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# EFFECT OF PEG INDUCED DROUGHT STRESS ON MAIZE (*ZEA MAYS* L.) INBREDS

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## Abstract

Drought stress is one of the most important abiotic stress issues that reduces growth, development and yield of the plants. Developing maize cultivars that can perform well in drought and other abiotic stresses is an important goal throughout the world. Germination is a useful criterion in screening for water stress tolerance. Germination is one of the main growth stages for seedling establishment and success in this stage is dependent on moisture availability in the soil. Exposure to polyethylene glycol (PEG-6000) solutions has been effectively used to mimic drought stress. An experiment was carried out to study the effect of Polyethylene glycol (PEG) on the root parameters like primary root length, number of seminals roots , number of lateral roots and root biomass of 30 maize (*Zea mays* L.) inbreds to screen them for drought tolerance. The experiment was carried out in four replicates under factorial Complete Randomized Design. All the root parameters had highest value under control and had significant decline with increasing PEG concentrations (0% < 5% < 10% < 20%). The variation among maize inbreds for these traits was found to be a reliable indicator to screen the drought tolerant genotypes at primary growth stage.

***Keywords***: Drought stress; drought tolerance, PEG (polyethylene glycol), primary root length, lateral roots, root biomass

## Introduction

Maize (*Zea mays* L.) is one of the most important crops of world agricultural economy and ranks third next to rice and wheat in production. Globally, maize is known as 'Queen of Cereals' because of its highest genetic yield potential among cereals. Maize is one of the three leading global cereals that feeds the world (Shiferaw *et al*., 2011). Globally maize is cultivated over an area of 187.95 million hectare with a production of 1060 million metric tonnes and productivity of 5.5 million tonnes per hectare (Anonymous, 2016). Maize requires 500-800 mm of water during life cycle of 80 to 150 days at critical stages of crop growth viz., knee height stage, flowering stage (tasseling and silking) and grain filling stage (Critchley and Klaus, 1991). Drought is a serious threat for crop production and food security (Hsiao, 1973). Drought is the most pervasive limitation to the realization of yield potential in maize (Edmeades *et al*., 2001). Average annual global losses due to drought in maize range from 15% in temperate zone to 17% in tropical zone as estimated by empirical methods (Edmeades *et al*., 2000b). Water stress affects almost every developmental stage of the plant. However, damaging effects of this stress was more noted when it coincided with various growth stages such germination; seedling shoot length, root length and flowering (Rauf *et al*., 2006; Khayatnezhad *et al*., 2010). Water stress not only affects seed germination but also increases mean germination time in maize plants (Willanborb *et al*., 2004).

For the development of elite lines having drought tolerance, the existence of variability among the available maize germplasm is a key to success for the maize breeders. PEG is a superior chemical to induce water stress (Kaur *et al*., 1998). Poly ethylene glycol (PEG) has been used often as abiotic stress inducer in many studies to screen drought tolerant germplasm (Turkan *et al*., 2005; Landjeva *et al*., 2008; Almaghrabi, 2012; Ahmad *et al*., 2013; Jatoi *et al*., 2014). The upsurge in concentration of PEG caused a decrease in germination percentage, seedling vigour in certain crop plants (Khodarahmpour, 2011). The higher germination rates of the tolerant germplasm may be due to their capability to absorb water even under PEG induced water stress. PEG-based in vitro screening for drought tolerance has been proven to be a suitable method to effectively screen large sets of germplasm with good accuracy (Kulkarni & Deshpande2007). The aim of the present study was to investigate the effects of PEG induced stress on root traits of maize (*Zea mays* L.) inbreds to screen them for drought tolerance.

## Materials and Methods

This study was carried out at Division of Genetics and Plant Breeding, SKUAST-K, Shalimar. Thirty maize (*Zea mays* L.) inbreds were used to study the the effects of PEG induced stress on root traits to screen them for drought tolerance. Thirty inbreds included, L-1, L-2, L-9, L-18, L-6, L-10, L-8, HKI- 101, CML-129, HKi-1015-W8,CML-470, L-72, CML-488, CML-167,LM-14, DMR-N6,CML-135, CML-415, LM-12, CML-139, CML-425, CML-286, CML-474, V-338, V-5, V-412, V-351, V-405, V-400 and V-335 PEG 6000 (HIMEDIA) was used in four concentrations viz., Control (0%), 5%, 10% and 20%. Four seeds for each genotype were surface sterilized with 0.5% NaOCl for one minute, rinsed thoroughly with distilled water and were put in petri plates containing moist filter paper with different concentrations of PEG and allowed to germinate in a germinator at $25^0$C and 75% humidity in darkness. Radicle length, root biomass, seminal root number and lateral root number was measured after seven days. The design used was factorial CRD with four replications.

## Results

The results of this study reveal that different concentrations of PEG-6000 (0-20%) had significant effect on the root traits of of maize inbreds. Analysis of variance and mean comparison showed that there were significant differences between drought stress levels and genotypes (TableS 1 & 2 and Fig. 1). The number of seminal roots was found non-significant for the maize inbreds. Mean comparison results also revealed that the root traits under different stress levels were different.

The data recorded on root traits under different levels of PEG-6000 (Table 1) is presented below:

**Primary Root length (cm)**

- **0% Level:**- Under controlled conditions primary root length had a mean value of 13.00 with highest value recorded in LM-12 (18.25) followed by V-351 (17.50) and L-8 (17.25) and was lowest in CML-470 (7.50).
- **5% Level:**- Under 5% the primary root length had a mean value of 8.70 with highest value recorded in V-412 (12.75) followed by V-335 (12.00) , LM-12, L-2 and L-8 (11.50) and was lowest in HKI-1015-W8, CML-470 AND CML-425 (5.50).
- **10% Level:-** Under 10% the primary root length had a mean value of 6.30 with highest value recorded in V-412 (9.75) followed by V-400 (9.25) and V-335 (9.00) and was lowest in HKI-1015 W8 and CML-425 (3.50).
- **20% Level:**- Under 20% the primary root length had a mean value of 4.11with highest value recorded in V-412(6.75) followed by L-8 (6.5), V-351 and V-400 (6.25) and was lowest in L-1 (2.25).

**Number of Seminals:**

- **0% Level**:- Under controlled conditions the number of seminals had a mean value of 5.05 with highest value recorded in V-335 (8.00) followed by DMR-N6 (7.25) and V-405 (6.75) and was lowest in CML-488 (3.00).
- **5% Level**:- Under 5% the number of seminals had a mean value of 4.16 with highest value recorded in V-335 (7.00) followed by DMR-N6 (6.25) ,CML-135 and V-405 (5.75) and was lowest in L-8 and V-412 (3.00).
- **10% Level**:- Under 10% the number of seminals had a mean value of 3.04 with highest value recorded in DMR-N6 (4.25) followed by CML-139, V-405 (4.00) and V-400 (3.75) and was lowest in L-8, CML-488 and V-412 (2.00).
- **20% Level**:- Under 20% the number of seminals had a mean value of 1.86 with highest value recorded in V-335 (4.00) followed by CML-139 (3.00) and CML-470 (2.50) and was lowest in L-8 and V-412 (1.00).

**Number of Laterals**

- **0% Level:**- Under controlled conditions the number of laterals had a mean value of 26.77 with highest value recorded in L-2 (62.50) followed by CML-139(59.25) and CML-415 (49.00) and was lowest in LM-14 (4.50).
- **5% Level:**- Under 5% the number of laterals had a mean value of 20.85 with highest value recorded in CML-139 (47.25) followed by L-2 (45.00) and CML-415 (39.00) and was lowest in LM-14 (3.50).
- **10% Level:-** Under 10% the number of laterals had a mean value of 11.60 with highest value recorded in L-2 (30.00) followed by CML-139 (27.25) and L-18 (20.00) and was lowest in LM-14 (2.50).
- **20% Level:**- Under 20% the number of laterals had a mean value of 4.41with highest value recorded in CML-139 (16.00) followed by V-335 (13.00) and CML-167(10.00) and was lowest in L-9 (1.00).

**Root Biomass(g):-**

- **0% Level:**- Under controlled conditions the root biomass had a mean value of 0.35 with highest value recorded in CML-139 (0.62) followed by V-335 (0.59) and V-412(0.55) and was lowest in L-72 (0.16).
- **5% Level:-** Under 5% the root biomass had a mean value of 0.30 with highest value recorded in CML-139 (0.52) followed by V-335 (0.48) and L-8 (0.47) and was lowest in L-72 (0.14).
- **10% Level:-** Under 10% the root biomass had a mean value of 0.20 with highest value recorded in L-8 (0.37) followed by CML-139 (0.36) and V-335 (0.33) and was lowest in L-72 (0.10).
- **20% Level:-** Under 20% the root biomass had a mean value of 0.09 with highest value recorded in L-8 (0.17) followed by CML-139 (0.16) and CML-135 (0.14) and was lowest in L-1 (0.02).

## Discussion

Water stress due to drought is one of the most significant abiotic factors that limit the seed germination, seeding growth, plants growth and yield (Hartmann *et al.*, 2005; Van den Berg and Zeng, 2006). Polyethylene glycol (PEG) molecules are inert, non-ionic, virtually impermeable chains and have been used frequently to induce water stress in crop plants (Carpita *et al*, 1979; Turkan *et al,* 2005; Landjeva *et al*, 2008; Rauf *et al*., 2006). One of the important speculations is that a positive correlation between drought tolerance of the genotypes in the field and in laboratory experiments was noted (Kosturkova *et al*., 2014). In our study all the root parameters including primary root length, number of seminals, number of laterals and root biomass decreased with increasing PEG concentrations from 0-20%. All the root parameters had highest value under control and had significant decline with increasing PEG concentrations (0% < 5% < 10% < 20%). Under control (0%) primary root length was found to be highest in LM-12 and under 5%, 10% and 20% primary root length was found to be highest in V-412. Under control (0%), 5% and 20% number of seminals were highest in V-335 and under 10% number of seminals were highest in DMR-N6. Under control (0%) and 10% number of laterals had highest value in L-2 while under 5% and 20% number of laterals had highest value in CML-139. Under control (0%) and 5% root mass was highest for CML-139 while under 10% and 20% it was highest for L-8. Remarkable decrease in root parameters with increasing PEG concentration has been reported by (Basha *et al*., 2015) in tomato, (Muscolo *et al*., 2013) in lentil, (Dar *et al*., 2018) in maize, (Kalefetoglu *et al.,* 2009) in chickpea, (Almansouri *et al*., 2001*)* in wheat , (Soltani *et al.,* 2006) in maize and (Jajarmi *et al*., 2009) in wheat. ). Root system with the ability of better growth under stress conditions can be considered as tolerant germplasm (Abdel-Raheem *et al*., 2007). Thus there is a scope to identify genotypes that have tolerance to drought at the primary growth stage.

**Table 1 :** In vitro response of maize (*Zea mays* L.) inbreds to different levels of PEG (6000)

| Inbreds | Primary root length(cm) | | | | Number of Seminals | | | | Number of Laterals | | | | Root Biomass(g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0% | 5% | 10% | 20% | 0% | 5% | 10% | 20% | 0% | 5% | 10% | 20% | 0% | 5% | 10% | 20% |
| L-1 | 14.25 | 7.25 | 4.25 | 2.25 | 5.25 | 4.25 | 3.25 | 2.25 | 25.75 | 20.75 | 10.75 | 3.50 | 0.21 | 0.16 | 0.12 | 0.02 |
| L-2 | 12.50 | 11.50 | 7.50 | 4.50 | 4.25 | 3.25 | 2.25 | 1.25 | 62.50 | 45.00 | 30.00 | 2.50 | 0.29 | 0.24 | 0.19 | 0.09 |
| L-9 | 15.50 | 10.75 | 7.75 | 4.75 | 5.00 | 4.00 | 3.00 | 2.00 | 36.25 | 29.75 | 19.75 | 1.00 | 0.38 | 0.29 | 0.21 | 0.10 |
| L-18 | 9.50 | 7.50 | 5.50 | 3.50 | 4.50 | 3.50 | 2.50 | 1.50 | 42.00 | 32.00 | 20.00 | 8.25 | 0.44 | 0.41 | 0.29 | 0.14 |
| L-6 | 11.50 | 7.50 | 5.50 | 4.50 | 5.00 | 4.00 | 30.00 | 20.00 | 27.25 | 21.00 | 11.00 | 3.00 | 0.22 | 0.19 | 0.14 | 0.04 |
| L-10 | 15.75 | 6.75 | 4.75 | 2.75 | 4.75 | 4.00 | 3.00 | 2.00 | 35.00 | 27.00 | 15.00 | 1.50 | 0.24 | 0.22 | 0.15 | 0.05 |
| L-8 | 17.25 | 11.50 | 8.50 | 6.50 | 3.50 | 3.00 | 2.00 | 1.00 | 22.00 | 18.00 | 8.00 | 2.50 | 0.51 | 0.47 | 0.37 | 0.17 |
| HKI-101 | 11.50 | 6.75 | 4.75 | 2.75 | 5.25 | 4.25 | 3.25 | 2.25 | 5.75 | 3.75 | 2.75 | 1.75 | 0.37 | 0.34 | 0.24 | 0.09 |
| CML-129 | 11.25 | 8.00 | 5.75 | 3.75 | 5.00 | 4.00 | 3.00 | 2.00 | 13.75 | 11.75 | 6.25 | 1.50 | 0.29 | 0.25 | 0.15 | 0.07 |
| HKI-1015-W8 | 8.25 | 5.50 | 3.50 | 2.50 | 5.00 | 4.00 | 3.00 | 2.00 | 13.75 | 9.75 | 4.75 | 2.50 | 0.24 | 0.21 | 0.15 | 0.09 |
| CML-470 | 7.50 | 5.50 | 4.50 | 2.50 | 5.50 | 4.50 | 3.50 | 2.50 | 9.75 | 7.75 | 3.75 | 1.75 | 0.23 | 0.20 | 0.14 | 0.06 |
| L-72 | 10.25 | 6.50 | 4.50 | 2.50 | 5.25 | 4.25 | 3.25 | 2.25 | 25.25 | 19.25 | 9.25 | 3.50 | 0.16 | 0.14 | 0.10 | 0.05 |
| CML-488 | 13.25 | 9.00 | 7.00 | 5.00 | 3.00 | 3.00 | 2.00 | 1.00 | 13.25 | 10.25 | 6.25 | 1.50 | 0.33 | 0.30 | 0.17 | 0.08 |
| CML-167 | 11.75 | 10.00 | 8.00 | 5.00 | 3.75 | 3.25 | 2.25 | 1.25 | 33.75 | 25.75 | 15.75 | 10.00 | 0.33 | 0.28 | 0.16 | 0.11 |
| LM-14 | 14.00 | 7.75 | 5.75 | 2.75 | 3.50 | 3.25 | 2.25 | 1.25 | 4.50 | 3.50 | 2.50 | 1.50 | 0.22 | 0.19 | 0.12 | 0.07 |
| DMR-N6 | 11.50 | 8.75 | 6.75 | 4.75 | 7.25 | 6.25 | 4.25 | 2.25 | 17.50 | 13.50 | 7.50 | 2.50 | 0.51 | 0.41 | 0.28 | 0.12 |
| CML-135 | 8.00 | 6.50 | 4.50 | 3.50 | 6.50 | 5.75 | 3.75 | 1.75 | 25.25 | 21.25 | 11.25 | 2.25 | 0.46 | 0.41 | 0.27 | 0.14 |
| CML-415 | 11.75 | 9.25 | 6.25 | 4.25 | 5.25 | 4.25 | 3.50 | 2.50 | 49.00 | 39.00 | 19.00 | 5.50 | 0.31 | 0.27 | 0.19 | 0.08 |
| LM-12 | 18.25 | 11.50 | 8.50 | 5.50 | 5.00 | 4.00 | 3.00 | 2.00 | 26.50 | 19.50 | 9.50 | 3.50 | 0.20 | 0.18 | 0.10 | 0.04 |
| CML-139 | 11.75 | 7.75 | 5.50 | 2.50 | 6.25 | 5.00 | 4.00 | 3.00 | 59.25 | 47.25 | 27.25 | 16.00 | 0.62 | 0.52 | 0.36 | 0.16 |
| CML-425 | 8.75 | 5.50 | 3.50 | 2.50 | 4.25 | 3.25 | 2.25 | 1.25 | 11.25 | 9.25 | 5.50 | 1.75 | 0.23 | 0.20 | 0.12 | 0.05 |
| CML-286 | 15.75 | 9.25 | 6.25 | 3.25 | 5.00 | 4.00 | 3.00 | 2.00 | 17.50 | 13.50 | 7.50 | 3.00 | 0.41 | 0.35 | 0.20 | 0.10 |
| CML-474 | 15.00 | 10.25 | 6.50 | 4.50 | 4.50 | 3.50 | 2.50 | 1.50 | 20.25 | 14.25 | 9.25 | 3.50 | 0.25 | 0.20 | 0.11 | 0.07 |
| V-338 | 15.25 | 11.00 | 8.00 | 5.00 | 4.50 | 3.50 | 2.50 | 1.50 | 11.50 | 8.50 | 4.50 | 3.00 | 0.53 | 0.43 | 0.31 | 0.16 |
| V-5 | 11.75 | 5.50 | 4.50 | 3.50 | 5.25 | 4.25 | 3.25 | 1.25 | 12.75 | 9.75 | 6.75 | 2.75 | 0.24 | 0.18 | 0.12 | 0.05 |
| V-412 | 17.00 | 12.75 | 9.75 | 6.75 | 3.75 | 3.00 | 2.00 | 1.00 | 41.00 | 34.00 | 19.00 | 9.00 | 0.55 | 0.43 | 0.29 | 0.13 |
| V-351 | 17.50 | 10.75 | 8.00 | 6.25 | 6.00 | 5.00 | 4.00 | 2.00 | 34.25 | 28.75 | 13.75 | 9.75 | 0.46 | 0.39 | 0.24 | 0.06 |
| V-405 | 11.25 | 7.50 | 5.50 | 3.50 | 6.75 | 5.75 | 3.75 | 1.75 | 48.25 | 38.25 | 18.25 | 8.25 | 0.38 | 0.33 | 0.21 | 0.05 |
| V-400 | 15.50 | 11.25 | 9.25 | 6.25 | 5.00 | 4.00 | 3.00 | 1.75 | 15.50 | 10.50 | 5.50 | 2.50 | 0.45 | 0.38 | 0.23 | 0.08 |
| V-335 | 17.00 | 12.00 | 9.00 | 6.00 | 8.00 | 7.00 | 5.00 | 4.00 | 43.00 | 33.00 | 18.00 | 13.00 | 0.59 | 0.48 | 0.33 | 0.12 |
| **Mean** | **13.00** | **8.70** | **6.30** | **4.11** | **5.05** | **4.16** | **3.04** | **1.86** | **26.77** | **20.85** | **11.60** | **4.41** | **0.35** | **0.30** | **0.20** | **0.09** |
| **C.D ( p ≤0.05)** | Genotype = 0.64 | | | | Genotype = 0.59 | | | | Genotype1 = 0.87 | | | | Genotype = 0.01 | | | |
| | PEG Levels =0.23 | | | | PEG Levels =0.21 | | | | PEG Levels =0.32 | | | | PEG Levels =0.004 | | | |
| | Genotype X PEG Levels=1.28 | | | | Genotype X PEG Levels = non-significant | | | | Genotype X PEG Levels=1.75 | | | | Genotype X PEG Levels=0.02 | | | |

**Table 2 :** Analysis of variance for traits scored under different levels of PEG 6000 in maize (*Zea mays* L.) inbreds

| Source of variation | d.f | Primary root length (cm) | Number of Seminals | Number of Laterals | Root Biomass (g) |
|---|---|---|---|---|---|
| Genotypes | 29 | 61.42** | 11.08** | 1,399.12** | 0.122** |
| PEG Levels | 3 | 1,737.57** | 229.85** | 11,722.11** | 1.660** |
| Genotypes X PEG Levels | 87 | 5.35** | 0.49** | 143.80** | 0.008** |
| Error | 360 | 0.85 | 0.71 | 1.583 | 0 |

Significant at 0.05% level

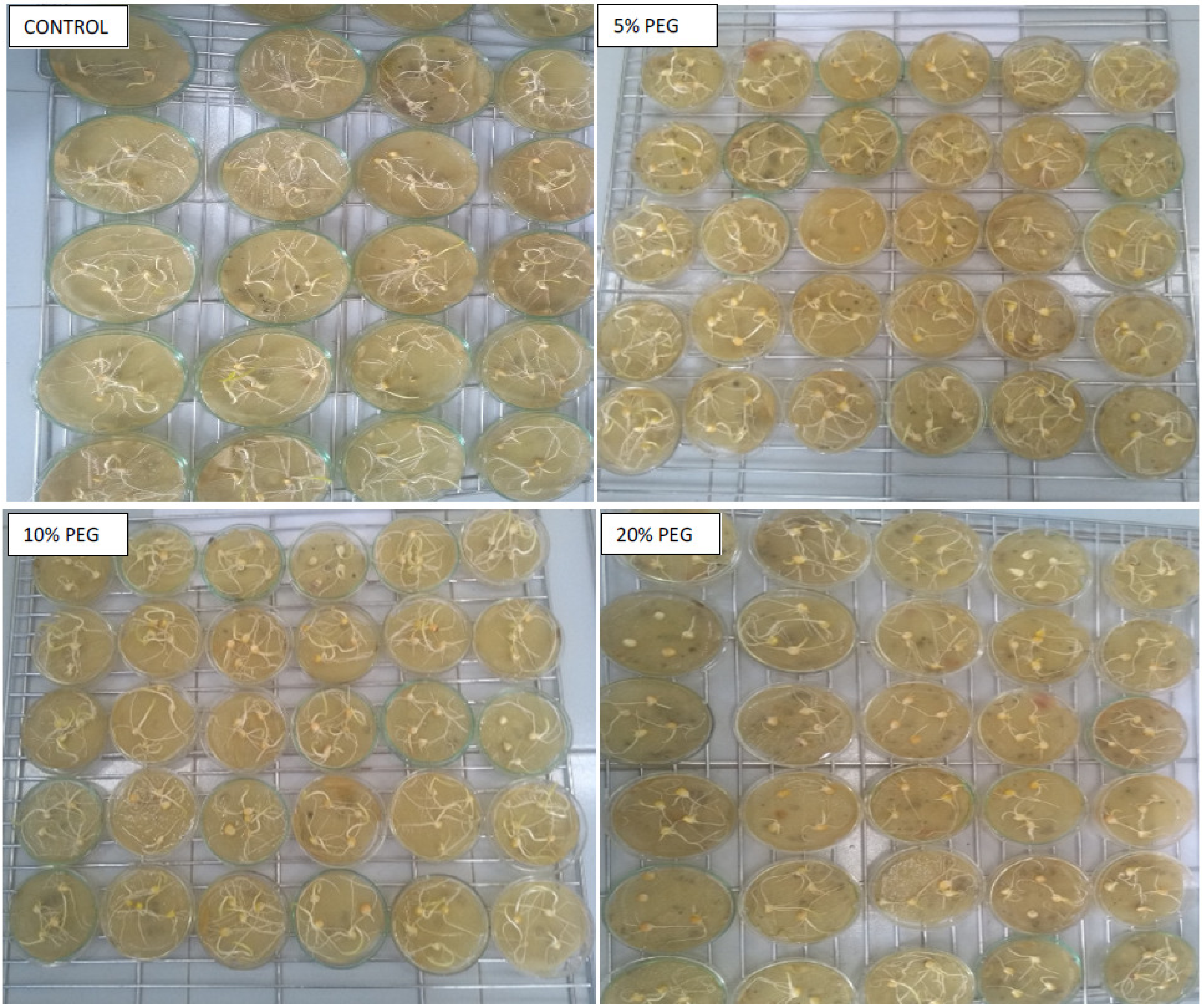


**Fig. 1 :** Comparison of root traits under different peg concentrations

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