



## Original Research

# In Vitro Screening of Chilli Germplasm for Drought Tolerance

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## ABSTRACT

Drought stress is a global problem. It is well established that it is a threat to almost all types of crops, including vegetables. Plant scientists have developed various strategies to deal with this menace. One of these strategies is to screen out tolerant genotypes which can withstand the stress. Chilli (*Capsicum frutescens* Mill.) is one of the most important horticultural crops used as a condiment all over the world. Chilli plants are susceptible to water-deficient conditions. Therefore, this study was conducted to screen out the available chilli germplasm for drought tolerance. In this study, 30 chilli genotypes were used to screen against drought stress. These chilli genotypes were screened under *in vitro* conditions using four different levels (0, 5, 10 and 15%) of polyethylene glycol-6000 (PEG-6000) solution, which were applied to seeds during germination. Drought stress induced by these levels of PEG-6000 solution indicated that all the studied parameters (germination percentage, average root and shoot lengths, average root and shoot fresh weights and average root and shoot dry weights) were negatively affected. On the basis of the results, chilli genotypes including Chilli Hot Queen, Advanta-509, Divya, HM-78, Hot Queen, High Fly 2 and Kot Sultan were found to be drought-tolerant genotypes. Whereas, HHP-091A, HHP-082B, Zenia, Acc.32362, Hot Red, C.K.D-2204, Sky Red, Sky Star 4, Sky Line 2, Kuni, Ghotki, Talhari, Amber, Red Giant, Hot Flame, Loralai and Pusa Jawala were drought-sensitive genotypes under *in vitro* conditions.

**Keywords:** *Capsicum frutescens*, genotypes, moisture stress, polyethylene glycol-6000.

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## INTRODUCTION

Chilli (*Capsicum frutescens* Mill.), a member of the plant family Solanaceae, is an important horticultural crop and is cultivated in many regions of the world, including Pakistan. All over the world, the crop is produced on a total area of 2.1 million hectares with an annual production of 36 million tons and an average yield of 17.46 tons ha<sup>-1</sup> (FAO, 2020). Green chilli fruits are added to salads and different dishes, and also used for garnishing. Its addition enriches the foods with several health-benefiting compounds such as ascorbic acid and other vitamins, carotenoids ( $\alpha$ - and  $\beta$ -carotene), capsaicinoids, flavonoids and minerals.

Drought is considered one of the main constraints threatening sustainable agricultural productivity as it may decrease crop yield up to 70% and also adversely affects the chemical composition and quality of the produce. Plants face drought stress due to two reasons: firstly, due to limited water

availability in the root zone for absorption by roots and secondly, a high rate of transpiration exceeding the plant water threshold level (Molla et al., 2021). Insufficient supply of water during the crop growing period is a serious concern throughout the world, including arid and semi-arid regions of Pakistan. However, plant species, even cultivars of the same species, considerably vary in their drought tolerance. Chilli is considered a drought-sensitive crop because of its shallow root system, and water deficit may result in drastic yield reductions (Molla et al., 2021). There is a need to investigate the drought tolerance of chilli genotypes and explore their physiological and biochemical reactions against stress (Kopta et al., 2020).

Moisture stress tolerance at seed germination stress has been correlated with drought tolerance at the whole plant level. Various osmotica such as polyethylene glycol (PEG), mannitol, sorbitol, sucrose, NaCl etc. have been used in stress tolerance studies to create moisture stress. However, PEG is most commonly used as an osmoticum to induce water stress in plant tissues because it increases the osmotic pressure of a solution and prevents inward flow of water across a semipermeable membrane.

PEG-induced moisture stress is the most commonly used screening method for drought tolerance studies in crop plants (Awan et al., 2021). It is a rapid method of screening for a large number of genotypes at the germination stage (Sharma et al.,

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**Table 1:** Chilli genotypes and their sources.

| No. | Genotype            | Source of collection                     |
|-----|---------------------|------------------------------------------|
| 1   | Acc.32362           | NARC Islamabad                           |
| 2   | Advanta-509         | ICI Pakistan Limited                     |
| 3   | Amber               | Dongbu Farm Seeds                        |
| 4   | Chander Mukhi       | Trusted Seeds                            |
| 5   | Chilli Hot Queen    | Agricopak Seeds                          |
| 6   | C.K.D-2204          | C.K.D Seeds                              |
| 7   | Divya               | Bayer Seeds (Bayer Crop Science)         |
| 8   | F <sub>1</sub> 1130 | Maryland Hybrid Seeds                    |
| 9   | Ghotki              | Chillies Research Institute Kunri, Sindh |
| 10  | HHP-082B            | Kanzo (Evyol Group)                      |
| 11  | HHP-091A            | Kanzo (Evyol Group)                      |
| 12  | High Fly 2          | Nongwoo Bio                              |
| 13  | HM-78 (Sv-7864-HM)  | Seminis Seeds                            |
| 14  | Hot Flame           | Genetic Seeds                            |
| 15  | Hot Queen           | Nature Seeds                             |
| 16  | Hot Red             | American Seeds                           |
| 17  | Kot Sultan          | Local Market                             |
| 18  | Kunri               | Chillies Research Institute Kunri, Sindh |
| 19  | Loralai             | Local Market                             |
| 20  | Nagena              | Chillies Research Institute Kunri, Sindh |
| 21  | Pusa Jawala         | Local Market                             |
| 22  | Rainbow             | C.K.D Seeds                              |
| 23  | Red Giant           | Birkel Seeds                             |
| 24  | Shakti              | Trusted Seeds                            |
| 25  | Sky Hot             | Golden Seed Company                      |
| 26  | Sky Red             | Seminis Seeds                            |
| 27  | Sky Star 4          | Agrotech Seeds                           |
| 28  | Sky Line 2          | Seminis Seeds                            |
| 29  | Talhari             | Chillies Research Institute Kunri, Sindh |
| 30  | Zenia               | Agrarian Seeds                           |

2024). However, response to osmotic stress varies among plant species, cultivars, growing conditions, growth stages and PEG concentrations (Yadav et al., 2019).

To study the impact of moisture stress on seed germination and early seedling growth, Steiner and Zuffo (2019) subjected seeds of eggplant, carrot, watermelon, and arugula to different osmotic potentials (0.0, -0.2, -0.4 and -0.8 MPa) induced by PEG. As the level of osmotic potential increased, the number of seeds germinated, the rate of germination, the length and dry matter content of root and shoot, and seedling vigour decreased. In contrast, the mean time to germinate and the root-to-shoot ratio increased in all four studied vegetables. Severe drought stress adversely inhibited seed germination and seedling growth. However, eggplant and arugula were more tolerant to drought stress than carrot and watermelon.

Molla et al. (2019) evaluated 47 genotypes of sweet pepper (*Capsicum annuum* L.) at the germination stage using 12.5% PEG-6000 for their genetic drought tolerance potential. They observed substantial differences among the studied genotypes, indicating a considerable variability for drought tolerance. Gangotri et al. (2022) evaluated 34 genotypes of chilli for drought tolerance using PEG-6000 (10%). Among the studied genotypes, three (Arka Lohit, DB variety and Dappa) were found drought tolerant on the basis of highest germination %, and root

and shoot lengths. Sharma et al. (2024) screened 16 chilli genotypes using 4 levels of PEG-6000, i.e. 0% (control), 5% (-0.3 Mpa), 10% (-0.6 Mpa) and 15% (-0.9 Mpa) under in vitro conditions at the seeding stage for their drought tolerance. Among the 16 genotypes evaluated, UARCH 42, UARCH 43 and Arka Swetha were found to be drought-tolerant. In a study, Eesha et al. (2024) concluded that PEG-induced moisture stress can be used to screen out the available germplasm for drought tolerance.

However, there is a need to screen available chilli cultivars in Pakistan for drought tolerance using this PEG-induced stress. Therefore, the objective of the present work was to screen out the available chilli germplasm for drought tolerance by inducing moisture stress for seeds through different levels of PEG-6000 solution.

## MATERIALS AND METHODS

Seeds of 30 chilli (*Capsicum frutescens* Mill.) genotypes were collected from different resources (Table 1). These genotypes were evaluated for their drought tolerance by subjecting their seeds to various concentrations of PEG-600 solution (0, 5, 10 and 15%) during germination under laboratory conditions. Prior to PEG treatments, the seeds were decontaminated with 5% sodium hypochlorite solution for 5 min. The PEG concentrations were shortlisted according to already published literature on *Capsicum* spp. by different researchers (Gangotri et al., 2022). The present study was conducted in the Post-graduate Laboratory at the Horticulture Department of Bahaiddin Zakariya University, Multan, Pakistan. The protocol suggested by Kumar et al. (1983) was followed to screen the genotypes against moisture stress. The experiment was conducted in petri dishes (Ø 9 cm). Chilli genotypes' seeds were subjected to PEG-6000-induced drought stress. There were three Petri dishes in each treatment, and 10 seeds in each Petri dish. Seeds of chilli genotypes were placed on Whatman filter paper (No. 42). In the control treatment, these were soaked with 3 mL of distilled water. In stress treatments, seeds were moistened with 3 mL of the respective PEG-6000 solution. Thiram (fungicide) 0.2% (w/v) was added to the PEG-6000 solutions to prevent fungal infection. Petri dishes were placed at 25±2°C in an incubator. The seeds were counted as germinated when the emerged primary root attained 1 mm in length. Data for germination and other parameters were recorded after 21 days of sowing, and the final germination percentage was calculated. The experiment comprises 30 genotypes, 4 PEG-6000 levels and three repeats following a two-factorial (genotypes and PEG-6000 treatments) completely randomised design (CRD). The data were recorded on different parameters during the study. Final germination percentage was estimated by employing the following formula.

Germination (%) = (Total number of seeds germinated)/(Total seeds placed for germination) × 100

Shoot and root lengths of germinated seeds were measured by using a digital Vernier calliper, while shoot and root fresh weights were determined by using an analytical weighing balance. Then, shoot and root samples of germinated seeds were dried at 80 °C in an oven for 24 hours, and their dry weights were estimated by means of an analytical weighing balance.

Statistical software package “Statistix 8.1” was employed to analyse the experimental data through the analysis of variance (ANOVA) procedure. For treatment means values comparison, the least significant difference (LSD) test at a probability level of 5% was applied.

## RESULTS

### Seed germination

The studied genotypes significantly varied in their seed germination. The maximum germination percentage was recorded in Advanta-509 (75.0), followed by Chilli Hot Queen (74.17), Divya (68.33) and Hot Queen (67.50). These four genotypes were statistically similar to each other. The genotype Talhari showed the minimum germination percentage (23.33) and significantly differed from all other genotypes. As the level of PEG-6000 increased, seed germination percentage decreased. The maximum germination percentage was noted in the control treatment (87.78%), while the minimum germination percentage (7.0%) was recorded when a 15% PEG-6000 solution was applied. All the PEG-6000 levels were significantly different from each other for the parameter (Table 2).

Interaction between different chilli genotypes and various PEG-6000 levels indicated that genotypes Advanta-509, Chilli Hot Queen, Divya, F<sub>1</sub> 1130, Hot Queen, Rainbow and Red Giant at 0% PEG-6000 (control) had the maximum (100.0%) seed germination followed by Amber (96.67%), High Fly 2 (96.67%), Hot Red, HHP-082B, HHP-091A (93.33%), Kot Sultan, Shakti, Zenia, Hot Queen (90.0%), Pusa Jawala, Advanta-509, Chilli Hot Queen and Divya (86.67%) also at 0% PEG-6000 level. All these treatment combinations were statistically similar. Conversely, seed germination observed was the minimum in Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (0.0%), followed by Hot Flame (10.0%), Kunri and Talhari (13.33%) at 15% PEG-6000 level. All these treatment combinations statistically stood at par with each other (Table 2).

At 5% PEG-6000 level, the minimum change in seed germination was noted in Advanta-509, Chilli Hot Queen and Divya (-13.33%), while the maximum change was observed in Red Giant (-37.96%). When a 10% PEG-6000 solution was applied, the minimum change in seed germination was noted in Kot Sultan (-

29.54%) and the maximum in Hot Flame (-87.37%). At 15% PEG-6000 level, the minimum change was observed in Advanta-509 (-50%) and the maximum was shown by genotypes Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100%) (Table 2).

The genotypes Advanta-509, Chilli Hot Queen, Kot Sultan, HM-78, High Fly 2, Divya and Hot Queen showed the minimum percent change in seed germination at 15% PEG-6000 level, which indicated that these were drought-tolerant genotypes. Except for these genotypes, all other genotypes failed to germinate at a 15% PEG-6000 level and were drought-sensitive genotypes. Hot Flame, Kunri, Pusa Jawala, Red Giant, Sky Line 2 and Sky Hot showed the maximum percent change in seed germination at 10% PEG level and are categorised as highly drought-sensitive genotypes at the early stage of growth.

**Table 2:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on seed germination percentage and percent change in germination rate (in parenthesis) of 30 chilli genotypes. The germination test was carried on 25±2°C.

| Genotypes           | Control              | 5% PEG                        | 10% PEG                       | 15% PEG                      | Mean                 |
|---------------------|----------------------|-------------------------------|-------------------------------|------------------------------|----------------------|
| Acc.32362           | 73.33 <sup>e-i</sup> | 60.0 <sup>i-m</sup> (-18.0)   | 40.0 <sup>o-s</sup> (-45.83)  | 0.0 <sup>y</sup> (-100.0)    | 43.33 <sup>h-l</sup> |
| Advanta-509         | 100.0 <sup>a</sup>   | 86.67 <sup>a-e</sup> (-13.33) | 63.33 <sup>h-l</sup> (-36.67) | 50.0 <sup>l-p</sup> (-50.0)  | 75.0 <sup>a</sup>    |
| Amber               | 96.667 <sup>ab</sup> | 66.67 <sup>g-k</sup> (-31.11) | 26.67 <sup>s-w</sup> (-72.59) | 0.0 <sup>y</sup> (-100.0)    | 47.50 <sup>f-i</sup> |
| Chilli Hot Queen    | 100.0 <sup>a</sup>   | 86.67 <sup>a-e</sup> (-13.33) | 70.0 <sup>f-j</sup> (-30.0)   | 40.0 <sup>o-s</sup> (-60.0)  | 74.17 <sup>ab</sup>  |
| C.K.D-2204          | 76.67 <sup>d-h</sup> | 60.0 <sup>i-m</sup> (-21.30)  | 33.33 <sup>q-u</sup> (-56.02) | 0.0 <sup>y</sup> (-100.0)    | 42.50 <sup>i-m</sup> |
| Chander Mukhi       | 76.67 <sup>d-h</sup> | 63.33 <sup>h-l</sup> (-17.99) | 36.67 <sup>p-t</sup> (-51.85) | 0.0 <sup>y</sup> (-100.0)    | 44.17 <sup>g-l</sup> |
| Divya               | 100.0 <sup>a</sup>   | 86.67 <sup>a-e</sup> (-13.33) | 66.67 <sup>g-k</sup> (-33.33) | 20.0 <sup>u-x</sup> (-80.0)  | 68.33 <sup>a-c</sup> |
| F <sub>1</sub> 1130 | 100.0 <sup>a</sup>   | 70.0 <sup>f-j</sup> (-30.0)   | 36.67 <sup>p-t</sup> (-63.33) | 0.0 <sup>y</sup> (-100.0)    | 51.67 <sup>e-g</sup> |
| Ghotki              | 66.67 <sup>g-k</sup> | 43.33 <sup>n-r</sup> (-33.33) | 16.67 <sup>v-x</sup> (-73.61) | 0.0 <sup>y</sup> (-100.0)    | 31.67 <sup>n</sup>   |
| High Fly 2          | 96.67 <sup>ab</sup>  | 83.33 <sup>b-f</sup> (-13.70) | 66.67 <sup>g-k</sup> (-30.37) | 20.0 <sup>u-x</sup> (-79.26) | 66.67 <sup>bc</sup>  |
| HM-78               | 93.33 <sup>a-c</sup> | 83.33 <sup>b-f</sup> (-10.74) | 60.0 <sup>i-m</sup> (-36.30)  | 30.0 <sup>r-v</sup> (-67.77) | 66.67 <sup>bc</sup>  |
| Hot Flame           | 80.0 <sup>c-g</sup>  | 50.0 <sup>l-p</sup> (-35.78)  | 10.0 <sup>xy</sup> (-87.37)   | 0.0 <sup>y</sup> (-100.0)    | 35.0 <sup>mn</sup>   |
| Hot Queen           | 100.0 <sup>a</sup>   | 90.0 <sup>a-d</sup> (-10.0)   | 60.0 <sup>i-m</sup> (-40.0)   | 20.0 <sup>u-x</sup> (-80.0)  | 67.50 <sup>a-c</sup> |
| Hot Red             | 93.33 <sup>a-c</sup> | 73.33 <sup>e-i</sup> (-21.48) | 40.0 <sup>o-s</sup> (-58.15)  | 0.0 <sup>y</sup> (-100.0)    | 51.67 <sup>e-g</sup> |
| HHP-082B            | 93.33 <sup>a-c</sup> | 76.67 <sup>d-h</sup> (-17.78) | 40.0 <sup>o-s</sup> (-57.04)  | 0.0 <sup>y</sup> (-100.0)    | 52.50 <sup>ef</sup>  |
| HHP-091A            | 93.33 <sup>a-c</sup> | 80.0 <sup>c-g</sup> (-14.07)  | 53.33 <sup>k-o</sup> (-42.22) | 0.0 <sup>y</sup> (-100.0)    | 56.67 <sup>de</sup>  |
| Kot Sultan          | 90.0 <sup>a-d</sup>  | 73.33 <sup>e-i</sup> (-17.87) | 63.33 <sup>h-l</sup> (-29.54) | 30.0 <sup>r-v</sup> (-66.39) | 64.17 <sup>cd</sup>  |
| Kunri               | 76.67 <sup>d-h</sup> | 50.0 <sup>l-p</sup> (-34.52)  | 13.33 <sup>w-y</sup> (-82.14) | 0.0 <sup>y</sup> (-100.0)    | 35.0 <sup>mn</sup>   |
| Loralai             | 70.0 <sup>f-j</sup>  | 50.0 <sup>l-p</sup> (-28.97)  | 26.67 <sup>s-w</sup> (-61.31) | 0.0 <sup>y</sup> (-100.0)    | 36.67 <sup>l-n</sup> |
| Nadena              | 76.67 <sup>d-h</sup> | 50.0 <sup>l-p</sup> (-33.93)  | 23.33 <sup>t-x</sup> (-69.64) | 0.0 <sup>y</sup> (-100.0)    | 37.50 <sup>k-n</sup> |
| Pusa Jawala         | 86.67 <sup>a-e</sup> | 53.33 <sup>k-o</sup> (-37.96) | 16.67 <sup>v-x</sup> (-80.56) | 0.0 <sup>y</sup> (-100.0)    | 39.17 <sup>j-n</sup> |
| Rainbow             | 100.0 <sup>a</sup>   | 80.0 <sup>c-g</sup> (-20.0)   | 30.0 <sup>r-v</sup> (-70.0)   | 0.0 <sup>y</sup> (-100.0)    | 52.50 <sup>ef</sup>  |
| Red Giant           | 100.0 <sup>a</sup>   | 60.0 <sup>i-m</sup> (-40.0)   | 20.0 <sup>u-x</sup> (-80.0)   | 0.0 <sup>y</sup> (-100.0)    | 45.0 <sup>f-k</sup>  |
| Shakti              | 90.0 <sup>a-d</sup>  | 70.0 <sup>f-j</sup> (-22.22)  | 23.33 <sup>t-x</sup> (-74.07) | 0.0 <sup>y</sup> (-100.0)    | 45.83 <sup>f-j</sup> |
| Sky Hot             | 93.33 <sup>a-c</sup> | 63.33 <sup>h-l</sup> (-31.48) | 20.0 <sup>u-x</sup> (-78.52)  | 0.0 <sup>y</sup> (-100.0)    | 44.17 <sup>g-l</sup> |
| Sky Red             | 100.0 <sup>a</sup>   | 70.0 <sup>f-j</sup> (-30.0)   | 33.33 <sup>q-u</sup> (-66.67) | 0.0 <sup>y</sup> (-100.0)    | 50.83 <sup>e-h</sup> |
| Sky Star 4          | 93.33 <sup>a-c</sup> | 66.67 <sup>g-k</sup> (-27.50) | 30.0 <sup>r-v</sup> (-67.50)  | 0.0 <sup>y</sup> (-100.0)    | 47.50 <sup>f-i</sup> |
| Sky Line 2          | 80.0 <sup>c-g</sup>  | 56.67 <sup>j-n</sup> (-29.17) | 16.67 <sup>v-x</sup> (-79.17) | 0.0 <sup>y</sup> (-100.0)    | 38.33 <sup>j-n</sup> |
| Talhari             | 46.67 <sup>m-q</sup> | 33.33 <sup>q-u</sup> (-27.78) | 13.33 <sup>w-y</sup> (-69.44) | 0.0 <sup>y</sup> (-100.0)    | 23.33 <sup>o</sup>   |
| Zenia               | 90.0 <sup>a-d</sup>  | 70.0 <sup>f-j</sup> (-21.57)  | 43.33 <sup>n-r</sup> (-47.96) | 0.0 <sup>y</sup> (-100.0)    | 50.83 <sup>e-h</sup> |
| Mean                | 87.78 <sup>a</sup>   | 66.89 <sup>b</sup>            | 36.44 <sup>c</sup>            | 7.0 <sup>d</sup>             |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $P = 0.05$  (LSD test).

**Table 3:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on shoot length (mm) and percent change in shoot length (in parenthesis) of 30 chilli genotypes.

| Genotypes           | Control                 | 5% PEG                           | 10% PEG                          | 15% PEG                      | Mean                 |
|---------------------|-------------------------|----------------------------------|----------------------------------|------------------------------|----------------------|
| Acc.32362           | 21.23 <sup>a-d</sup>    | 16.87 <sup>f-n</sup> (-19.31)    | 9.56 <sup>x-zA-J</sup> (-54.44)  | 0.0 <sup>T</sup> (-100.0)    | 11.91 <sup>bc</sup>  |
| Advanta-509         | 19.41 <sup>c-h</sup>    | 16.41 <sup>g-o</sup> (-15.46)    | 11.10 <sup>t-zA-F</sup> (-42.79) | 3.11 <sup>Q-T</sup> (-84.03) | 12.51 <sup>bc</sup>  |
| Amber               | 15.80 <sup>h-r</sup>    | 8.70 <sup>zA-L</sup> (-43.93)    | 2.63 <sup>R-T</sup> (-83.18)     | 0.0 <sup>T</sup> (-100.0)    | 6.78 <sup>i-l</sup>  |
| Chilli Hot Queen    | 20.30 <sup>b-f</sup>    | 17.39 <sup>e-k</sup> (-13.64)    | 11.02 <sup>u-zA-F</sup> (-44.52) | 6.11 <sup>J-R</sup> (-68.60) | 13.71 <sup>ab</sup>  |
| CKD-2204            | 16.33 <sup>g-p</sup>    | 12.78 <sup>o-y</sup> (-21.84)    | 7.79 <sup>D-M</sup> (-52.35)     | 0.0 <sup>T</sup> (-100.0)    | 9.23 <sup>e-h</sup>  |
| Chander Mukhi       | 15.14 <sup>i-s</sup>    | 11.36 <sup>t-zA-E</sup> (-25.0)  | 5.23 <sup>L-S</sup> (-65.67)     | 0.0 <sup>T</sup> (-100.0)    | 7.93 <sup>g-j</sup>  |
| Divya               | 13.95 <sup>k-v</sup>    | 11.46 <sup>s-zA-D</sup> (-17.41) | 6.67 <sup>I-Q</sup> (-51.77)     | 3.33 <sup>P-T</sup> (-76.37) | 8.85 <sup>f-i</sup>  |
| F <sub>1</sub> 1130 | 14.80 <sup>j-t</sup>    | 9.87 <sup>w-zA-I</sup> (-33.02)  | 3.45 <sup>O-T</sup> (-76.59)     | 0.0 <sup>T</sup> (-100.0)    | 7.03 <sup>i-k</sup>  |
| Ghotki              | 19.67 <sup>c-g</sup>    | 13.90 <sup>k-v</sup> (-29.77)    | 4.17 <sup>M-S</sup> (-78.19)     | 0.0 <sup>T</sup> (-100.0)    | 9.43 <sup>e-h</sup>  |
| High Fly 2          | 13.81 <sup>k-v</sup>    | 12.37 <sup>r-z</sup> (-11.55)    | 9.10 <sup>y-zA-K</sup> (-35.46)  | 3.33 <sup>P-T</sup> (-72.71) | 9.65 <sup>e-g</sup>  |
| HM-78               | 17.74 <sup>d-j</sup>    | 15.08 <sup>i-s</sup> (-14.47)    | 10.68 <sup>v-zA-G</sup> (-38.63) | 3.75 <sup>N-S</sup> (-78.64) | 11.81 <sup>cd</sup>  |
| Hot Flame           | 23.85 <sup>ab</sup>     | 13.34 <sup>m-w</sup> (-44.65)    | 3.03 <sup>Q-T</sup> (-87.34)     | 0.0 <sup>T</sup> (-100.0)    | 10.05 <sup>d-f</sup> |
| Hot Queen           | 13.71 <sup>k-v</sup>    | 12.40 <sup>r-z</sup> (-9.32)     | 7.20 <sup>G-N</sup> (-47.51)     | 2.23 <sup>ST</sup> (-83.67)  | 8.88 <sup>f-h</sup>  |
| Hot Red             | 12.14 <sup>r-zA</sup>   | 9.38 <sup>y-zA-J</sup> (-22.84)  | 5.13 <sup>L-S</sup> (-58.02)     | 0.0 <sup>T</sup> (-100.0)    | 6.66 <sup>i-l</sup>  |
| HHP-082B            | 20.20 <sup>b-f</sup>    | 14.67 <sup>j-u</sup> (-26.90)    | 8.17 <sup>C-L</sup> (-59.60)     | 0.0 <sup>T</sup> (-100.0)    | 10.76 <sup>c-e</sup> |
| HHP-091A            | 16.88 <sup>f-n</sup>    | 12.62 <sup>q-y</sup> (-24.35)    | 7.68 <sup>E-M</sup> (-55.02)     | 0.0 <sup>T</sup> (-100.0)    | 9.30 <sup>e-h</sup>  |
| Kot Sultan          | 22.49 <sup>a-c</sup>    | 18.68 <sup>d-l</sup> (-16.84)    | 13.47 <sup>l-w</sup> (-40.13)    | 3.56 <sup>N-T</sup> (-84.23) | 14.59 <sup>a</sup>   |
| Kunri               | 11.85 <sup>s-zA-C</sup> | 7.91 <sup>D-L</sup> (-28.49)     | 2.30 <sup>ST</sup> (-78.48)      | 0.0 <sup>T</sup> (-100.0)    | 5.51 <sup>kl</sup>   |
| Loralai             | 17.25 <sup>e-k</sup>    | 14.11 <sup>j-v</sup> (-18.31)    | 8.23 <sup>B-L</sup> (-49.83)     | 0.0 <sup>T</sup> (-100.0)    | 9.90 <sup>ef</sup>   |
| Nagena              | 13.70 <sup>k-v</sup>    | 9.48 <sup>y-zA-J</sup> (-28.55)  | 3.86 <sup>N-S</sup> (-71.30)     | 0.0 <sup>T</sup> (-100.0)    | 6.76 <sup>i-l</sup>  |
| Pusa Jawala         | 20.91 <sup>b-e</sup>    | 12.23 <sup>r-zA</sup> (-41.39)   | 3.21 <sup>P-T</sup> (-84.32)     | 0.0 <sup>T</sup> (-100.0)    | 9.09 <sup>e-h</sup>  |
| Rainbow             | 19.33 <sup>c-h</sup>    | 13.52 <sup>l-w</sup> (-28.57)    | 6.86 <sup>H-P</sup> (-63.79)     | 0.0 <sup>T</sup> (-100.0)    | 9.93 <sup>ef</sup>   |
| Red Giant           | 24.36 <sup>a</sup>      | 17.17 <sup>i-l</sup> (-49.95)    | 7.11 <sup>G-O</sup> (-70.68)     | 0.0 <sup>T</sup> (-100.0)    | 12.16 <sup>bc</sup>  |
| Shakti              | 16.16 <sup>g-q</sup>    | 11.91 <sup>s-zA-B</sup> (-24.89) | 2.86 <sup>R-T</sup> (-82.26)     | 0.0 <sup>T</sup> (-100.0)    | 7.73 <sup>h-j</sup>  |
| Sky Hot             | 13.25 <sup>n-x</sup>    | 8.57 <sup>A-L</sup> (-33.56)     | 3.00 <sup>Q-T</sup> (-76.83)     | 0.0 <sup>T</sup> (-100.0)    | 6.20 <sup>i-l</sup>  |
| Sky Red             | 19.0 <sup>c-h</sup>     | 12.29 <sup>r-z</sup> (-34.24)    | 5.46 <sup>K-S</sup> (-70.79)     | 0.0 <sup>T</sup> (-100.0)    | 9.19 <sup>e-h</sup>  |
| Sky Star 4          | 10.44 <sup>v-zA-H</sup> | 6.67 <sup>I-Q</sup> (-37.08)     | 3.58 <sup>N-T</sup> (-64.07)     | 0.0 <sup>T</sup> (-100.0)    | 5.17 <sup>i</sup>    |
| Sky Line 2          | 18.60 <sup>d-i</sup>    | 12.67 <sup>p-y</sup> (-30.72)    | 5.35 <sup>L-S</sup> (-70.66)     | 0.0 <sup>T</sup> (-100.0)    | 9.15 <sup>e-h</sup>  |
| Talhari             | 20.33 <sup>b-f</sup>    | 16.97 <sup>f-m</sup> (-16.21)    | 6.20 <sup>I-R</sup> (-68.15)     | 0.0 <sup>T</sup> (-100.0)    | 10.88 <sup>c-e</sup> |
| Zenia               | 17.36 <sup>e-k</sup>    | 13.36 <sup>m-w</sup> (-20.70)    | 7.64 <sup>F-M</sup> (-52.45)     | 0.0 <sup>T</sup> (-100.0)    | 9.59 <sup>e-g</sup>  |
| Mean                | 17.32 <sup>a</sup>      | 12.80 <sup>b</sup>               | 6.39 <sup>c</sup>                | 0.85 <sup>d</sup>            |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $p = 0.05$  (LSD test). Means were initially labelled by small letters and afterwards by capital letters due to great variation in means.

### Shoot length

Among the genotypes, Kot Sultan attained significantly greater shoot length (14.59 mm), followed by Chilli Hot Queen (13.71 mm), and these two genotypes were statistically similar. However, genotype Sky Star 4 (5.17 mm) showed the minimum shoot length, followed by Kunri (5.51 mm), Sky Hot (6.20 mm), Hot Red (6.66 mm), Nagena (6.76 mm) and Amber (6.78 mm). These six genotypes behaved statistically alike for the parameter. As the level of PEG-6000 increased, the shoot length of the seedlings progressively decreased. The maximum shoot length was measured in the control treatment (17.32 mm), while the minimum shoot length (0.85 mm) was noted when a 15% PEG-6000 solution was applied. All four PEG-6000 levels were significantly different from each other (Table 3). Interaction between chilli genotypes and PEG-6000 levels indicated that genotype Red Giant had the maximum (24.36 mm) shoot length, followed by Hot Flame (23.85 mm), Kot Sultan (24.49 mm) and Acc.32362 (21.23 mm), all at 0% PEG-6000 (control). These four treatment combinations behaved statistically alike. In contrast, the minimum shoot length was observed in Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala,

Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2 and Talhari (0.0 mm) all at 15% PEG-6000 level, followed by Hot Queen (2.23 mm) at 15% PEG-6000 level, Kunri (2.30 mm), Amber (2.63 mm), Shakti (2.86 mm), Sky Hot (3.0 mm), Hot Flame (3.03 mm) at 10% PEG-6000 level, Advanta-509 (3.11 mm) at 15% PEG-6000 level, Pusa Jawala (3.21 mm) at 10% PEG-6000 level, and High Fly 2 (3.33 mm) and Divya (3.33 mm) at 15% PEG-6000 level. All these treatment combinations were statistically at par with each other (Table 3).

At 5% PEG-6000 level, the minimum change in shoot length was noted in Hot Queen (-9.32%), while the maximum change was observed in Hot Flame (-44.65%). When a 10% PEG-6000 solution was applied, the minimum change was noted in High Fly 2 (-35.46%) and the maximum in Hot Flame (-87.34%). At 15% PEG-6000 level, the minimum

change was observed in Chilli Hot Queen (-68.60%) and the maximum was shown by genotypes Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100%) (Table 3).

Results depicted that genotypes Chilli Hot Queen, High Fly 2, Divya, HM-78, Hot Queen, Advanta-509 and Kot Sultan had the minimum percent change in shoot length at 15% PEG-6000 level. It can be assumed that these genotypes were drought-tolerant. Except for these, all other genotypes failed to produce shoots at 15% PEG level, and these genotypes are categorised as drought-sensitive genotypes. Hot Flame, Pusa Jawala, Amber, Shakti, Kunri and Ghotki showed the maximum percent reduction in shoot length at 10% PEG-6000 level and were highly drought-sensitive genotypes.

### Root length

Chilli genotypes significantly differed for root length. High Fly 2 attained the maximum (40.60 mm) root length, which significantly differed from all other genotypes studied. The

minimum root length was noted in Hot Flame (10.07 mm) and HHP-082B (10.38 mm), followed by Shakti (13.70 mm), and these three genotypes were statistically similar for the parameter. Data revealed that PEG-6000 imposed drastic effects on root length. As the concentration of PEG-6000 increased, the root length of chilli seedlings gradually decreased. The maximum root length (41.12 mm) was noted at 0% PEG-6000 (control); on the other hand, the minimum root length (2.33 mm) was noted when a 15% PEG-6000 solution was applied. All the PEG-6000 levels significantly differed from each other (Table 4). Interaction of chilli genotypes and PEG-6000 levels was also found to be significant on root length. It was noted that significantly greater root length was observed in High Fly 2 (61.37 mm), followed by Pusa Jawala (53.51 mm) at 0% PEG-6000 (control), and these two treatment combinations were statistically similar. Whereas, significantly shorter root length was observed in Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky line 2, Talhari and Zenia (0.0 mm) all at 15% PEG-6000 level followed by Hot Flame (3.86 mm), Red Giant (4.46 mm), Kunri (5.39 mm) and Sky Line 2 (5.40 mm) at 10% PEG-6000 level, Kot Sultan (5.78 mm) and HM-78

(6.44 mm) at 15% PEG-6000 level, Sky Hot (6.79 mm), Chander Mukhi (7.33 mm), HHP-082B (7.67 mm), Pusa Jawala (7.74 mm), Sky Red (7.85 mm) and Divya (7.92 mm) at 10% PEG-6000 level. All these treatment combinations behaved statistically alike (Table 4).

At 5% PEG-6000 level, the minimum change in root length was recorded in High Fly 2 (-17.41%), while the maximum change was noted in Sky Red (-67.87%). When a 10% PEG-6000 solution was applied, the minimum change was noted in Divya (-43.42%) and the maximum in genotype Red Giant (-91.41%). At 15% PEG-6000 level, the minimum change was observed in Divya (-67.13 %) and the maximum was shown by genotypes Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100 %) (Table 4).

The minimum percent change in root length at 15% PEG-6000 level was observed in Divya, Advanta-509, High Fly 2, Chilli Hot Queen, Hot Queen, HM-78 and Kot Sultan, so according to the results, these genotypes were drought tolerant. On the other hand, all other genotypes did not initiate roots at 15% PEG-6000

**Table 4:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on root length (mm) and percent change in root length (in parenthesis) of 30 chilli genotypes.

| Genotypes           | Control                | 5% PEG                           | 10% PEG                          | 15% PEG                          | Mean                 |
|---------------------|------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------|
| Acc.32362           | 31.67 <sup>l-r</sup>   | 19.47 <sup>t-zA-D</sup> (-38.70) | 9.70 <sup>F-K</sup> (-69.06)     | 0.0 <sup>L</sup> (-100.0)        | 15.21 <sup>gh</sup>  |
| Advanta-509         | 38.52 <sup>e-m</sup>   | 28.13 <sup>o-t</sup> (-19.30)    | 17.45 <sup>w-zA-F</sup> (-51.27) | 11.56 <sup>C-K</sup> (-69.92)    | 23.91 <sup>bc</sup>  |
| Amber               | 38.28 <sup>e-m</sup>   | 21.05 <sup>s-zA</sup> (-42.0)    | 9.57 <sup>F-K</sup> (-66.92)     | 0.0 <sup>L</sup> (-100.0)        | 17.21 <sup>e-h</sup> |
| Chilli Hot Queen    | 31.30 <sup>m-r</sup>   | 25.53 <sup>p-w</sup> (-26.30)    | 21.51 <sup>S-Z</sup> (-49.53)    | 12.17 <sup>B-K</sup> (-72.12)    | 27.15 <sup>b</sup>   |
| CKD 2204            | 40.31 <sup>e-l</sup>   | 27.57 <sup>o-u</sup> (-30.78)    | 17.38 <sup>w-zA-F</sup> (-55.66) | 0.0 <sup>L</sup> (-100.0)        | 21.31 <sup>c-e</sup> |
| Chander Mukhi       | 42.26 <sup>d-k</sup>   | 27.29 <sup>o-v</sup> (-35.19)    | 7.33 <sup>H-L</sup> (-82.59)     | 0.0 <sup>L</sup> (-100.0)        | 19.22 <sup>d-g</sup> |
| Divya               | 32.43 <sup>l-q</sup>   | 22.40 <sup>s-x</sup> (-28.78)    | 13.18 <sup>zA-J</sup> (-43.42)   | 7.92 <sup>H-L</sup> (-67.13)     | 18.98 <sup>d-g</sup> |
| F <sub>1</sub> 1130 | 37.33 <sup>g-n</sup>   | 22.52 <sup>s-x</sup> (-40.22)    | 12.17 <sup>B-K</sup> (-67.23)    | 0.0 <sup>L</sup> (-100.0)        | 18.01 <sup>e-h</sup> |
| Ghotki              | 33.92 <sup>k-p</sup>   | 19.10 <sup>u-zA-D</sup> (-44.25) | 9.33 <sup>F-K</sup> (-71.94)     | 0.0 <sup>L</sup> (-100.0)        | 15.59 <sup>gh</sup>  |
| High Fly 2          | 61.37 <sup>a</sup>     | 50.66 <sup>b-d</sup> (-17.41)    | 32.85 <sup>l-q</sup> (-46.46)    | 17.53 <sup>w-zA-F</sup> (-71.52) | 40.60 <sup>a</sup>   |
| HM-78               | 37.03 <sup>h-n</sup>   | 29.25 <sup>n-s</sup> (-20.35)    | 20.10 <sup>t-zA-C</sup> (-44.15) | 6.44 <sup>H-L</sup> (-82.45)     | 23.21 <sup>b-d</sup> |
| Hot Flame           | 24.18 <sup>q-w</sup>   | 12.23 <sup>B-K</sup> (-39.31)    | 3.86 <sup>KL</sup> (-81.45)      | 0.0 <sup>L</sup> (-100.0)        | 10.07 <sup>i</sup>   |
| Hot Queen           | 43.62 <sup>c-i</sup>   | 34.13 <sup>j-p</sup> (-25.48)    | 17.29 <sup>w-zA-F</sup> (-49.43) | 8.55 <sup>G-L</sup> (-74.94)     | 21.37 <sup>c-e</sup> |
| Hot Red             | 49.62 <sup>b-d</sup>   | 31.28 <sup>m-r</sup> (-34.70)    | 22.08 <sup>s-y</sup> (-54.43)    | 0.0 <sup>L</sup> (-100.0)        | 25.74 <sup>b</sup>   |
| HHP-082B            | 20.28 <sup>t-zAB</sup> | 13.57 <sup>yA-I</sup> (-29.14)   | 7.67 <sup>H-L</sup> (-61.11)     | 0.0 <sup>L</sup> (-100.0)        | 10.38 <sup>i</sup>   |
| HHP-091A            | 38.89 <sup>e-m</sup>   | 26.52 <sup>p-v</sup> (-32.12)    | 11.35 <sup>D-K</sup> (-70.82)    | 0.0 <sup>L</sup> (-100.0)        | 19.19 <sup>d-g</sup> |
| Kot Sultan          | 46.77 <sup>b-e</sup>   | 35.34 <sup>i-o</sup> (-23.54)    | 21.97 <sup>s-y</sup> (-52.07)    | 5.78 <sup>H-L</sup> (-87.57)     | 27.47 <sup>b</sup>   |
| Kunri               | 43.37 <sup>c-i</sup>   | 21.25 <sup>s-z</sup> (-50.58)    | 5.39 <sup>I-L</sup> (-87.56)     | 0.0 <sup>L</sup> (-100.0)        | 17.50 <sup>e-h</sup> |
| Loralai             | 51.70 <sup>bc</sup>    | 20.57 <sup>s-zAB</sup> (-56.42)  | 12.46 <sup>A-K</sup> (-80.99)    | 0.0 <sup>L</sup> (-100.0)        | 21.18 <sup>c-f</sup> |
| Nagena              | 37.77 <sup>f-n</sup>   | 20.40 <sup>t-zAB</sup> (-45.3)   | 9.24 <sup>F-K</sup> (-75.15)     | 0.0 <sup>L</sup> (-100.0)        | 16.85 <sup>f-h</sup> |
| Pusa Jawala         | 53.51 <sup>ab</sup>    | 21.67 <sup>s-z</sup> (-59.47)    | 7.74 <sup>H-L</sup> (-85.53)     | 0.0 <sup>L</sup> (-100.0)        | 20.73 <sup>c-f</sup> |
| Rainbow             | 49.10 <sup>b-d</sup>   | 24.68 <sup>q-w</sup> (-49.30)    | 10.12 <sup>E-K</sup> (-79.14)    | 0.0 <sup>L</sup> (-100.0)        | 20.98 <sup>c-f</sup> |
| Red Giant           | 51.63 <sup>bc</sup>    | 19.50 <sup>t-zA-D</sup> (-61.46) | 4.46 <sup>J-L</sup> (-91.41)     | 0.0 <sup>L</sup> (-100.0)        | 18.90 <sup>d-g</sup> |
| Shakti              | 27.96 <sup>o-t</sup>   | 17.0 <sup>w-zA-G</sup> (-37.35)  | 9.83 <sup>F-K</sup> (-62.94)     | 0.0 <sup>L</sup> (-100.0)        | 13.70 <sup>hi</sup>  |
| Sky Hot             | 46.46 <sup>b-f</sup>   | 18.67 <sup>v-zA-E</sup> (-54.3)  | 6.79 <sup>H-L</sup> (-84.84)     | 0.0 <sup>L</sup> (-100.0)        | 17.98 <sup>e-h</sup> |
| Sky Red             | 45.20 <sup>b-h</sup>   | 14.43 <sup>x-zA-H</sup> (-67.87) | 7.85 <sup>H-L</sup> (-82.24)     | 0.0 <sup>L</sup> (-100.0)        | 16.87 <sup>f-h</sup> |
| Sky Star 4          | 42.79 <sup>d-j</sup>   | 18.67 <sup>v-zA-E</sup> (-53.73) | 9.73 <sup>F-K</sup> (-75.63)     | 0.0 <sup>L</sup> (-100.0)        | 17.80 <sup>e-h</sup> |
| Sky Line 2          | 44.83 <sup>b-h</sup>   | 23.05 <sup>r-x</sup> (-48.43)    | 5.40 <sup>I-L</sup> (-87.99)     | 0.0 <sup>L</sup> (-100.0)        | 18.32 <sup>e-g</sup> |
| Talhari             | 45.96 <sup>b-g</sup>   | 29.22 <sup>n-s</sup> (-35.62)    | 8.10 <sup>H-L</sup> (-82.28)     | 0.0 <sup>L</sup> (-100.0)        | 20.82 <sup>c-f</sup> |
| Zenia               | 42.72 <sup>d-j</sup>   | 27.67 <sup>o-u</sup> (-34.30)    | 13.08 <sup>za-j</sup> (-66.92)   | 0.0 <sup>L</sup> (-100.0)        | 20.87 <sup>c-f</sup> |
| Mean                | 41.12 <sup>a</sup>     | 24.0 <sup>b</sup>                | 12.17 <sup>c</sup>               | 2.33 <sup>d</sup>                |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $p = 0.05$  (LSD test). Means were initially labelled by small letters and afterwards by capital letters due to great variation in means.

level and were drought sensitive. Red Giant, Sky Line 2, Kunri, Pusa Jawala, Sky Hot, Chander Mukhi, Talhari, Sky Red, Hot Flame and Loralai showed the maximum percentage change in root length among all the studied genotypes at 10% PEG-6000 level and were categorised as highly drought-sensitive genotypes.

#### Shoot fresh weight

Chilli genotypes showed significant variation for the parameter. The highest shoot fresh weight (142.28 mg) was attained by Divya, which was significantly different from all other genotypes. The genotype Talhari (24.58 mg) showed the lowest shoot fresh weight, followed by Ghotki (25.83 mg) and Kunri (33.58 mg), and these three

**Table 5:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on shoot fresh weight (mg) and percent change in shoot fresh weight (in parenthesis) of 30 chilli genotypes.

| Genotypes           | Control                 | 5% PEG                           | 10% PEG                          | 15% PEG                       | Mean                 |
|---------------------|-------------------------|----------------------------------|----------------------------------|-------------------------------|----------------------|
| Acc.32362           | 163.0 <sup>d-h</sup>    | 122.67 <sup>k-s</sup> (-24.61)   | 55.33 <sup>E-J</sup> (-65.51)    | 0.0 <sup>Q</sup> (-100.0)     | 85.25 <sup>d-h</sup> |
| Advanta-509         | 169.33 <sup>c-f</sup>   | 132.0 <sup>i-q</sup> (-21.82)    | 91.0 <sup>t-zAB</sup> (-46.28)   | 15.80 <sup>M-Q</sup> (-90.55) | 102.03 <sup>bc</sup> |
| Amber               | 176.33 <sup>b-e</sup>   | 97.67 <sup>r-zA</sup> (-39.53)   | 11.34 <sup>N-Q</sup> (-93.01)    | 0.0 <sup>Q</sup> (-100.0)     | 71.34 <sup>h-j</sup> |
| Chilli Hot Queen    | 174.0 <sup>B-E</sup>    | 142.33 <sup>f-m</sup> (-18.12)   | 75.67 <sup>x-zA-E</sup> (-56.27) | 18.25 <sup>L-Q</sup> (-89.44) | 102.56 <sup>bc</sup> |
| CKD 2204            | 97.0 <sup>s-zA</sup>    | 74.0 <sup>y-zA-G</sup> (-22.24)  | 37.67 <sup>H-N</sup> (-58.97)    | 0.0 <sup>Q</sup> (-100.0)     | 52.17 <sup>k-m</sup> |
| Chander Mukhi       | 154.67 <sup>e-j</sup>   | 99.33 <sup>r-zA</sup> (-32.38)   | 55.0 <sup>E-J</sup> (-63.26)     | 0.0 <sup>Q</sup> (-100.0)     | 77.25 <sup>f-i</sup> |
| Divya               | 235.67 <sup>a</sup>     | 199.0 <sup>b</sup> (-15.85)      | 109.0 <sup>p-w</sup> (-53.67)    | 25.45 <sup>K-Q</sup> (-89.17) | 142.28 <sup>a</sup>  |
| F <sub>1</sub> 1130 | 163.67 <sup>d-g</sup>   | 104.67 <sup>p-x</sup> (-35.96)   | 23.10 <sup>K-Q</sup> (-85.86)    | 0.0 <sup>Q</sup> (-100.0)     | 72.86 <sup>h-j</sup> |
| Ghotki              | 60.0 <sup>D-I</sup>     | 35.33 <sup>H-O</sup> (-40.42)    | 8.0 <sup>O-Q</sup> (-86.81)      | 0.0 <sup>Q</sup> (-100.0)     | 25.83 <sup>op</sup>  |
| High Fly 2          | 167.33 <sup>c-g</sup>   | 141.0 <sup>f-n</sup> (-16.08)    | 91.67 <sup>t-zAB</sup> (-45.0)   | 22.60 <sup>K-Q</sup> (-86.22) | 105.65 <sup>b</sup>  |
| HM-78               | 152.33 <sup>e-j</sup>   | 131.0 <sup>i-q</sup> (-13.90)    | 85.67 <sup>u-zA-D</sup> (-41.14) | 20.90 <sup>L-Q</sup> (-85.27) | 97.47 <sup>b-d</sup> |
| Hot Flame           | 157.33 <sup>e-l</sup>   | 75.0 <sup>y-zA-F</sup> (-51.04)  | 12.24 <sup>N-Q</sup> (-91.99)    | 0.0 <sup>Q</sup> (-100.0)     | 61.14 <sup>jk</sup>  |
| Hot Queen           | 143.0 <sup>f-m</sup>    | 119.0 <sup>l-t</sup> (-16.77)    | 81.33 <sup>v-zA-E</sup> (-42.83) | 12.45 <sup>N-Q</sup> (-91.24) | 88.95 <sup>c-g</sup> |
| Hot Red             | 148.0 <sup>e-l</sup>    | 102.67 <sup>q-z</sup> (-28.55)   | 55.33 <sup>E-J</sup> (-61.66)    | 0.0 <sup>Q</sup> (-100.0)     | 76.50 <sup>g-i</sup> |
| HHP-082B            | 147.33 <sup>e-l</sup>   | 112.33 <sup>n-u</sup> (-23.70)   | 58.0 <sup>D-I</sup> (-62.68)     | 0.0 <sup>Q</sup> (-100.0)     | 79.42 <sup>e-i</sup> |
| HHP-091A            | 188.0 <sup>b-d</sup>    | 138.67 <sup>g-o</sup> (-25.51)   | 45.67 <sup>F-L</sup> (-76.42)    | 0.0 <sup>Q</sup> (-100.0)     | 93.08 <sup>b-e</sup> |
| Kot Sultan          | 149.67 <sup>e-k</sup>   | 122.33 <sup>k-s</sup> (-17.56)   | 75.33 <sup>x-zA-E</sup> (-49.18) | 19.46 <sup>L-Q</sup> (-86.84) | 91.70 <sup>b-f</sup> |
| Kunri               | 80.33 <sup>w-zA-E</sup> | 44.67 <sup>G-M</sup> (-45.90)    | 9.31 <sup>N-Q</sup> (-87.09)     | 0.0 <sup>Q</sup> (-100.0)     | 33.58 <sup>n-p</sup> |
| Loralai             | 157.0 <sup>e-l</sup>    | 96.33 <sup>s-zA</sup> (-36.41)   | 21.33 <sup>L-Q</sup> (-85.76)    | 0.0 <sup>Q</sup> (-100.0)     | 68.67 <sup>ij</sup>  |
| Nagena              | 89.67 <sup>t-zA-C</sup> | 59.0 <sup>D-I</sup> (-33.56)     | 9.67 <sup>N-Q</sup> (-89.22)     | 0.0 <sup>Q</sup> (-100.0)     | 39.58 <sup>m-o</sup> |
| Pusa Jawala         | 165.0 <sup>c-g</sup>    | 92.33 <sup>t-zAB</sup> (-44.06)  | 13.54 <sup>N-Q</sup> (-91.78)    | 0.0 <sup>Q</sup> (-100.0)     | 67.72 <sup>ij</sup>  |
| Rainbow             | 165.33 <sup>c-g</sup>   | 115.67 <sup>m-t</sup> (-30.39)   | 34.0 <sup>I-O</sup> (-79.18)     | 0.0 <sup>Q</sup> (-100.0)     | 78.75 <sup>e-i</sup> |
| Red Giant           | 122.33 <sup>k-s</sup>   | 64.0 <sup>B-H</sup> (-47.62)     | 15.18 <sup>N-Q</sup> (-87.33)    | 0.0 <sup>Q</sup> (-100.0)     | 50.38 <sup>k-m</sup> |
| Shakti              | 100.33 <sup>r-zA</sup>  | 71.0 <sup>A-G</sup> (-30.0)      | 19.67 <sup>L-Q</sup> (-79.87)    | 0.0 <sup>Q</sup> (-100.0)     | 47.75 <sup>k-n</sup> |
| Sky Hot             | 110.33 <sup>o-v</sup>   | 73.33 <sup>zA-G</sup> (-35.0)    | 19.0 <sup>L-Q</sup> (-81.53)     | 0.0 <sup>Q</sup> (-100.0)     | 50.67 <sup>k-m</sup> |
| Sky Red             | 103.0 <sup>q-y</sup>    | 61.0 <sup>C-I</sup> (-42.27)     | 21.33 <sup>L-Q</sup> (-79.79)    | 0.0 <sup>Q</sup> (-100.0)     | 46.33 <sup>l-n</sup> |
| Sky Star 4          | 154.67 <sup>e-j</sup>   | 100.67 <sup>r-z</sup> (-34.35)   | 33.0 <sup>I-P</sup> (-77.73)     | 0.0 <sup>Q</sup> (-100.0)     | 72.08 <sup>h-j</sup> |
| Sky Line 2          | 127.0 <sup>j-r</sup>    | 80.33 <sup>w-zA-E</sup> (-37.17) | 27.0 <sup>J-Q</sup> (-78.97)     | 0.0 <sup>Q</sup> (-100.0)     | 58.58 <sup>l-l</sup> |
| Talhari             | 61.0 <sup>C-I</sup>     | 33.0 <sup>I-P</sup> (-42.14)     | 4.33 <sup>PQ</sup> (-92.08)      | 0.0 <sup>Q</sup> (-100.0)     | 24.58 <sup>p</sup>   |
| Zenia               | 193.67 <sup>bc</sup>    | 134.0 <sup>h-p</sup> (-29.80)    | 52.0 <sup>E-K</sup> (-72.44)     | 0.0 <sup>Q</sup> (-100.0)     | 94.92 <sup>b-d</sup> |
| Mean                | 142.54 <sup>a</sup>     | 99.14 <sup>b</sup>               | 41.69 <sup>c</sup>               | 4.50 <sup>d</sup>             |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $p = 0.05$  (LSD test). Means were initially labelled by small letters and afterwards by capital letters due to great variation in means.

genotypes stood statistically at par. Concerning PEG-6000 levels, as the level of PEG-6000 increased, the shoot fresh weight of chilli seedlings gradually decreased. The maximum shoot fresh weight was measured in the control treatment (142.54 mg), while the minimum shoot fresh weight (4.50 mg) was noted when a 15% PEG-6000 solution was applied. All the PEG-6000 levels significantly differed from each other (Table 5). Interaction between different chilli genotypes and various PEG-6000 levels indicated that genotype Divya at 0% PEG-6000 level (control) had significantly greater (235.67 mg) shoot fresh weight. On the other hand, significantly lower shoot fresh weight was noted in Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zeina (0.0 mg) all at 15% PEG-6000 level followed by Talhari (4.33 mg), Ghotki (8.0 mg), Kunri (9.31 mg), Nagena (9.67 mg), Amber (11.34 mg) and Hot Flame (12.24 mg) at 10% PEG-6000 level, Hot Queen (12.45) at 15% PEG-6000 level, Pusa Jawala (13.54 mg) and Red Giant (15.18 mg) at 10% PEG-6000 level, Advanta-509 (15.80 mg) and Chilli Hot Queen (18.25 mg) at 15% PEG-6000 level, Sky Hot (19.0 mg) at 10% PEG-6000 level and Kot Sultan (19.46 mg) at 15% PEG-6000 level. All these treatment combinations were

statistically at par with each other (Table 5).

The minimum change in shoot fresh weight at 5% PEG-6000 level was noted in Divya (-15.85%), while the maximum change was observed in Hot Flame (-51.04%). When a 10% PEG-6000 solution was applied, the minimum change was noted in HM-78 (-41.14%) and the maximum in Amber (-93.01%). At 15% PEG-6000 level, the minimum change was observed in HM-78 (-85.27%) and the maximum was shown by the genotypes Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100%) (Table 5).

At 15% PEG-6000 level, HM-78, High Fly 2, Kot Sultan, Divya, Chilli Hot Queen, Advanta-509 and Hot Queen had the minimum % change in their shoot fresh weight and were classified as highly drought-tolerant genotypes. Whereas the maximum percent change in shoot fresh weight at 10% PEG-6000 level was recorded in Talhari, Ghotki, Kunri, Nagena, Amber and Hot Flame, and these genotypes were categorised as drought-sensitive genotypes.

### Shoot dry weight

Chilli genotypes significantly differed for the attribute under study. The genotype Kot Sultan attained the maximum (33.15 mg) shoot dry weight and significantly differed from all other genotypes. Whereas, the minimum shoot dry weight was noted in Talhari (6.25 mg), Nagena (6.83 mg), Red Giant (7.08 mg), Hot Red (7.50 mg) and Ghotki (7.92 mg) followed by CKD 2204 (8.17 mg), Shakti (8.25 mg), Sky Red (8.38 mg) and Pusa Jawala (9.75 mg). All these genotypes were statistically similar to each other. Data indicated that PEG-6000 imposed drastic effects on the shoot dry weight of chilli seedlings. As the concentration of PEG-6000 increased, the shoot dry weight of the seedlings decreased. The maximum mean value for shoot dry weight (34.57 mg) was

noted at 0% PEG-6000 level (control). On the other hand, the minimum mean value for shoot dry weight (0.73 mg) was recorded at 15% PEG-6000 solution application. All the PEG-6000 levels varied significantly from each other (Table 6). The interaction of chilli genotypes and PEG-6000 levels was also significant for shoot dry weight. It was noted that significantly higher shoot dry weight was observed in Kot Sultan (68.33 mg) and Chilli Hot queen (60.0 mg), both at 0% PEG-6000 level (control). These two treatment combinations were statistically similar. Whereas, significantly lower shoot dry weight was observed in Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (0.0 mg) all at 15% PEG-6000 level followed by Loralai (1.27 mg) and Sky Hot (1.32 mg) at 10% PEG-6000 level, Hot Queen (1.91 mg) and Chilli Hot Queen (2.0 mg) at 15% PEG-6000 level, Sky Line 2 (2.13 mg) and Amber (2.27 mg) at 10% PEG-6000 level, Advanta-509 (2.33 mm) at 15% PEG-6000 level and F<sub>1</sub> 1130 (2.77 mg) at 10% PEG-6000 level. All these treatment combinations were statistically similar (Table 6).

At 5% PEG-6000 level, the minimum change in shoot dry weight

was noted in Advanta-509 (-20.27%), while the maximum change was observed in Hot Flame (-57.21%). When a 10% PEG-6000 solution was applied, the minimum change was noted in High Fly 2 (-64.15%) and HM-78 (-64.80%), and genotypes Ghotki, Hot Flame, Kunri, Nagena, Pusa Jawala, Red Giant and Talhari went through the maximum change (-100%). At 15% PEG-6000 level, the minimum % change was observed in Divya (-88.16%) and the maximum was shown by genotypes Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100%) (Table 6).

Divya, HM-78, High Fly 2, Advanta-509, Kot Sultan, Hot Queen and Chilli Hot Queen had the minimum % change in their shoot dry weight among all the studied genotypes at 15% PEG-6000 level and were drought-tolerant genotypes. Besides these, all other genotypes were categorised as drought-sensitive genotypes. At 10% PEG-6000 level, the maximum percent change in shoot dry weight was observed in Talhari, Red Giant, Pusa Jawala, Nagena, Kunri, Hot Flame and Ghotki, indicating that these genotypes were highly drought sensitive.

### Root fresh weight

Chilli genotypes significantly differed for the parameter. Genotype Hot Queen attained the maximum (79.91 mg) root fresh weight, followed by Chilli Hot Queen (75.0 mg) and Advanta-509 (71.83 mg). The behaviour of these three genotypes was statistically similar. The minimum root fresh weight was noted in Talhari (11.67 mg), followed by Acc.32362 (12.83 mg), F<sub>1</sub> 1130 (13.33 mg), Sky Star 4 (14.25 mg) and a few other genotypes. All these genotypes were also statistically equal to each other. Data indicated that PEG-6000 imposed drastic effects on the root fresh weight of chilli seedlings. As the concentration of PEG-6000 increased, the root fresh weight of the seedlings progressively decreased. The maximum root fresh weight (70.77 mg) was noted at 0% PEG-6000 level (control), and the minimum (3.73

**Table 6:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on shoot dry weight (mg) and percent change in shoot dry weight (in parenthesis) of 30 chilli genotypes.

| Genotypes           | Control               | 5% PEG                           | 10% PEG                          | 15% PEG                      | Mean                 |
|---------------------|-----------------------|----------------------------------|----------------------------------|------------------------------|----------------------|
| Acc.32362           | 38.33 <sup>c-j</sup>  | 26.33 <sup>l-s</sup> (-32.12)    | 10.0 <sup>x-zA-G</sup> (-72.77)  | 0.0 <sup>H</sup> (-100.0)    | 18.67 <sup>cd</sup>  |
| Advanta-509         | 31.33 <sup>h-n</sup>  | 24.67 <sup>m-u</sup> (-20.27)    | 9.0 <sup>zA-G</sup> (-68.40)     | 2.33 <sup>E-H</sup> (-91.71) | 16.83 <sup>d-g</sup> |
| Amber               | 44.67 <sup>bc</sup>   | 24.67 <sup>m-u</sup> (-42.61)    | 2.27 <sup>E-H</sup> (-94.60)     | 0.0 <sup>H</sup> (-100.0)    | 17.90 <sup>d-f</sup> |
| Chilli Hot Queen    | 60.0 <sup>a</sup>     | 37.0 <sup>c-j</sup> (-38.19)     | 15.0 <sup>v-zAB</sup> (-74.34)   | 2.0 <sup>F-H</sup> (-96.42)  | 28.50 <sup>b</sup>   |
| CKD 2204            | 17.0 <sup>t-zA</sup>  | 11.67 <sup>w-zA-C</sup> (-30.70) | 4.0 <sup>C-H</sup> (-76.32)      | 0.0 <sup>H</sup> (-100.0)    | 8.17 <sup>jk</sup>   |
| Chander Mukhi       | 34.67 <sup>e-l</sup>  | 23.0 <sup>n-v</sup> (-34.38)     | 3.0 <sup>C-H</sup> (-91.18)      | 0.0 <sup>H</sup> (-100.0)    | 15.17 <sup>d-h</sup> |
| Divya               | 50.33 <sup>b</sup>    | 37.97 <sup>c-j</sup> (-24.49)    | 16.33 <sup>u-zA</sup> (-66.25)   | 5.67 <sup>C-H</sup> (-88.16) | 27.58 <sup>b</sup>   |
| F <sub>1</sub> 1130 | 39.0 <sup>c-i</sup>   | 22.0 <sup>o-v</sup> (-43.44)     | 2.77 <sup>D-H</sup> (-92.53)     | 0.0 <sup>H</sup> (-100.0)    | 15.94 <sup>d-h</sup> |
| Ghotki              | 21.0 <sup>p-v</sup>   | 10.67 <sup>x-zA-F</sup> (-49.21) | 0.0 <sup>h</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 7.92 <sup>k</sup>    |
| High Fly 2          | 43.0 <sup>b-e</sup>   | 30.33 <sup>i-o</sup> (-28.57)    | 15.23 <sup>v-zAB</sup> (-64.15)  | 3.66 <sup>C-H</sup> (-91.48) | 23.06 <sup>c</sup>   |
| HM-78               | 35.67 <sup>d-k</sup>  | 26.67 <sup>l-r</sup> (-24.64)    | 11.67 <sup>w-zA-C</sup> (-64.80) | 2.98 <sup>C-H</sup> (-91.25) | 19.25 <sup>cd</sup>  |
| Hot Flame           | 40.0 <sup>c-h</sup>   | 16.67 <sup>t-zA</sup> (-57.21)   | 0.0 <sup>h</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 14.17 <sup>e-h</sup> |
| Hot Queen           | 40.0 <sup>c-h</sup>   | 25.33 <sup>m-t</sup> (-36.56)    | 8.67 <sup>A-H</sup> (-78.29)     | 1.91 <sup>F-H</sup> (-95.23) | 18.98 <sup>cd</sup>  |
| Hot Red             | 16.67 <sup>t-zA</sup> | 11.33 <sup>w-zA-D</sup> (-35.14) | 2.0 <sup>F-H</sup> (-88.10)      | 0.0 <sup>H</sup> (-100.0)    | 7.50 <sup>k</sup>    |
| HHP-082B            | 44.0 <sup>b-d</sup>   | 27.67 <sup>k-p</sup> (-37.12)    | 4.67 <sup>v</sup> (-89.39)       | 0.0 <sup>H</sup> (-100.0)    | 19.08 <sup>cd</sup>  |
| HHP-091A            | 30.0 <sup>j-o</sup>   | 18.67 <sup>q-x</sup> (-38.31)    | 3.67 <sup>C-H</sup> (-83.93)     | 0.0 <sup>H</sup> (-100.0)    | 13.08 <sup>g-i</sup> |
| Kot Sultan          | 68.33 <sup>a</sup>    | 44.0 <sup>b-d</sup> (-35.39)     | 17.0 <sup>v</sup> (-75.14)       | 3.28 <sup>C-H</sup> (-95.14) | 33.15 <sup>a</sup>   |
| Kunri               | 33.33 <sup>f-m</sup>  | 16.0 <sup>u-zA</sup> (-52.02)    | 0.0 <sup>h</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 12.33 <sup>h-j</sup> |
| Loralai             | 35.67 <sup>d-k</sup>  | 17.0 <sup>t-zA</sup> (-47.63)    | 1.27 <sup>v</sup> (-94.54)       | 0.0 <sup>H</sup> (-100.0)    | 13.48 <sup>f-i</sup> |
| Nadena              | 17.67 <sup>s-z</sup>  | 9.67 <sup>yzA-G</sup> (-45.61)   | 0.0 <sup>h</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 6.83 <sup>k</sup>    |
| Pusa Jawala         | 27.33 <sup>k-q</sup>  | 11.67 <sup>w-zA-C</sup> (-54.66) | 0.0 <sup>h</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 9.75 <sup>i-k</sup>  |
| Rainbow             | 41.67 <sup>b-g</sup>  | 24.67 <sup>m-u</sup> (-39.57)    | 7.0 <sup>B-H</sup> (-82.47)      | 0.0 <sup>H</sup> (-100.0)    | 18.33 <sup>de</sup>  |
| Red Giant           | 19.67 <sup>p-w</sup>  | 8.67 <sup>A-H</sup> (-53.34)     | 0.0 <sup>h</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 7.08 <sup>k</sup>    |
| Shakti              | 18.0 <sup>r-y</sup>   | 11.0 <sup>w-zA-E</sup> (-41.11)  | 4.0 <sup>v</sup> (-75.06)        | 0.0 <sup>H</sup> (-100.0)    | 8.25 <sup>jk</sup>   |
| Sky Hot             | 43.33 <sup>b-e</sup>  | 22.0 <sup>o-v</sup> (-50.34)     | 1.32 <sup>GH</sup> (-96.64)      | 0.0 <sup>H</sup> (-100.0)    | 16.66 <sup>d-h</sup> |
| Sky Red             | 19.67 <sup>p-w</sup>  | 10.67 <sup>x-zA-F</sup> (-44.96) | 3.20 <sup>C-H</sup> (-82.03)     | 0.0 <sup>H</sup> (-100.0)    | 8.38 <sup>jk</sup>   |
| Sky Star 4          | 33.0 <sup>g-m</sup>   | 15.67 <sup>v-zAB</sup> (-46.10)  | 3.77 <sup>C-H</sup> (-87.81)     | 0.0 <sup>H</sup> (-100.0)    | 13.11 <sup>g-i</sup> |
| Sky Line 2          | 42.0 <sup>B-F</sup>   | 21.67 <sup>o-v</sup> (-48.41)    | 2.13 <sup>F-H</sup> (-94.92)     | 0.0 <sup>H</sup> (-100.0)    | 16.45 <sup>d-h</sup> |
| Talhari             | 16.0 <sup>u-zA</sup>  | 9.0 <sup>zA-G</sup> (-41.21)     | 0.0 <sup>H</sup> (-100.0)        | 0.0 <sup>H</sup> (-100.0)    | 6.25 <sup>k</sup>    |
| Zenia               | 35.67 <sup>d-k</sup>  | 22.0 <sup>o-v</sup> (-36.88)     | 7.0 <sup>B-H</sup> (-79.56)      | 0.0 <sup>H</sup> (-100.0)    | 16.17 <sup>d-h</sup> |
| Mean                | 34.57 <sup>a</sup>    | 20.61 <sup>b</sup>               | 5.17 <sup>c</sup>                | 0.73 <sup>d</sup>            |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $p = 0.05$  (LSD test). Means were initially labelled by small letters and afterwards by capital letters due to great variation in means.

**Table 7:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on root fresh weight (mg) and percent change in root fresh weight (in parenthesis) of 30 chilli genotypes.

| Genotypes           | Control                 | 5% PEG                           | 10% PEG                          | 15% PEG                         | Mean                 |
|---------------------|-------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------|
| Acc.32362           | 31.33 <sup>t-zA-D</sup> | 20.0 <sup>yzA-O</sup> (-36.73)   | 0.0 <sup>P</sup> (-100.0)        | 0.0 <sup>P</sup> (-100.0)       | 12.83 <sup>kl</sup>  |
| Advanta-509         | 120.0 <sup>bc</sup>     | 89.33 <sup>d-f</sup> (-25.18)    | 51.0 <sup>m-r</sup> (-57.46)     | 27.0 <sup>v-zA-K</sup> (-91.71) | 71.83 <sup>ab</sup>  |
| Amber               | 51.333 <sup>m-r</sup>   | 27.67 <sup>u-zA-J</sup> (-47.06) | 0.0 <sup>P</sup> (-100.0)        | 0.0 <sup>P</sup> (-100.0)       | 19.75 <sup>g-l</sup> |
| Chilli Hot Queen    | 132.67 <sup>b</sup>     | 101.67 <sup>cd</sup> (-22.84)    | 47.0 <sup>n-t</sup> (-64.16)     | 18.667 <sup>zA-O</sup> (-96.42) | 75.0 <sup>ab</sup>   |
| CKD 2204            | 38.0 <sup>q-y</sup>     | 25.67 <sup>v-zA-L</sup> (-31.92) | 12.0 <sup>F-P</sup> (-68.88)     | 0.0 <sup>P</sup> (-100.0)       | 18.92 <sup>h-l</sup> |
| Chander Mukhi       | 45.67 <sup>n-u</sup>    | 32.0 <sup>s-zA-C</sup> (-30.72)  | 0.0 <sup>P</sup> (-100.0)        | 0.0 <sup>P</sup> (-100.0)       | 19.42 <sup>h-l</sup> |
| Divya               | 116.33 <sup>bc</sup>    | 87.67 <sup>d-g</sup> (-24.43)    | 50.0 <sup>m-s</sup> (-56.69)     | 19.33 <sup>zA-O</sup> (-88.16)  | 68.33 <sup>b</sup>   |
| F <sub>1</sub> 1130 | 31.67 <sup>s-zA-C</sup> | 18.0 <sup>A-P</sup> (-43.59)     | 3.67 <sup>OP</sup> (-87.52)      | 0.0 <sup>P</sup> (-100.0)       | 13.33 <sup>kl</sup>  |
| Ghotki              | 59.0 <sup>k-p</sup>     | 28.67 <sup>t-zA-H</sup> (-50.21) | 10.33 <sup>H-P</sup> (-80.78)    | 0.0 <sup>P</sup> (-100.0)       | 24.50 <sup>e-j</sup> |
| High Fly 2          | 52.33 <sup>l-q</sup>    | 39.0 <sup>q-x</sup> (-26.57)     | 19.33 <sup>zA-O</sup> (-64.87)   | 11.33 <sup>G-P</sup> (-91.48)   | 30.50 <sup>e</sup>   |
| HM-78               | 94.0 <sup>de</sup>      | 68.0 <sup>h-m</sup> (-27.74)     | 36.67 <sup>q-z</sup> (-60.90)    | 9.29 <sup>I-P</sup> (-91.25)    | 51.99 <sup>cd</sup>  |
| Hot Flame           | 79.33 <sup>e-l</sup>    | 29.67 <sup>t-zA-G</sup> (-61.54) | 0.0 <sup>P</sup> (-100.0)        | 0.0 <sup>P</sup> (-100.0)       | 27.25 <sup>e-h</sup> |
| Hot Queen           | 155.0 <sup>a</sup>      | 119.0 <sup>bc</sup> (-21.64)     | 34.0 <sup>q-zA-B</sup> (-76.72)  | 11.65 <sup>G-P</sup> (-95.23)   | 79.91 <sup>a</sup>   |
| Hot Red             | 123.65 <sup>b</sup>     | 81.33 <sup>e-h</sup> (-34.33)    | 30.33 <sup>t-zA-F</sup> (-75.46) | 0.0 <sup>P</sup> (-100.0)       | 58.83 <sup>c</sup>   |
| HHP-082B            | 37.0 <sup>q-z</sup>     | 23.33 <sup>x-zA-N</sup> (-38.25) | 7.67 <sup>L-P</sup> (-78.75)     | 0.0 <sup>P</sup> (-100.0)       | 17.0 <sup>j-l</sup>  |
| HHP-091A            | 46.0 <sup>n-u</sup>     | 28.68 <sup>t-zA-H</sup> (-33.48) | 9.67 <sup>I-P</sup> (-69.34)     | 0.0 <sup>P</sup> (-100.0)       | 21.08 <sup>f-k</sup> |
| Kot Sultan          | 74.33 <sup>f-k</sup>    | 59.33 <sup>j-p</sup> (-20.59)    | 28.0 <sup>u-zA-I</sup> (-62.50)  | 14.60 <sup>C-P</sup> (-95.14)   | 44.07 <sup>d</sup>   |
| Kunri               | 67.33 <sup>h-m</sup>    | 25.0 <sup>w-zA-M</sup> (-56.98)  | 8.50 <sup>K-P</sup> (-85.66)     | 0.0 <sup>P</sup> (-100.0)       | 25.21 <sup>e-j</sup> |
| Loralai             | 77.67 <sup>e-j</sup>    | 38.0 <sup>q-y</sup> (-45.98)     | 3.63 <sup>OP</sup> (-94.83)      | 0.0 <sup>P</sup> (-100.0)       | 29.82 <sup>ef</sup>  |
| Nagena              | 71.33 <sup>f-k</sup>    | 36.0 <sup>q-zA</sup> (-49.09)    | 7.70 <sup>L-P</sup> (-89.23)     | 0.0 <sup>P</sup> (-100.0)       | 28.76 <sup>e-g</sup> |
| Pusa Jawala         | 66.67 <sup>h-m</sup>    | 30.33 <sup>t-zA-F</sup> (-53.52) | 8.17 <sup>L-P</sup> (-87.20)     | 0.0 <sup>P</sup> (-100.0)       | 26.29 <sup>e-i</sup> |
| Rainbow             | 70.0 <sup>g-l</sup>     | 46.0 <sup>n-u</sup> (-31.42)     | 16.40 <sup>B-P</sup> (-86.15)    | 0.0 <sup>P</sup> (-100.0)       | 33.10 <sup>e</sup>   |
| Red Giant           | 88.0 <sup>d-g</sup>     | 40.33 <sup>q-x</sup> (-54.17)    | 0.0 <sup>P</sup> (-100.0)        | 0.0 <sup>P</sup> (-100.0)       | 32.08 <sup>e</sup>   |
| Shakti              | 42.67 <sup>p-w</sup>    | 25.67 <sup>v-zA-L</sup> (-40.33) | 13.0 <sup>D-P</sup> (-69.36)     | 0.0 <sup>P</sup> (-100.0)       | 20.33 <sup>g-l</sup> |
| Sky Hot             | 63.67 <sup>h-n</sup>    | 33.67 <sup>r-zA-B</sup> (-47.39) | 6.67 <sup>M-P</sup> (-89.61)     | 0.0 <sup>P</sup> (-100.0)       | 26.0 <sup>e-j</sup>  |
| Sky Red             | 43.67 <sup>o-v</sup>    | 24.67 <sup>w-zA-M</sup> (-42.61) | 3.0 <sup>OP</sup> (-92.51)       | 0.0 <sup>P</sup> (-100.0)       | 17.83 <sup>i-l</sup> |
| Sky Star 4          | 33.33 <sup>r-zA-B</sup> | 17.67 <sup>A-P</sup> (-45.46)    | 6.0 <sup>N-P</sup> (-81.02)      | 0.0 <sup>P</sup> (-100.0)       | 14.25 <sup>kl</sup>  |
| Sky Line 2          | 61.67 <sup>i-o</sup>    | 33.67 <sup>r-zA-B</sup> (-43.93) | 12.33 <sup>E-P</sup> (-78.31)    | 0.0 <sup>P</sup> (-100.0)       | 26.92 <sup>e-i</sup> |
| Talhari             | 30.67 <sup>t-zA-E</sup> | 14.0 <sup>C-P</sup> (-52.89)     | 2.0 <sup>OP</sup> (-93.10)       | 0.0 <sup>P</sup> (-100.0)       | 11.67 <sup>l</sup>   |
| Zenia               | 118.67 <sup>bc</sup>    | 76.0 <sup>e-k</sup> (-33.24)     | 11.44 <sup>G-P</sup> (-89.82)    | 0.0 <sup>P</sup> (-100.0)       | 51.53 <sup>cd</sup>  |
| Mean                | 70.77 <sup>a</sup>      | 44.0 <sup>b</sup>                | 14.62 <sup>c</sup>               | 3.73 <sup>d</sup>               |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $p = 0.05$  (LSD test). Means were initially labelled by small letters and afterwards by capital letters due to great variation in means.

observed in HM-78 (-91.25%) and the maximum was shown by genotypes Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100%) (Table 7).

Root fresh weight was least changed in Divya, High Fly 2, Advanta-509, Kot Sultan, Hot Queen, HM-78 and Chilli Hot Queen at 15% PEG-6000 level, which indicated their drought tolerance ability. Acc.32362, Amber, Chander Mukhi, Hot Flame and Red Giant had no roots even at a 10% PEG-6000 level, which showed that these genotypes were highly drought sensitive.

mg) was estimated at 15% PEG-6000 level. All four PEG-6000 levels varied significantly from each other (Table 7). Interaction of chilli genotypes and PEG-6000 levels was also found to be significant on root fresh weight. It was noted that the maximum mean value for root fresh weight was observed in Hot Queen (155.0 mg) at 0% PEG-6000 level (control), which was significantly higher than all other treatment combinations. The minimum root fresh weight was observed in Zenia, Talhari, Skyline 2, Sky Star 4, Sky Red, Sky Hot, Shakti, Red Giant, Rainbow, Pusa Jawala, Nagena, Kunri, Loralai, Hot Red (0.0 mg) all at 15% PEG-6000 level followed by Talhari (2.0 mg), Sky Red (3.0 mg), Loralai (3.63 mg), F<sub>1</sub> 1130 (3.67 mg), Sky Star 4 (6.0 mg) and Sky Hot (6.67 mg) all at 10% PEG-6000 level. All these treatment combinations behaved statistically alike (Table 7).

At 5% PEG-6000 level, the minimum change in root fresh weight was noted in Kot Sultan (-20.59 %), while the maximum change was observed in Hot Flame (-61.54%). When a 10% PEG-6000 solution was applied, the minimum change was noted in Advanta-509 (-57.46%), while Acc.32362, Amber, Chander Mukhi, Hot Flame and Red Giant exhibited the maximum change (-100.0%). At 15% PEG-6000 level, the minimum change was

### Root dry weight

Chilli genotypes differed significantly for root dry weight. Hot Queen attained the maximum (30.32 mg) root dry weight, followed by Chilli Hot Queen (24.75 mg), Hot Flame (24.75 mg) and Divya (24.0 mg). These four genotypes stood statistically at par. The minimum root dry weight was noted in Sky Red (5.33 mg) followed by Talhari (6.08 mg), Sky Star 4 (6.92 mg), Acc.32362 (7.58 mg), Red Giant (7.92 mg), Kunri (8.25 mg), HHP-082B (8.42 mg), HHP-091A, Pusa Jawala (8.67 mg), Loralai (9.75 mg) and few other genotypes. All these genotypes behaved statistically alike. Data indicated that PEG-6000 levied adverse effects on the root dry weight of chilli seedlings. As the concentration of PEG-6000 increased, the root dry weight of the seedlings decreased. The maximum root dry weight (29.63 mg) was noted at 0% PEG-6000 level (control). Nonetheless, the minimum root dry weight (0.95 mg) was recorded at 15% PEG-6000 level. Behaviour of all the PEG-6000 levels was significantly different (Table 8). Interaction of chilli genotypes and PEG-6000 levels was also significant on root dry weight. The maximum root dry weight was recorded in Hot Flame (87.0 mg) at 0% PEG-6000 level (control), which was significantly different

**Table 8:** Effect of different levels of PEG-6000 (5%, 10% and 15%) on root dry weight (mg) and percent change in root dry weight (in parenthesis) of 30 chilli genotypes.

| Genotypes           | Control              | 5% PEG                        | 10% PEG                       | 15% PEG                      | Mean                 |
|---------------------|----------------------|-------------------------------|-------------------------------|------------------------------|----------------------|
| Acc.32362           | 18.67 <sup>h-w</sup> | 11.67 <sup>n-y</sup> (-34.69) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 7.58 <sup>g-i</sup>  |
| Advanta-509         | 31.0 <sup>c-k</sup>  | 24.0 <sup>d-s</sup> (-21.92)  | 10.67 <sup>o-y</sup> (-64.64) | 7.33 <sup>t-y</sup> (-75.27) | 18.25 <sup>b-f</sup> |
| Amber               | 28.33 <sup>c-m</sup> | 13.0 <sup>l-y</sup> (-52.18)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 10.33 <sup>e-j</sup> |
| Chilli Hot Queen    | 38.0 <sup>b-f</sup>  | 29.0 <sup>c-l</sup> (-23.02)  | 22.0 <sup>f-u</sup> (-41.54)  | 10.0 <sup>o-y</sup> (-73.27) | 24.75 <sup>ab</sup>  |
| CKD 2204            | 27.33 <sup>c-n</sup> | 17.0 <sup>h-x</sup> (-38.66)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 11.08 <sup>e-j</sup> |
| Chander Mukhi       | 25.0 <sup>d-q</sup>  | 16.0 <sup>j-y</sup> (-36.71)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 10.25 <sup>f-j</sup> |
| Divya               | 39.67 <sup>b-d</sup> | 28.67 <sup>c-l</sup> (-27.50) | 22.67 <sup>e-u</sup> (-41.98) | 5.0 <sup>v-y</sup> (-87.12)  | 24.0 <sup>a-c</sup>  |
| F <sub>1</sub> 1130 | 15.0 <sup>k-y</sup>  | 9.0 <sup>p-y</sup> (-40.48)   | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 6.0 <sup>ij</sup>    |
| Ghotki              | 28.33 <sup>c-m</sup> | 14.33 <sup>l-y</sup> (-47.75) | 5.0 <sup>v-y</sup> (-81.16)   | 0.0 <sup>y</sup> (-100.0)    | 11.92 <sup>e-j</sup> |
| High Fly 2          | 32.33 <sup>c-j</sup> | 24.67 <sup>d-r</sup> (-23.99) | 6.20 <sup>u-y</sup> (-80.51)  | 0.0 <sup>y</sup> (-100.0)    | 15.80 <sup>c-g</sup> |
| HM-78               | 38.67 <sup>b-e</sup> | 31.0 <sup>c-k</sup> (-18.50)  | 16.33 <sup>i-y</sup> (-56.89) | 1.96 <sup>xy</sup> (-94.90)  | 21.99 <sup>b-d</sup> |
| Hot Flame           | 87.0 <sup>a</sup>    | 12.0 <sup>m-y</sup> (-64.60)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 24.75 <sup>ab</sup>  |
| Hot Queen           | 52.33 <sup>b</sup>   | 42.67 <sup>bc</sup> (-17.99)  | 24.0 <sup>d-s</sup> (-54.17)  | 2.26 <sup>w-y</sup> (-95.65) | 30.32 <sup>a</sup>   |
| Hot Red             | 35.67 <sup>c-g</sup> | 22.67 <sup>e-u</sup> (-35.61) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 14.58 <sup>d-h</sup> |
| HHP-082B            | 20.33 <sup>g-v</sup> | 13.33 <sup>l-y</sup> (-33.21) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 8.42 <sup>g-i</sup>  |
| HHP-091A            | 21.67 <sup>f-u</sup> | 13.0 <sup>l-y</sup> (-40.98)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 8.67 <sup>g-i</sup>  |
| Kot Sultan          | 33.33 <sup>c-h</sup> | 25.0 <sup>d-q</sup> (-24.53)  | 14.0 <sup>l-y</sup> (-58.04)  | 1.89 <sup>xy</sup> (-94.31)  | 18.56 <sup>b-e</sup> |
| Kunri               | 24.0 <sup>d-s</sup>  | 9.0 <sup>p-y</sup> (-61.0)    | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 8.25 <sup>g-i</sup>  |
| Loralai             | 25.33 <sup>d-p</sup> | 13.67 <sup>l-y</sup> (-45.07) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 9.75 <sup>g-i</sup>  |
| Nagena              | 31.0 <sup>c-k</sup>  | 16.67 <sup>i-x</sup> (-43.57) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 11.92 <sup>e-j</sup> |
| Pusa Jawala         | 25.33 <sup>d-p</sup> | 9.33 <sup>p-y</sup> (-61.81)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 8.67 <sup>g-i</sup>  |
| Rainbow             | 32.67 <sup>c-i</sup> | 18.67 <sup>h-w</sup> (-36.93) | 3.69 <sup>w-y</sup> (-88.34)  | 0.0 <sup>y</sup> (-100.0)    | 13.76 <sup>d-i</sup> |
| Red Giant           | 23.0 <sup>e-t</sup>  | 8.67 <sup>q-y</sup> (-61.73)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 7.92 <sup>g-i</sup>  |
| Shakti              | 26.0 <sup>d-o</sup>  | 17.0 <sup>h-x</sup> (-34.41)  | 2.94 <sup>w-y</sup> (-88.65)  | 0.0 <sup>y</sup> (-100.0)    | 11.49 <sup>e-j</sup> |
| Sky Hot             | 27.33 <sup>c-n</sup> | 13.33 <sup>l-y</sup> (-50.26) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 10.17 <sup>f-j</sup> |
| Sky Red             | 13.67 <sup>l-y</sup> | 7.67 <sup>s-y</sup> (-42.62)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 5.33 <sup>l</sup>    |
| Sky Star 4          | 17.0 <sup>h-x</sup>  | 10.67 <sup>o-y</sup> (-38.07) | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 6.92 <sup>h-j</sup>  |
| Sky Line 2          | 23.67 <sup>d-t</sup> | 14.0 <sup>l-y</sup> (-40.88)  | 4.67 <sup>v-y</sup> (-80.19)  | 0.0 <sup>y</sup> (-100.0)    | 10.58 <sup>e-j</sup> |
| Talhari             | 16.0 <sup>j-y</sup>  | 8.33 <sup>r-y</sup> (-48.50)  | 0.0 <sup>y</sup> (-100.0)     | 0.0 <sup>y</sup> (-100.0)    | 6.08 <sup>ij</sup>   |
| Zenia               | 31.33 <sup>c-k</sup> | 20.33 <sup>g-v</sup> (-35.52) | 10.0 <sup>o-y</sup> (-68.74)  | 0.0 <sup>y</sup> (-100.0)    | 15.42 <sup>d-g</sup> |
| Mean                | 29.63 <sup>a</sup>   | 17.14 <sup>ab</sup>           | 4.73 <sup>9c</sup>            | 0.95 <sup>d</sup>            |                      |

Means sharing similar letter(s) in a group are statistically non-significant at  $p = 0.05$  (LSD test).

from all other treatment combinations. The minimum root dry weight was observed in Acc.32362, Amber, C.K.D-2204, Chander Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Hot, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (0.0 mg) followed by Kot Sultan (1.89 mg), HM- 78 (1.96 mg), Hot Queen (2.26 mg) all at 15% PEG-6000 level, Shakti (2.94 mg), Rainbow (3.69 mg) and Sky Line 2 (4.67 mg) at 10% PEG-6000 level, Divya (5.0 mg) at 15% PEG-6000 level, and Ghotki (5.0 mg) and High Fly 2 (6.20 mg) at 10% PEG-6000 level. The response of all these treatment combinations was statistically similar (Table 8).

At 5% PEG-6000 level, the minimum change in root dry weight was noted in Hot Queen (-17.99%), while the maximum change was observed in Hot Flame (-64.60%). When a 10% PEG-6000 solution was applied, the minimum change was noted in Chilli Hot Queen (-41.54%), while Acc.32362, Amber, C.K.D 2204, Chander Mukhi, F<sub>1</sub> 1130, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Red Giant, Sky Hot, Sky Red, Sky Star 4 and Talhari showed the maximum change (-100.0%). At 15% PEG-6000 level, the minimum change was observed in Chilli Hot Queen (-73.27%) and the maximum was shown by genotypes Acc.32362, Amber, C.K.D-2204, Chander

Mukhi, F<sub>1</sub> 1130, Ghotki, Hot Flame, Hot Red, HHP-082B, HHP-091A, Kunri, Loralai, Nagena, Pusa Jawala, Rainbow, Red Giant, Shakti, Sky Ho and Talhari, Sky Red, Sky Star 4, Sky Line 2, Talhari and Zenia (-100%) (Table 8).

Chilli Hot Queen, Advanta-509, Divya, Kot Sultan, HM-78 and Hot Queen had the minimum change in their root dry weight at 15% PEG-6000 level, which confirms that these genotypes were drought tolerant. In contrast, Acc.32362, Amber, C.K.D. 2204, Chander Mukhi, F<sub>1</sub> 1130, Hot Flame, Hot Red, HHP-082B, HHP-91A, Kunri, Loralai, Nagena, Pusa Jawala, Red Giant, Sky Hot, Sky Red, Sky Stat 4, and Talhari were highly sensitive genotypes because they showed the maximum % change in their root dry weight at 10% PEG-6000 level.

## DISCUSSION

Selection of drought-tolerant genotypes is essential under a dry environment (Tuberosa and Salvi, 2006). However, uniform, controlled and sustainable drought stress cannot be achieved in field conditions (Shaheen and Hood-

Nowotny, 2005). The unavailability of a large number of genotypes for breeding and the absence of specific screening methods are the main hurdles in the development of drought-tolerant hybrids (Zeigler and Puckridge, 1995). At the early plant growth stage, water deficit conditions can be imposed through PEG (Muscolo et al., 2014). Water deficit conditions cannot be imposed under field conditions because precipitation can eliminate drought stress. However, methods of drought screening under *in vitro* or laboratory conditions help in the advancement of our knowledge about drought tolerance traits and the selection of drought-tolerant genotypes.

*In vitro* screening of drought-tolerant genotypes against different levels of PEG is helpful for screening out a large amount of germplasm precisely (Manoj and Uday, 2007). At different levels of PEG, the response of genotypes could be different due to their genetic sensitivity to water deficit conditions. So, it is very important for plant breeders to screen out drought-tolerant genotypes at the seedling stage without extensive and expensive field trials (Shivakrishna et al., 2018).

One of the critical and sensitive phases in the life span of plants is the seed germination stage. PEG-6000 levels significantly

affected germination percentage, as the level of PEG-6000 increased from 0 to 15%, germination percentage decreased. Chilli genotypes germinated at 5% PEG-6000 level showed a marginal to mild reduction in germination percentage, while chilli genotypes grown at a 10% PEG-6000 level showed a significant reduction in germination percentage. Genotypes experienced a severe reduction in germination percentage at a 15% PEG-6000 level. Results of the present study showed that chilli genotypes Advanta-509, Chilli Hot Queen, Divya, and Hot Queen attained the maximum germination percentage, whereas the minimum germination percentage was observed in Talhari among all the studied chilli genotypes. Present findings are in accordance with the results of previous workers (Jamaati-e-Somarin and Zabihi-e-Mahmoodabad, 2011), who found that a gradual increment in PEG level finally leads to a drastic reduction in lentil germination percentage. When a seed is exposed to unfavourable environments such as drought, it impacts its germination rate and seedling establishment (Soleymani and Shahrajabian, 2012). Drought stress not only reduces seed germination percentage but also decreases the lengths of radicle and plumule (Duman, 2006). PEG reduced germination percentage and increased osmotic potential in bean seedlings.

In plants, the root system is the main organ which fulfils their water and nutrient requirements and influences their growth, development, and yield (Palta and Yang, 2014). Regarding the influence of PEG-6000 on shoot and root lengths, the results of the current study demonstrated that shoot and root lengths decreased with an increase in PEG level from 0% to 15%. Current findings showed that the root length recorded was the maximum in High Fly 2, and it was the minimum in Hot Flame and HHP-082B, followed by Shakti. Our findings are in accordance with previous results, which confirmed that the development of an extensive root system indicates significant variation among chilli cultivars for drought stress tolerance. Further, for selecting drought-tolerant cultivars, an extensive root system is the main attribute (Abd Allah et al., 2010). Therefore, by analysing the morphology of the root system and its growth rate, drought-tolerant genotypes can be selected (Malik et al., 2002). Root length is considered one of the important parameters while selecting drought-tolerant genotypes; generally, a cultivar with longer roots and better growth has more ability to resist drought stress (Kaydan and Yagmur, 2008). The reduction in the growth of root and stem in plants under drought stress is possibly linked with the fact that meristematic tissues at the growing points of root and stem are hampered, and cell multiplication and expansion processes are impeded. In lentil, with a decline in water potential, seed germination rate and final percentage, root and stem lengths, and root and stem dry weights also declined (Kafi et al., 2005). Root length in wheat decreased with the increase in stress level. PEG-6000 induced osmotic stress, which suppressed plant growth by decreasing total root length, volume and surface area, and also the total number of growing root tips in castor bean (Shi et al., 2015). Decreased water absorption and reduced external osmotic potential induced by PEG lead towards a reduction in shoot length (Kaydan and Yagmur, 2008). Environmental stresses significantly hamper agricultural production (Habibi, 2014). The seedling development stage is susceptible to drought stress, and water shortage in the early stage of seedling growth

is very harmful (Hellal et al., 2018). Regarding the effect of different levels of PEG-6000, shoot length decreased with an increase in PEG-6000 level from 0 to 15%. Chilli genotype Kot Sultan attained greater shoot length, followed by Chilli Hot Queen, while Sky Star showed shorter shoot length among all the studied genotypes, followed by Kunri, Sky Hot, Hot Red, Nagenia and Amber. Previous findings demonstrated that seedling growth is a very useful criterion for selecting drought-tolerant genotypes in crops at early growth stages (Basha et al., 2015). Reduction in seedling growth could be due to a decrease in cell multiplication rate and further expansion as a result of water stress (Kramer, 1983). A decrease in shoot length is probably because of low water absorption and reduced external osmotic potential produced by PEG-6000. However, drought stress decreases shoot length less than root length (Kaydan and Yagmur, 2008).

The present study signifies that PEG-6000-related drought stress limits all the phenotypic expression of seedling traits such as fresh shoot and root weights, and dry shoot and root weights (Tables 2-8). Decline in fresh shoot and root weights was recorded with a rise in PEG-6000 level from 0 to 15%. Chilli genotype Divya achieved a greater value for shoot fresh weight; in contrast, a higher value for fresh root weight was observed in Hot Queen, followed by Chilli Hot Queen and Advanta-509. The minimum fresh shoot weight was noted in Talhari, followed by Ghotki and Kunri among all the studied genotypes. Likewise, a reduction in root fresh weight was observed in Zenia, Talhari, Sky Line 2, Sky Star 4, Sky Red, Sky Hot, Shakti, Red Giant, Rainbow, Pusa Jawala, Nagenia, Kunri, Loralai and Hot Red at 15% PEG-6000 level, followed by Talhari, Sky Red, Loralai, F1 1130, Sky Star 4 and Sky Hot at 10% PEG-6000 level. Similar results for fresh shoot and root weights were achieved by Rauf et al. (2008), who stated that as drought stress increased, there was a decrease in fresh shoot and root weights. It might be due to the adverse effects of drought stress that suppressed plant growth. Identical to current results, Gholamin et al. (2010) found that radicle and plumule length and dry matter also decreased under PEG-6000 induced drought stress. Plant breeders consider seedling dry weight as an important parameter for screening drought stress-tolerant cultivars (Ali, 2019).

Current results demonstrated that as PEG-6000 levels increased from 0 to 15%, a decline was noted in dry shoot and root weights. It was also noted that significantly greater shoot dry weight was measured in Kot Sultan. However, a lower shoot dry weight was observed in Talhari, Nagenia, Red giant, Hot Red and Ghotki, followed by C.K.D-2204, Shakti, Sky Red and Pusa Jawala. In contrast, the maximum root dry weight was observed in Hot Queen, Chilli Hot Queen and Hot Flame, while the minimum root dry weight was attained by Sky Red, followed by Talhari, Sky Star 4, Acc.32362, Red Giant, Kunri, HHP-082B, HHP-091A, Pusa Jawala and Loralai. Baalbaki et al. (1999) noted that when osmotic potential was reduced, shoot and root dry weights decreased as compared to their relative controls. However, the magnitude of decline in root growth was less when compared to shoot growth, which supported our findings. Development of deep root systems and the ability to accumulate dry biomass are the characteristics of drought-tolerant genotypes (Zhao et al., 2004). Several other scientists (Kamran et al., 2009) also reported a reduction in shoot and root dry weights; they noted

that water deficit condition significantly reduces shoot and root dry weights. It could be because the lower number of leaves was developed at increased PEG-6000 concentration in the growing medium, which supports our findings. Marginal reduction in shoot and root growth is a sign of drought tolerance under water deficit conditions (Ming et al., 2012). Biomass and morphology of the root are very crucial during the selection of drought-tolerant germplasm (Becker et al., 2016). Several research workers (Kamran et al., 2009; Ahmad et al., 2013; Marcińska et al., 2013) described that shoot and root dry matter production is significantly reduced under a water-deficient environment, which is in line with the results of the current research.

## CONCLUSION

In recent times, various global research studies have focused on studying the impacts of drought on agricultural production and food security. Therefore, introducing a novel drought-tolerant chilli genotype may help enhance the yield and quality of this important vegetable. For this purpose, a fast-screening method like PEG-induced screening can be of marked importance for expanding the cultivation area under this crop. Conclusively, chilli cultivars including Chilli Hot Queen, Advanta-509, Divya, HM-78, Hot Queen, High Fly 2 and Kot Sultan are drought-tolerant genotypes at the initial growth stage. However, Acc.32362, Amber, C.K.D-2204, Ghotki, Hot Flame, Hot Red, HHP-091A, HHP-082B, Kunri, Loralai, Pusa Jawala, Red Giant, Sky Line 2, Sky Red, Sky Star 4, Talhari, and Zenia are drought-sensitive genotypes. Cultivating the drought-tolerant chilli cultivars highlighted by this study can enhance chilli cultivation in water-deficient regions, adding a new chapter in agricultural resilience. However, further research is needed to study the physiological and biochemical behaviour of these tolerant genotypes under osmotic stress to explore their drought stress tolerance mechanism.

## DECLARATION OF COMPETING INTERESTS

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTION STATEMENT

**Muhammad Ali, Arsalan Akbar:** Completed the experiments and prepared the initial draft. **Shaghef Ejaz:** Reviewed and revised the article. **Muhammad Akbar Anjum:** Planned and supervised the research.

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All data is published in this research article.

## INFORMED CONSENT

Not applicable.

## CONSENT FOR PUBLICATION

All authors have submitted consent to publish this research article in the 'Journal of Horticulture Science and Technology'.

## SDGs ADDRESSED

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