digvijay are proved as a promising thermal stress tolerant genotypes at early growth stage of crop, thus they can be used in breeding programme for improvement of temperature stress tolerant varieties in chickpea crop.

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