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# SEED GERMINATION OF *GUNDELIA TOURNEFORTII* L. UNDER DIFFERENT DORMANCY BREAKING TREATMENTS

**Vian Dler Ali[1] and Farhad Hassan Aziz[2]**

[1] Department of Field Crop, College of Agriculture, Engineering. Science, Salahaddin University, Erbil Iraq
[2] Department of Environment, College of Science Salahaddin University, Erbil. Iraq
Email: farhad.aziz@su.edu.krd
Email:vian.ali1@su.edu.krd

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**ABSTRACT**

*Gundelia tournefortii* L. is adapted to mountains area climate, and the germination of this plant is not easily. This research conducted to study the effect of different seed treatments in various treatment durations in two experiments in petri dish in the laboratory and in seedling tray in the lath house to breaking seed dormancy and germination stimulus. Results indicated that there is significant enhancement of germination by all treatments and the maximum germination percentage was obtained by seed freezing 99.17% in the laboratory and 93.33% in the lath house for all treatment durations 12, 14, 48 and 72 hours. The other parameters of seed germination like germination speed, peak value, mean daily germination, mean germination time, germination value, radicle length, radicle elongation velocity, plumule length, plumule elongation velocity, seedling fresh and dry weight escalated by seed freezing and seed soaking in tap water at all soaking durations 12, 24, 48 and 72 hours. *Gundelia tournefortii* L. germinated seed was an anatomically examined by paraffin method and calculated diploid number of chromosomes 2n=2x=18 by aceto-carmine squash methods.

***Keywords:*** *Gundelia tournefortii* L., seed germination, breaking dormancy.

## INTRODUCTION

*Gundelia tournefortii* L. is a perennial wild plant the Asteraceae family, found in the plains and mountains of Iraq, Kurdistan region - Iraq, Iran, Jordan, Palestine, Syria, Azerbaijan, Armenia and Turkey (Samani *el al.,* 2013). The local name of this plant is Kenger in Kurdish language, also the same name applied in English language (Firat, 2013) and Akub or Kuub in Arabic (Lev-Yadun and Abbo, 1999). The underground portion (stem) is edible and marketable as fresh yield commonly used by people as a vegetative cooking dishes, the dry seeds locally named (Ce Ce) using as a nut (Azi*zet al.,* 1999). Al-Shaibani *et al*., (1986) stated that the dry seed of *Gundelia tournefortii* L. contain about 3.9% humidity, 22.2%protein, 46.6% oil, 7.5% ash, 4.8% fiber, 14.8% carbohydrate. However, 63mg/1000g calcium, 31mg/1000g phosphor, 1.8mg/1000g iron and 58.92 calorie kelo/100g.Aziz *et al.,* (1999) described the main components of the edible portion of *Gundelia tournefortii* L., every 100g of edible portion content 94.2% moisture, 1.87% protein, 2.1% oil, 12.95% calcium, 8.95% phosphor, 0.47% iron, 4.95% Sodium, 5.78% Potassium and 9.85% Magnesium.
Seed is a ripened ovule, consist of an embryonic plant together with store of food, all surrounded by a protective coat, the structure developed from the ovule after fertilization (Khalaf, 2010).

Germination is the process of seeds developing into new plants. Seed germination can be prevented by a process known seed dormancy. Seed dormancy can take place due to unfavorable condition for instance environmental factors or physiological factors (Khakpoor *et al.,* 2015).

Abu-Qaoud and Alkoni, (1995) investigated that *Gundelia tournefortii* L.breaking dormancy by using seed soaking, chemical treatment, germinated hormone, mechanical scarification and stratification. Results indicated that the higher germination percentage (48%) of *Gundelia tournefortii* L. seed when the outer seed coat removed and presoaked in water.

Shibli *et al.,* (2009) postulated that seed treatment of *Gundelia tournefortii* L. by gibberllic acid, $KNO_3$ and thiourea stimulate seed germination and break seed dormancy. Resulted that the maximum germination rate (83%) was recorded by soaking the seed in 250ppm of gibberllic acid for 6 hours.

Vaisi *et al*., (2018) studied *Gundelia tournefortii* L. plant by using several types of seed treatment to break the seed dormancy, they used mechanical scarification,seed soaking, chemical treatment and gibberellic acid at different concentrations and assessed that the seed dormancy type in *Gundelia tournefortii* L. is physiological and physical dormancy.

Okonwn and Eboh (2017) represent that by soaking the seed of *Crotalaria verrucose* L. from the legume family plant in hydrochloride acid (HCl) for 2,5,10,15,20 and

30 minutes and in hot water at 50C°, 70C° and 100C°for 2,5,10,15 and 20 minutes, the results show that all treatment significantly increased the rate of seed germination of this plant.

Due to the importance and problematic seed germination of this plant, testing of different pre-sowing seed treatment to evaluate the germination percentage of the seeds is of great importance as attempt to adopt this plant for sowing.

## MATERIALS AND METHODS

Two experiments were conducted in two locations, petri dish in the laboratory and seedling tray in the lath house, to study the effect of different seed dormancy breaking treatments (tap water, boiled water, freezing, citric acid and hydrochloric acid) of *Gundelia tournefortii* L. seed at different treatment duration. Also, anatomical and cytological of germinated seed were provided in this study. *Gundelia tournefortii* L. seeds were obtained from the Barzan factory – Erbil (figure 1).

### Laboratory experiment

This experiment shows the effect of different treatments on *Gundelia tournefortii* L. in the laboratory at different periods (figure 2), the seeds were treated by:

1. Tap water: 30seeds were soaked in a container filled with tap water at room temperature for 12, 24, 48 and 72 hours.

2. Freezing: 30 seeds Freezed in plastic bag at -4C° for 12, 24, 48 and 72 hours.

3. Boiled water:30 seeds were poured in a container and added boiled water, at room temperature for 15, 30, 45 and 60 minutes.

4. Citric acid: 30 seeds were treated with 10% citric acid, then left at room temperature for15, 30, 45 and 60 minutes.

5. Hydrochloric acid (HCl): 30 seeds, were treated with 10% HCl, then left at room temperature for 15, 30, 45 and 60 minutes.

6. Control treatment: 30 seeds were not treated to break dormancy.

The 10 seeds of each treatment were placed on filter paper in each petri dish with 10ml of distilled water on October 20th, 2020 in the laboratory with three replicates arranged in a completely randomized design (CRD), moisture was maintained by adding 5ml when needed.

### Lath house experiment

This experiment was carried out by using seedling trays with depth and diameter of 5cm. Trays were filled with peat moss, one treated seed per hole was sown on October 20th, 2020 in the lath house (figure 3) by using a completely randomized design (CRD) with three replications. moisture was maintained by adding water when needed.

The statistical analysis was carried out by using SPSS (Statistical Package for Social Sciences) Program, version (22.0) in 2015. Comparisons between means were made using Duncan's Multiple Range Test at 1% level for all germination parameters (Weinberg and Abramowitz, 2008, Field, 2009).

### Cytological part

Aceto-carmine squash method was applied to counting the chromosomal number (Johansen, 1940, Radforad *et al.,* 1974 and Genc and Firat, 2019). Somatic cell utilized for studying diploid number from root tips of germinated seed. The samples were fixed for 20-24hours in (alcohol 70% and glacial acetic acid, in 3:1 ratios), immersed twice in alcohol 70% for 15, hydrolyses in mixture (1N HCl and alchole 70% in 1:3 ratio) for 10 minutes and stained by 2% aqueous acetocarmine for 1-2hours, then slides were prepared with entellan (water-free) mounting medium. Olympus microscope AC 100 with camera, Japanese-made using to examined and picture of samples.

### Anatomical part

Paraffin method was applied for preparation of permanent slides for tissues in germinated seed (Najmaddin and Mahmood, 2016 and Al-dabbagh and Saeed, 2020). The tread seed fixed in FAA and left in room temperature for 24hours, dehydration of samples done by using series concentration of ethyl alcohol. After that, the samples immersed in mixture solution of absolute alcohol and xylene combination (3:1, 1:1, 1:3alcohol, xylene respectively) one hour for each, embeddingthe samples in paraffin was done and left in the oven at 60°C for a night. Paraffin blocks were made by preparing the block of metals with dominations of (2*4) then, the samples were put in suitable manner for cutting. The rotary microtome (Bright, LTD) was using for cutting with thickness of 8-10 micrometer to prepare the slide sections, the ribbons fixed and mounted on slides, after that, the sections transferred to hot plate for overnight. Sides stanning was done by safranin and fast-green then, covered by cover slips after adding a drop of DPX. Olympus microscope AC 100 with camera, Japanese-made using to examine and picture of samples.

### Germination parameters

**Germination percentage (%)** =

$$\frac{\text{Number of germinationed seed}}{\text{Total number of seeds sown}} \times 100$$

(Chebouti-Meziou *et al.,* 2014)

**Germination speed (seed/day)** =

$$\sum \frac{\text{number of germinated seeds}}{\text{number of days}}$$

(Chebouti-Meziou *et al.,* 2014)

**Radicle or plumule elongation velocity (cm/day)** =

$$\frac{\text{Radicle or plumule lenght}}{\text{Total number of days}} \times 100$$

(Ashagre *et al.,* 2013)

**Peak value (%day)** =

$$\frac{\text{Final germination percentage}}{\text{Number of days to reach maximum germination}}$$

(Khalaf, 2016)

**Figure 1.** *Gundelia tournefortii*L. seeds

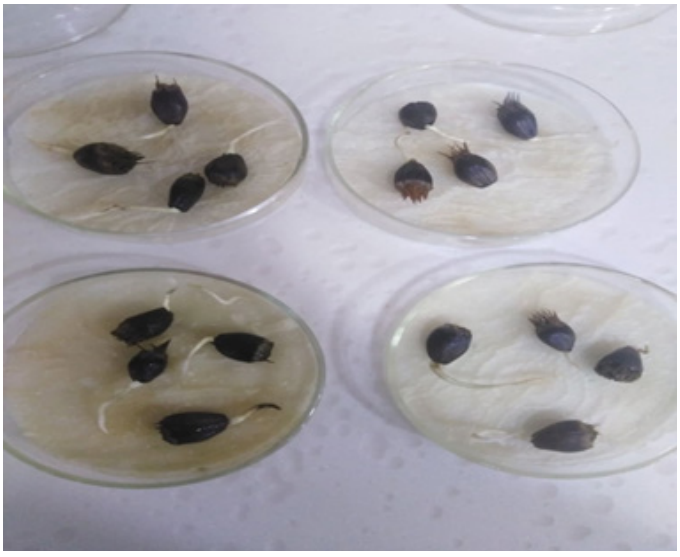

**Figure 2.** *Gundelia tournefortii*L. seeds in petri dish in the laboratory

**Figure 3.***Gundelia tournefortii* L. seeds in seedling tray in the lath house

**Mean daily germination (%day)** =

$$\frac{\text{Final germination \%}}{\text{Total number of days in test}}$$

(Prasad *et al.,* 2012)

**Germination value** = mean daily germination % × peak value (Xu *et al.,* 2016)

**Mean germination time (day)** =

$$\frac{\sum nd}{\sum n} (days)$$

(Ellis and Roberts, 1981)

Where n is the number of seeds germinated on day d.
d is number of days counted from the beginning of the test.

∑n is the total germinated seeds.

**Number of leaves/seedlings**: Total number of leaves was measured including those branches that can be seen by naked eyes

**Plumule length and radicle length**: length of both plumule and radical were measured by ruler.

**Seedling fresh weight and seedling dry weight**: Fresh weight of seedling was measured by using sensitive balance. Dry weight of seedling was measured by seedling oven dried to constant weight at 75c° for 72hours then weigh by sensitive balance.

## RESULTS AND DISCUSSION

### 1-Laboratory experiment

According to the results that presented in figures 5 and 6, the highest rate of germination percentage was obtained by seed freezing 99.17% also this treatment stayed in the

top with all treatment duration 12, 24, 48 and 72houres to give the maximum rate of germination percentage, but the lowest value of germination percentage was recorded by seed soaking in the boiled water 28.33%,as well as, with interaction between seed treatments and treatment duration germination percentage decreased with this treatment especially when socking the seed for 60mintes. It was found that many rangeland grasses seed exposure to winter weather increased the rate of seed germination in the laboratory (Romo, 1990). This is the phenomenon is similar to freezing temperature in this study. Temperature is one of the most important environmental factors for seed germination and seedling establishment in plants, the range of temperature to seed germination is very wide from freezing point to higher temperature (Khalaf, 2016).

Figure (7) clarifies that the rate of germination speed and peak value significantly increased by seed soaking in tap water (1.436 and 8.127 days) respectively followed by seed soaking in HCl solution, and the minimum value of these parameters was obtained by seed soaking in the boiled water (0.531 and 3.74 days) respectively. The highest ratio of mean daily germination (3.30% day) and mean germination time (9.742 day) were recorded by seed freezing but germination value (22.803) was obtained by control treatment.

Table (1) shows the interaction between seed treatment and treatment duration for some seed germination parameters. The results observed that germination speed and peak value significantly affected by seed soaking in tap water for 24 hours and become the superior between all treatments. While, the lowest rate of these characters was recorded for seed soaking in boiled water for all treatment duration. Mean daily germination and mean germination time elevated by seed freezing for 48 hours, but the maximum rate of germination value was given by seed treated with citric acid for 15mintes.These results partially agreed with those obtained by Vasi *et al.,* (2018) concerning *Gundelia tournefortii* L. plant and with Khakpoor *et al.,* (2015) concerning *Salvia verticillata* L. plant.

Habib (2010) reported that seed treatment with water could be inexpensive and most effective seed treatment before seed sowing and have been used in a number of crops to break dormancy by eliminated chemical inhibitors from seed coat. According to Abubakar and Maimuna (2013) seed soaking in concentrated acid like HCl 50% disrupts the seed coat, exposure the lumen of the macrolides cells and allowing imbibition of water. Boiling water usually stimulate seed germination to critical point beyond which there is a decrease in the final germination of seed (Doran and Turnbull, 1983).

Figures 8 and 9 shows the response of some radicle parameters to seed treatment and their interaction with treatment duration. Seed soaked in tap water shows significant differences among the treatments on radicle length and radicle elongation velocity, they produced the highest value (13.232 and 44.226 cm) respectively. While, the lowest value was observed from seed freezing treatment and control. The tap water treatment stayed super with interaction between treatment and treatment period and give the maximum rate of both radicle length and radicle elongation velocity for 24 and 72 hours.

Natural factors such as rainfall can remove the seed dormancy, because some plant seed can geminate after heavy rain, and seeds imbedded adequate moisture for germination, growth and development (Bareke, 2018).

**2-Lath house experiment**

Germination percentage in this experiment influenced by different treatments and the best treatment that scored the maximum rate of germination percentage (93.33%) by seed freezing. Also seed freezing for 24 and 48 hours give the highest ratio of germination percentage and the lowest value was recorded with seed socking in citric acid for 30mintes and in HCl for 15mintes (figures 10 and 11).
*Gundelia tournefortii* L. is a perennial plant and can grow well in the mountains area and capable of germinating at low temperature (Yazdanshenas *et al.,* 2016). However, Kootenay Local Agriculture Society, 2008 reported that the seed of *Gundelia tournefortii* L. sowing at 20C$^{o}$, if the seeds no germinate in 3-4 weeks, seeds are exposure to -4 to +4C$^{o}$ for a period of 2-4 weeks.

From the results in figure (12) freezing of *Gundelia tournefortii* L. seed escalated germination speed and mean daily germination (0.597 days and 2.277% day) respectively, but no significant difference was found between all treatments for mean germination time parameter. The maximum rate of peak value and germination value was recorded for control.

The results of interaction between seed treatments and treatment duration on some germination parameters were shown in table (2). Seed freezing for 24 and 48 hours occupy the first grade among all treatments to give the maximum value of germination speed, peak value, mean daily germination and germination value. But, the highest value of mean germination time was recorded by seed soaking in boiled water for 60mintes. The results partially similar to those obtained by Farajollahi *et al.,* (2014) concerning *Calotropis persica* plant,Tania *et al.,* (2019) concerning *Momordica charantia* L. plant and Usman *et al.,* (2010) concerning *Acacia senegal* plant.

Seed soaking in hot water, scarifying with acid or mechanical methods are pre-germination treatments in seeds with hard coat, there for some treatment such as sand, $H_2SO_4$, $KNO_3$ and hot water leads to remove seed dormancy problems in some type of plants (Saberi, 2011). Some spices of plant are dormant and can't germinate

when placed in environment, and can germinate under favorable conditions like low or high temperature, moisture and aeration (Stoke, 1965).

In the figure (13) presented the effect of various seed treatment on radicle and plumule parameters. Results show that the maximum value of radicle length and radicle elongation velocity were recorded by seed freezing (12.391cm and 30.288cm) respectively. While, the plumule length and plumule elongation velocity gave the highest value by seed soaking in tap water (7.490cm and 18.264cm) respectively. However, the lowest rate of these parameters was observed by seed soaking in the HCl. According to the results that represented in the table (3) it is demonstrated that the seed soaking in citric acid for 45 mintes and tap water for 72hours significantly increased the radicle length and radicle elongation velocity, but plumule length and plumule elongation velocity recorded the highest value with seed freezing for 72hours.

Figures 14 and 15 clarifies the influences of seed treatment and their interaction with treatment duration on seedling fresh and dry weight. The results show that seed soaking in tap water especially for 12 and 48 hours significantly increased the seedling fresh and dry weight. These results partially agreed with Sabongari and Aliero, (2004) concerning *Lycopersicum esculentum* L. plant and Vaisi *et al.,* (2018) concerning *Gundelia tournefortii*L.

The soaking process in addition to facilitating the removal of the seed coat, is also has a positive effect on seed ability to germinate, and the treatments for soaking the seeds before planting are considered among the common treatments in many plants to get rid some inhibitory substances (Abu-Qaoud and Alkoni, 1995). Seed hydropriming is done by seed soaking in water cold, hot or normal at various duration before sowing in the field (Tania *et al.,* 2019).

In some plant species with hard coat seed, palisade cells effectively close the site where water will enter in the seed and it can artificially relive the hard coat seed by boiling, mechanical or chemical like acid treatment (lambers *et al.,* 2008).

**3- Cytological part:**

Figure (16) shows the number of chromosomes in germinated seed. the diploid chromosomes number have been calculated from germinated seed of *Gundelia tournefortii* L. (2n=2x=18). These results agreed with Al-Taey and Hossain (1984), Ghaffari and Charaiat-panahi (1985), Nersesyan and Nazarova (1989), Nazarova and Gukasian (1990) and Genc and Firat (2019).

**4- Anatomical part**

Figure (17) shows the anatomy of *Gundelia tournefortii* L.germinated seed. The inner cotyledons storage cell contains aleurone grain, starch grain, Druses (crystal), obvious nuclear, oil drops and epidermis. However, the longitudinal section of seed shows differentiation zone in root tip that consist of parenchyma cell, root hair, cortex, apical meristem and root cap.

## CONCLUSION

0ur conclusions could be:

1- The highest rate of Germination percentage in both locations recorded for seed freezing, especially for 24 and 48 hours.

2- The maximum ratio of germination speed and peak value was produced by seed socking in tap water in the laboratory for 24 hours, mean daily germination and mean germination time significantly increased with seed freezing especially for 48hours, germination value was recorded by control treatment and by seed socking in citric acid for 15 minutes in the laboratory.

3- In the lath house seed freezing elevated the germination speed and Mean daily germination rate, no significant effect was recorded for mean germination time, but peak value and germination value was obtained by control treatment. Seed freezing for 24 and 48 hours becomes the superior between all treatments with interaction with treatment duration for these parameters, excepted that mean germination time was found by seed socking in the boiled water for 60 minutes.

4- Radicle length and radicle elongation velocity scored the greatest value by seed freezing for 24 and 72 hours in

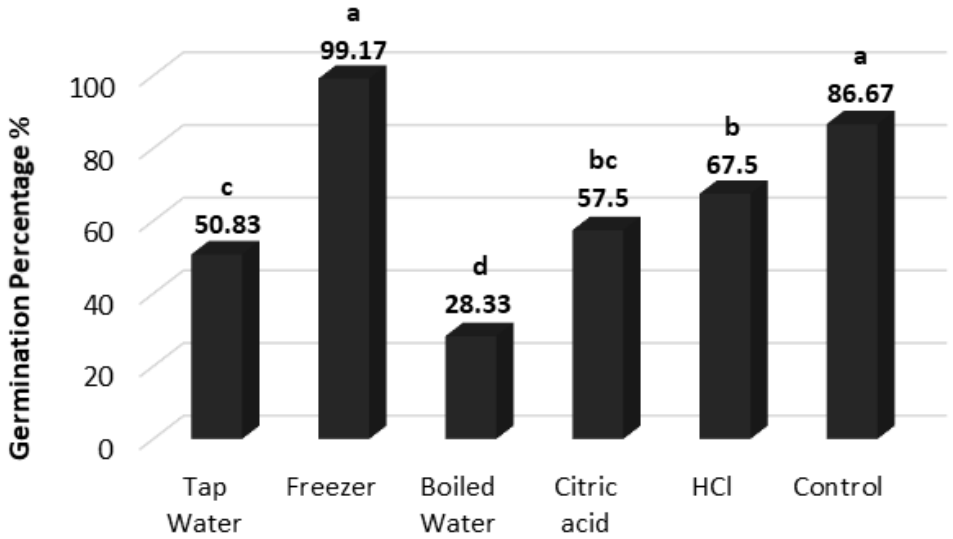


**Figure (5):** Effect of different seed treatment on germination percentage in the laboratory

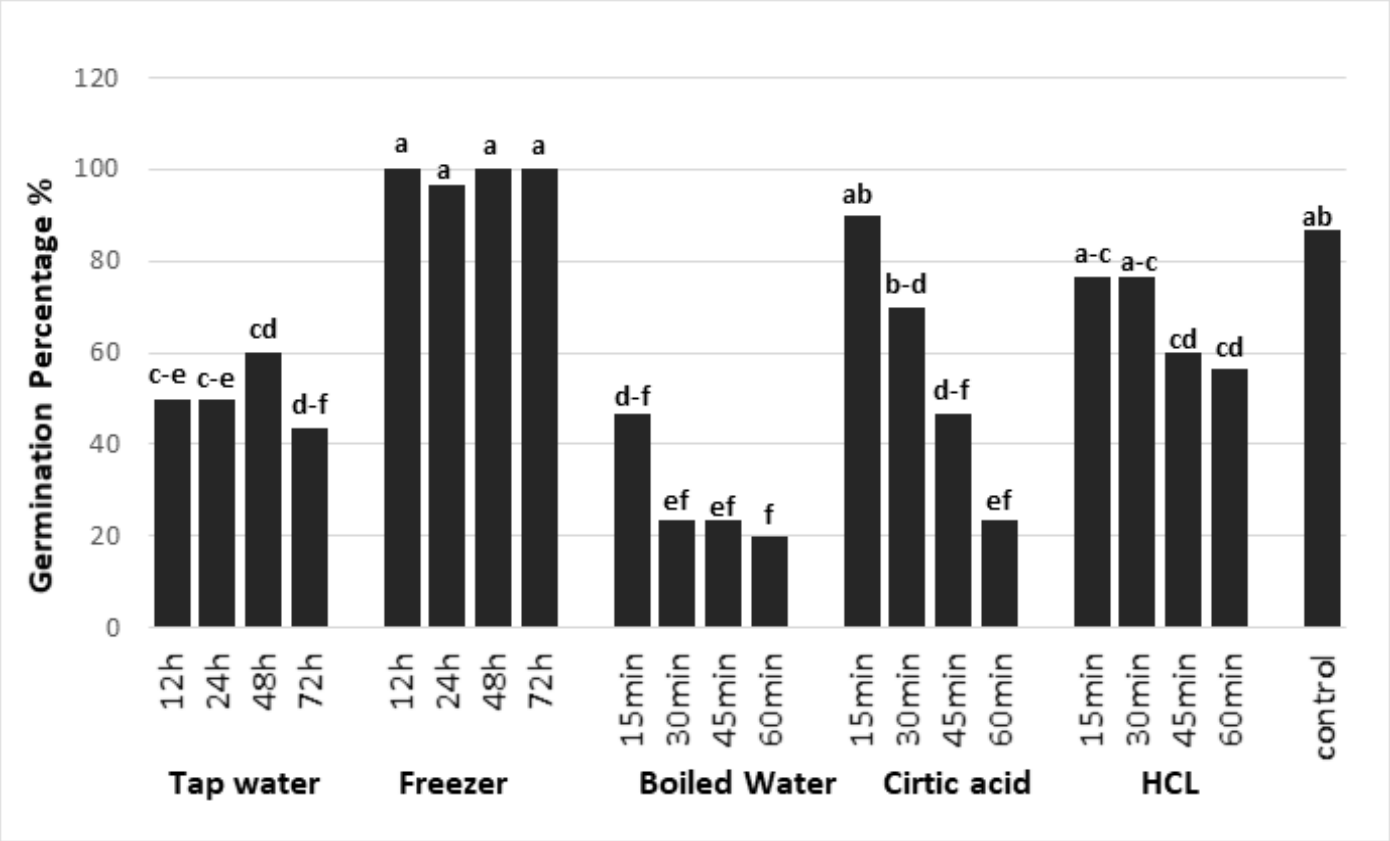


**Figure (6):** Interaction effect of different seed treatment and treatment duration on germination percentage in the laboratory

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

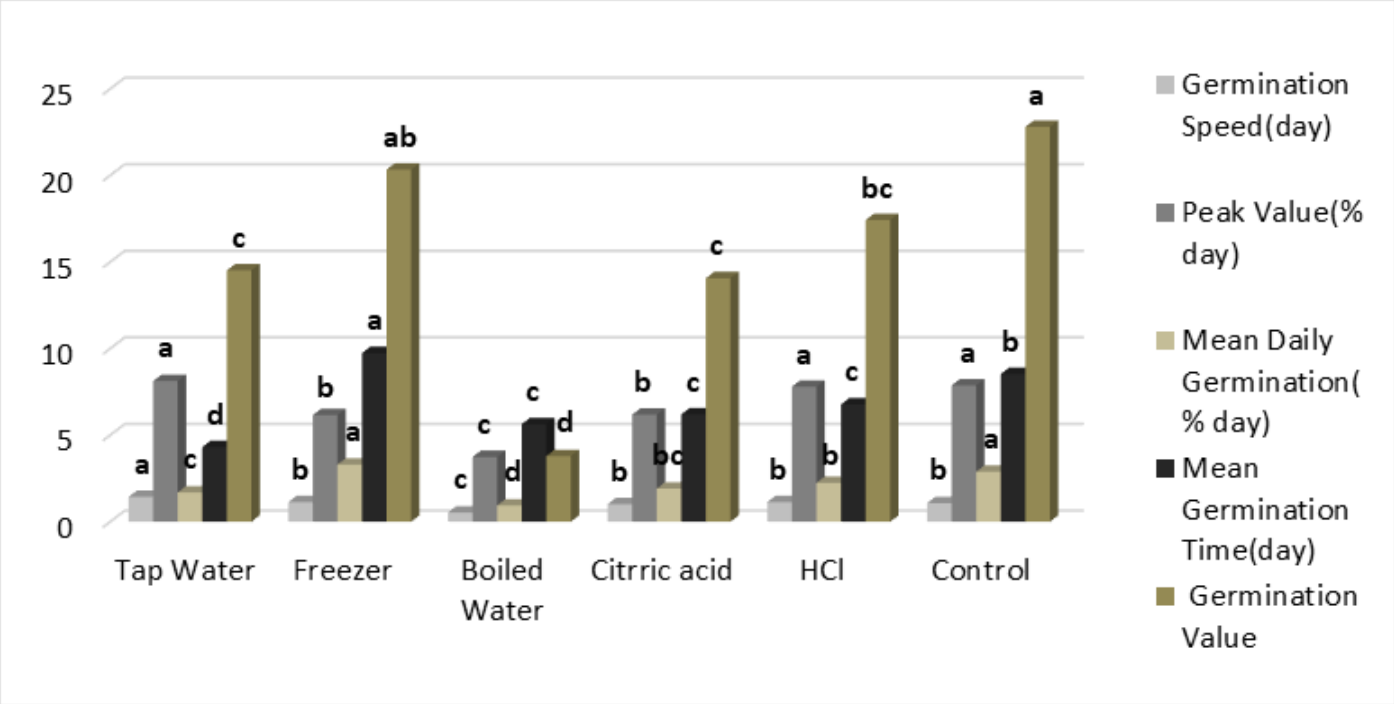


**Figure (7):** Effect of different seed treatment on some germination characteristics in the laboratory

the laboratory.

5- Seed freezing and seed socking in tap water for 12, 48 and 72 hours top between all treatments to give the highest rate of Radicle length, radicle elongation velocity, plumule length, plumule elongation velocity, seedling fresh weight and seedling dry weight in lath house.

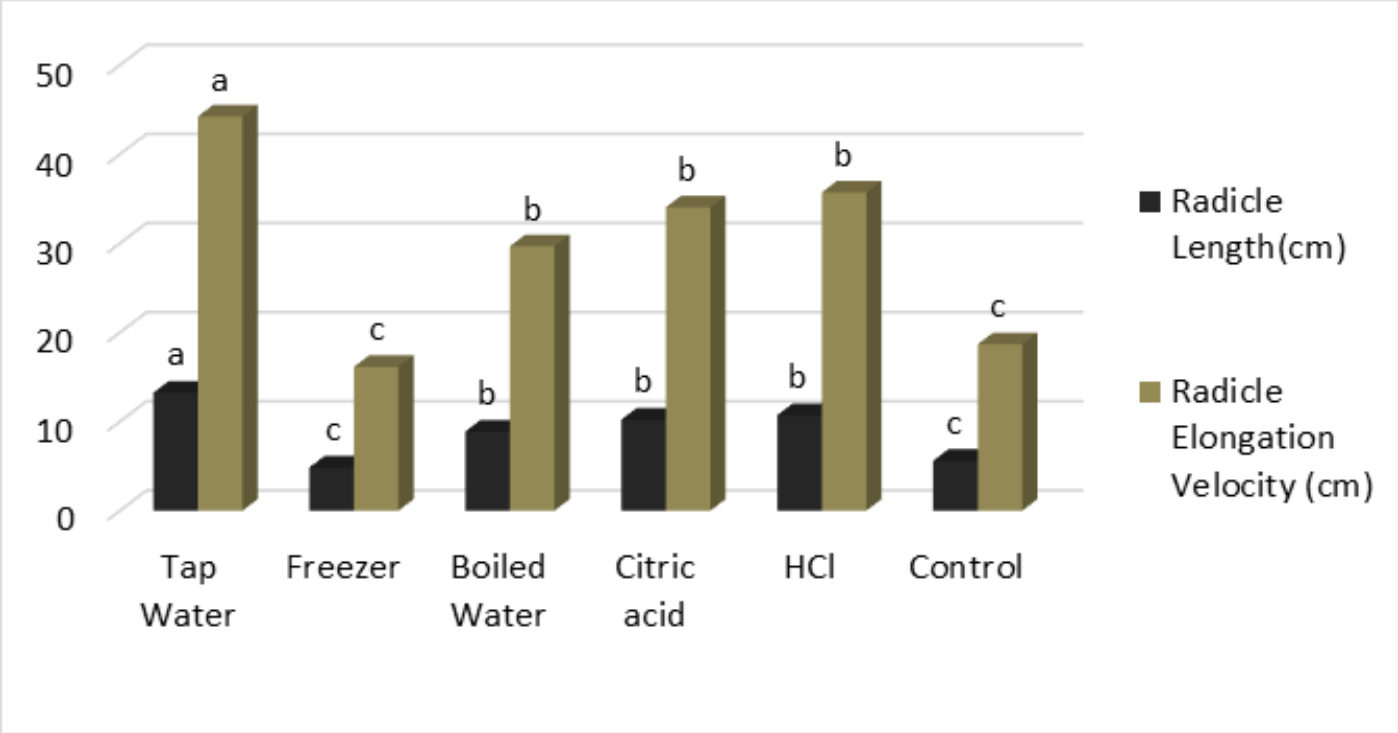


**Figure (8):** Effect of different seed treatment on some radicle characteristics in the laboratory

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

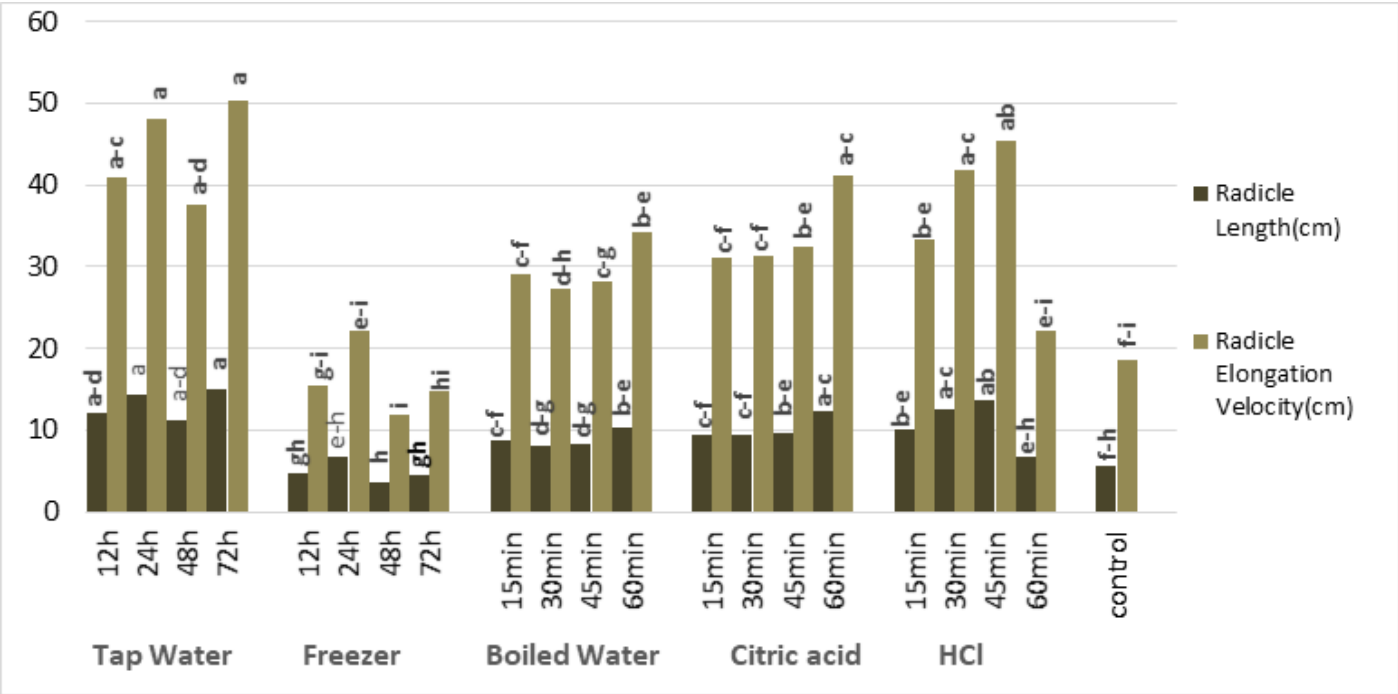


**Figure (9):** Interaction effect of different seed treatment and treatment duration on some radicle characteristics in the laboratory

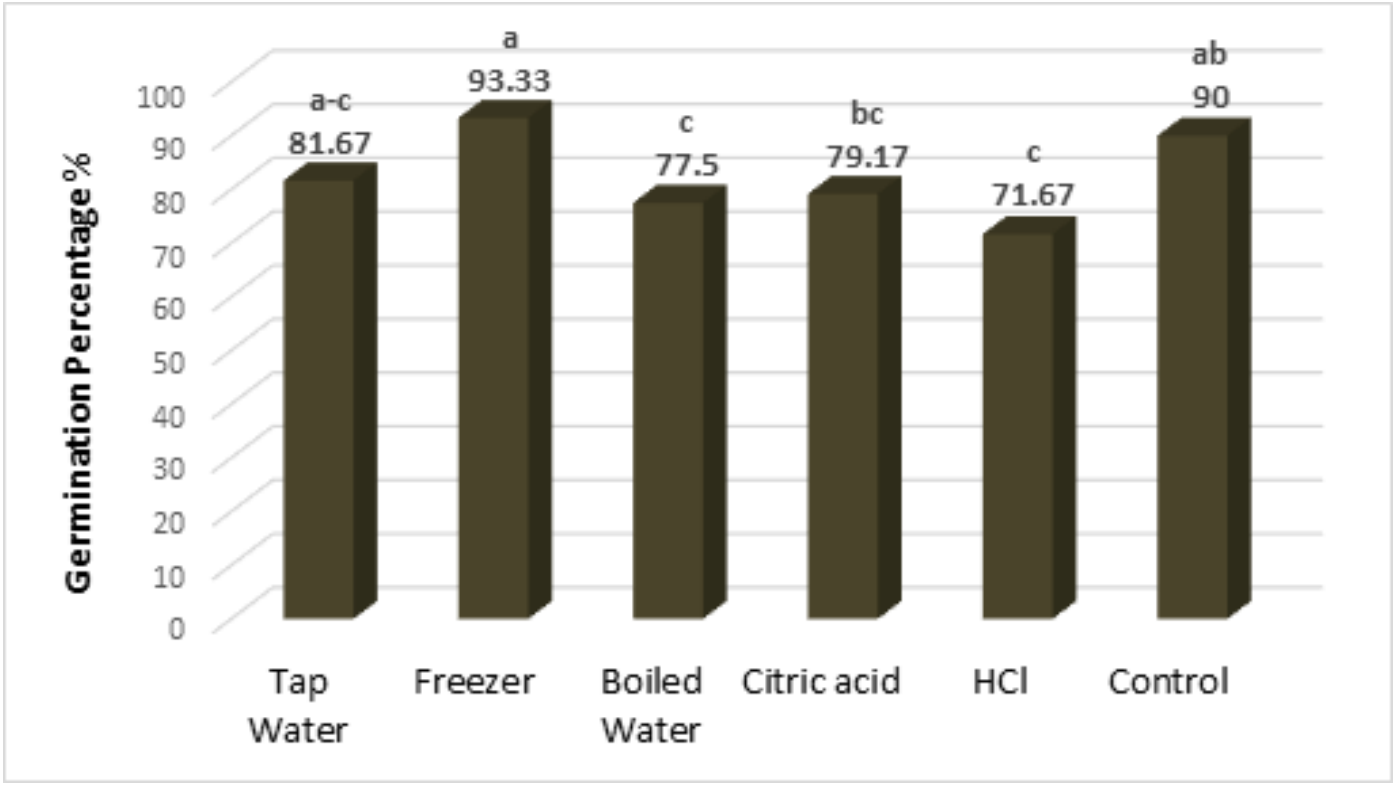


**Figure (10):** Effect of different seed treatment on germination percentage in the lath house

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

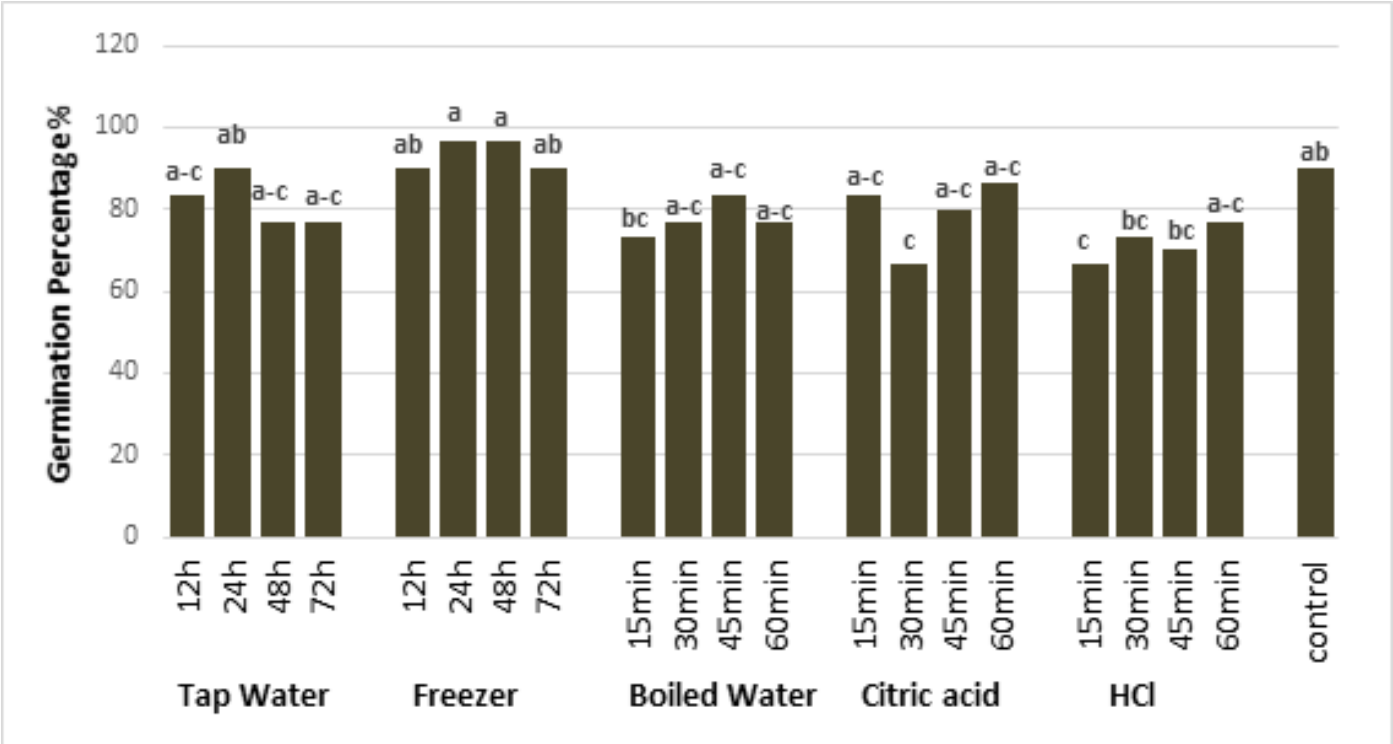


**Figure (11):** Interaction effect of different seed treatment and treatment duration on germination percentage in the lath house

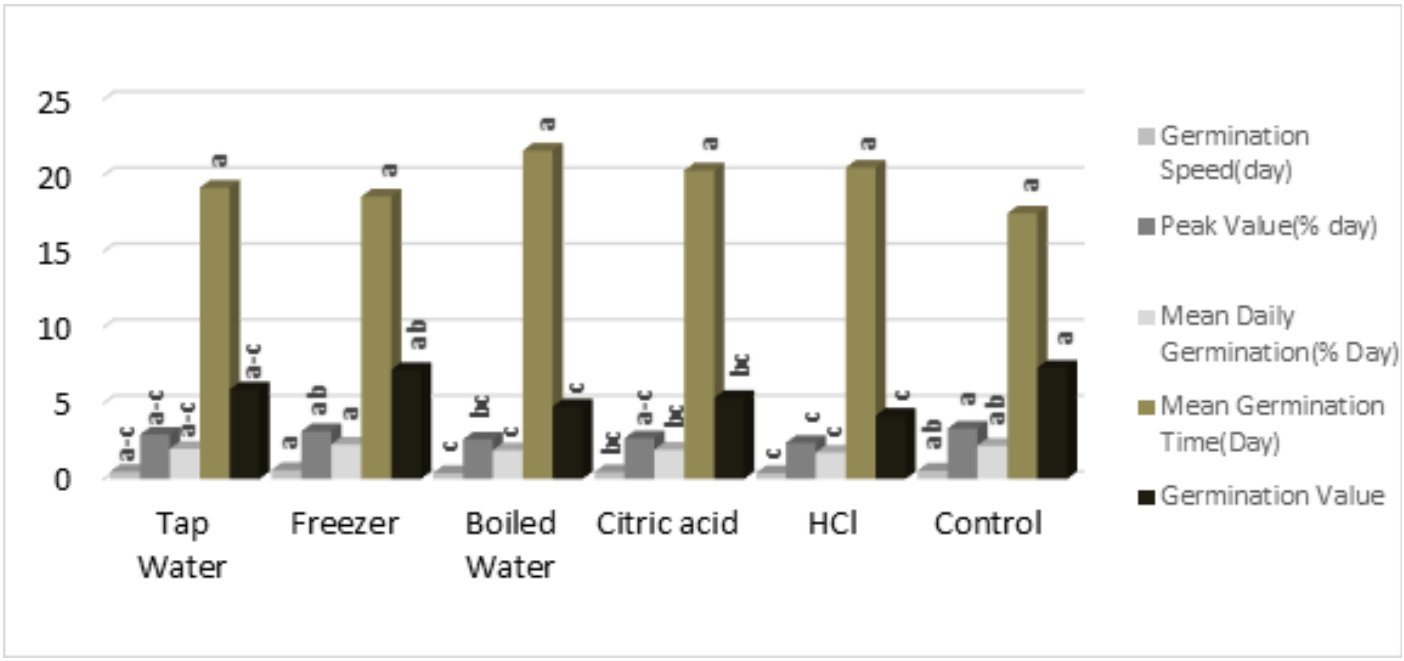


**Figure (12):** Effect of different seed treatment on some germination characteristics in the lath house

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

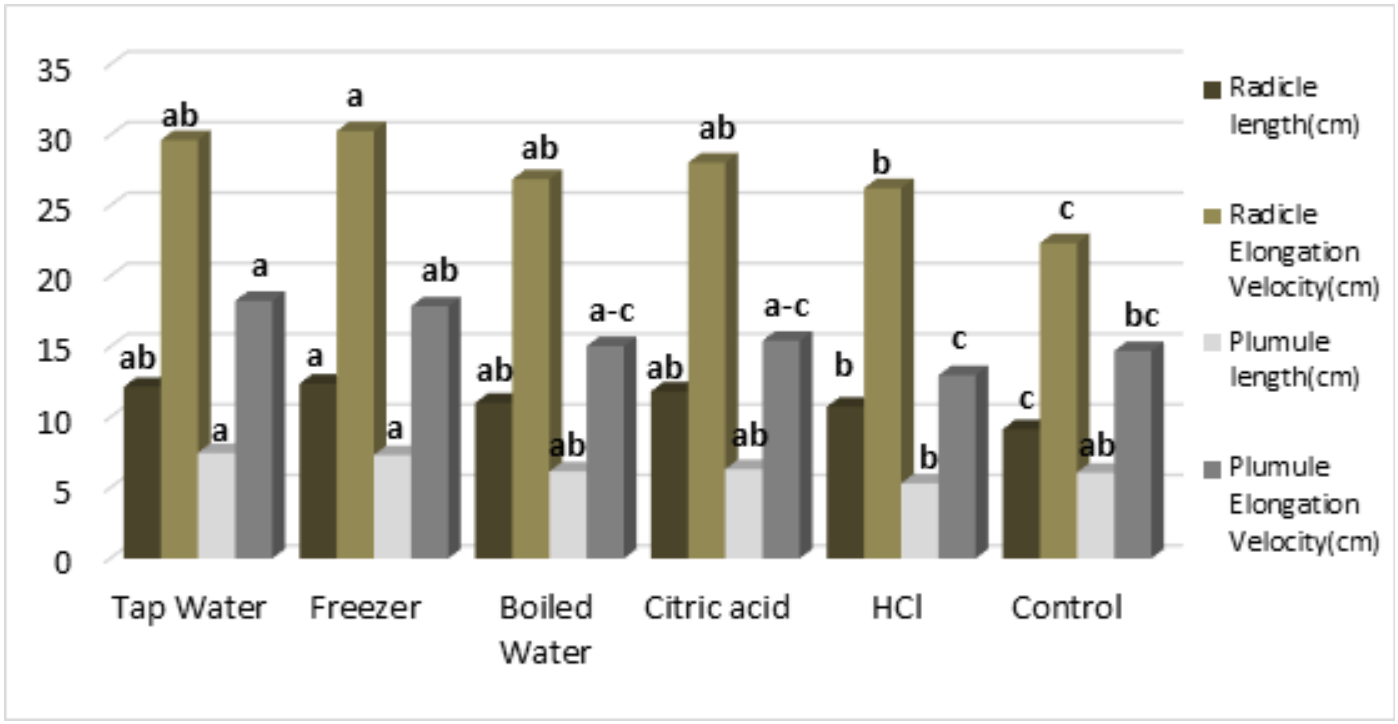


**Figure (13):** Effect of different seed treatment on some radicle and plumule characteristics in the lath house

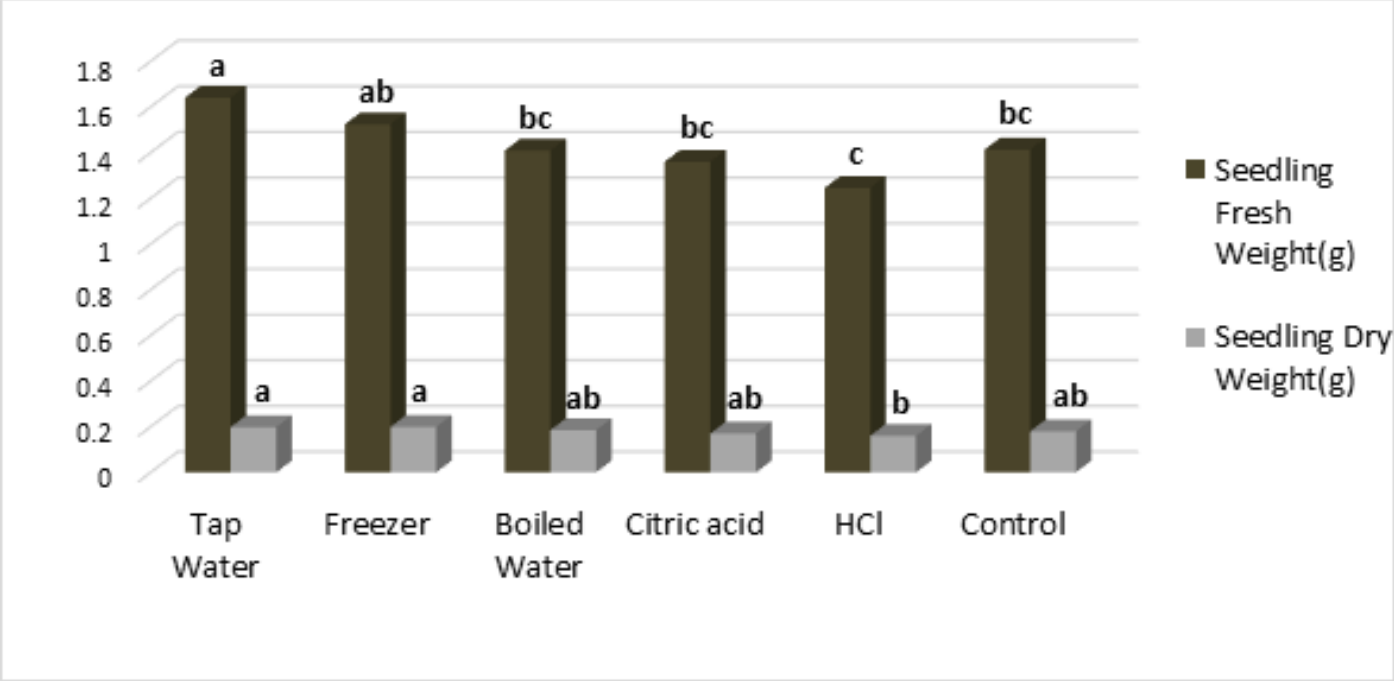


**Figure (14):** Effect of different seed treatment on seedling fresh and dry weight in the lath house

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

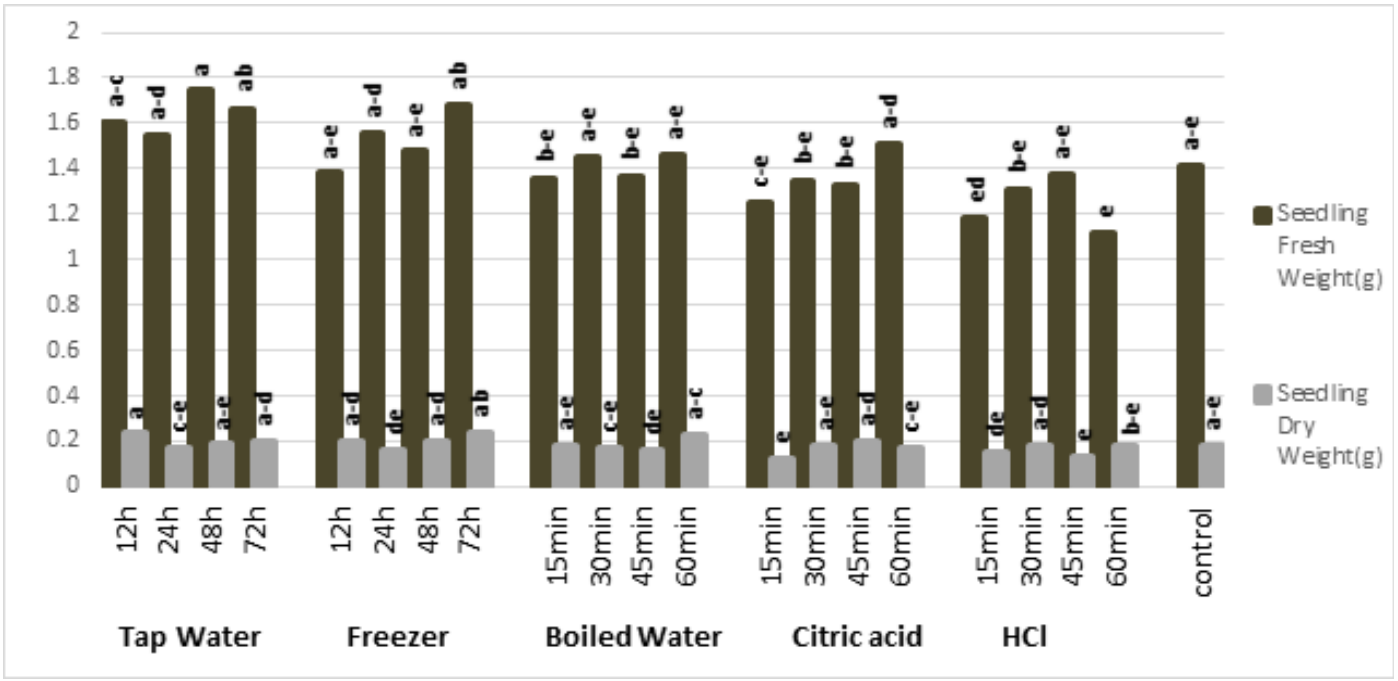


**Figure (15):** Interaction effect of different seed treatment and treatment duration on seedling fresh and dry weight in the lath house

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

**Table (1):** Interaction effect of different seed treatment and treatment duration on some germination characteristics in the laboratory

| Treatment | Treatment time | Germination Speed (day) | Peak Value (% day) | Mean Daily Germination (% day) | Mean Germination Time (day) | Germination Value |
|---|---|---|---|---|---|---|
| **Tap Water** | **12h** | 1.053 b-d | 5.986 d-i | 1.663 c-e | 5.373 e-g | 9.989 d-g |
| | **24h** | 1.766 a | 8.996 bc | 1.663 c-e | 3.330 h | 15.556 b-f |
| | **48h** | 1.883 a | 12.00 a | 1.996 cd | 3.553 gh | 24.406 b |
| | **72h** | 1.042 b-d | 5.526 d-j | 1.440 d-f | 5.000 e-h | 8.133 e-g |
| **Freezer** | **12h** | 1.238 b-d | 7.323 c-f | 3.330 a | 8.850 a-c | 24.380 b |
| | **24h** | 1.010 b-d | 5.646 d-j | 3.220 a | 10.420 ab | 18.093 b-d |
| | **48h** | 1.093 b-d | 4.540 g-k | 3.330 a | 10.500 a | 15.110 b-f |
| | **72h** | 1.187 b-d | 7.140 c-g | 3.330 a | 9.200 a-c | 23.770 b |
| **Boiled Water** | **15min** | 0.888 cd | 4.773 f-k | 1.553 d-f | 6.050 def | 7.376 fg |
| | **30min** | 0.387 e | 2.533 k | 0.773 ef | 6.250 d-f | 2.253 g |
| | **45min** | 0.450 e | 3.326 jk | 0.773 ef | 5.750 ef | 2.680 g |
| | **60min** | 0.400 e | 4.333 i-k | 0.660 f | 4.500 f-h | 2.860 g |
| **Citric acid** | **15min** | 1.694 a | 11.250 ab | 3.000 ab | 5.440 e-g | 33.750 a |
| | **30min** | 1.003 b-d | 5.133 e-k | 2.330 b-d | 7.843 cd | 12.676 c-f |
| | **45min** | 0.894 cd | 4.486 h-k | 1.553 d-f | 6.373 d-f | 6.803 fg |
| | **60min** | 0.483 e | 3.870 i-k | 0.773 ef | 5.163 e-h | 3.036 g |
| **HCl** | **15min** | 1.257 bc | 7.680 c-e | 2.550 a-c | 6.593 de | 19.570 bc |
| | **30min** | 1.360 b | 6.966 c-h | 2.550 a-c | 6.000 d-f | 17.823 b-d |
| | **45min** | 1.071 b-d | 7.586 c-e | 1.996 cd | 6.050 d-f | 15.326 b-f |
| | **60min** | 0.871 d | 8.996 bc | 1.886 cd | 8.463 c | 16.986 b-e |
| **Control** | | 1.071 b-d | 7.876 cd | 2.886 ab | 8.530 bc | 22.803 b |

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

**Table (2):** Interaction effect of different seed treatment and treatment duration on some germination characteristics in the lath house

| Treatment | Treatment time | Germination Speed (day) | Peak Value (% day) | Mean Daily Germination (% day) | Mean Germination Time (day) | Germination Value |
|---|---|---|---|---|---|---|
| **Tap Water** | **12h** | 0.509 a-d | 3.016 ab | 2.032 a-c | 18.930 ab | 6.112 a-d |
| | **24h** | 0.498 a-d | 3.202 ab | 2.195 ab | 20.073 ab | 7.027 a-d |
| | **48h** | 0.435 a-d | 2.740 ab | 1.869 a-c | 20.005 ab | 5.314 a-d |
| | **72h** | 0.492 a-d | 2.721 ab | 1.869 a-c | 17.726 ab | 5.131 a-d |
| **Freezer** | **12h** | 0.516 a-d | 2.948 ab | 2.195 ab | 20.592 ab | 6.470 a-d |
| | **24h** | 0.609 a-c | 3.616 a | 2.357 a | 17.851 ab | 8.468 a |
| | **48h** | 0.654 a | 3.234 ab | 2.357 a | 16.718 b | 7.636 ab |
| | **72h** | 0.612 ab | 2.812 ab | 2.200 ab | 19.221 ab | 6.170 a-d |
| **Boiled Water** | **15min** | 0.363 d | 2.400 ab | 1.788 bc | 21.428 ab | 4.306 b-d |
| | **30min** | 0.386 b-d | 2.655 ab | 1.869 a-c | 19.120 ab | 4.166 cd |
| | **45min** | 0.429 a-d | 2.838 ab | 2.032 a-c | 19.555 ab | 5.766 a-d |
| | **60min** | 0.395 b-d | 2.529 ab | 1.869 a-c | 26.375 a | 4.840 b-d |
| **Citric acid** | **15min** | 0.481 a-d | 2.642 ab | 2.032 a-c | 19.872 ab | 5.454 a-d |
| | **30min** | 0.396 b-d | 2.379 b | 1.625 c | 21.335 ab | 4.057 cd |
| | **45min** | 0.384 b-d | 2.664 ab | 1.951 a-c | 22.110 ab | 5.389 a-d |
| | **60min** | 0.582 a-d | 3.044 ab | 2.113 a-c | 17.953 ab | 6.449 a-d |
| **HCl** | **15min** | 0.341 d | 2.360 b | 1.625 c | 20.095 ab | 3.840 d |
| | **30min** | 0.453 a-d | 2.552 ab | 1.788 bc | 17.562 b | 4.563 b-d |
| | **45min** | 0.366 cd | 2.324 b | 1.707 bc | 19.166 ab | 4.008 cd |
| | **60min** | 0.417 a-d | 2.290 b | 1.869 a-c | 25.187 ab | 4.304 b-d |
| **Control** | | 0.553 a-d | 3.323 ab | 2.195 ab | 17.488 b | 7.325 a-c |

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

**Table (3):** Interaction effect of different seed treatment and treatment duration on some radicle and plumule characteristics in the lath house

| Treatment | Treatment time | Radicle length (cm) | Radicle Elongation Velocity (cm) | Plumule Length (cm) | Plumule Elongation Velocity (cm) |
|---|---|---|---|---|---|
| **Tap Water** | **12h** | 11.800 a-f | 28.776 a-f | 6.323 bc | 15.416 bc |
| | **24h** | 12.386 a-e | 30.206 a-e | 7.256 ab | 17.693 ab |
| | **48h** | 11.000 b-f | 26.820 a-f | 7.466 ab | 18.203 ab |
| | **72h** | 13.473 ab | 32.853 a | 8.916 a | 21.743 a |
| **Freezer** | **12h** | 12.860 a-c | 31.360 ab | 5.383 bc | 13.126 bc |
| | **24h** | 12.550 a-e | 30.603 a-d | 7.320 ab | 17.850 ab |
| | **48h** | 11.900 a-e | 29.016 a-e | 7.566 ab | 18.450 ab |
| | **72h** | 12.256 a-e | 30.173 a-e | 9.050 a | 22.070 a |
| **Boiled Water** | **15min** | 10.023 d-f | 24.443 c-f | 5.653 bc | 13.783 bc |
| | **30min** | 10.880 b-f | 26.483 a-f | 6.233 bc | 15.196 bc |
| | **45min** | 11.633 a-f | 28.370 a-f | 6.876 ab | 16.770 ab |
| | **60min** | 11.616 a-f | 28.246 a-f | 5.943 bc | 14.490 bc |
| **Citric acid** | **15min** | 10.886 b-f | 26.546 a-f | 6.903 ab | 16.833 ab |
| | **30min** | 10.426 c-f | 25.426 b-f | 5.553 bc | 13.543 bc |
| | **45min** | 13.833 a | 30.400 a-e | 6.246 bc | 15.230 bc |
| | **60min** | 12.253 a-de | 29.876 a-e | 6.626 a-c | 16.156 a-c |
| **HCl** | **15min** | 9.826 ef | 23.963 ef | 5.823 bc | 14.196 bc |
| | **30min** | 12.696 a-d | 30.960 a-c | 5.250 bc | 12.800 bc |
| | **45min** | 10.663 c-f | 26.003 b-f | 5.916 bc | 14.423 bc |
| | **60min** | 9.866 ef | 24.060 d-f | 4.316 c | 10.523 c |
| **Control** | | 9.163 f | 22.346 f | 6.093 bc | 14.710 bc |

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

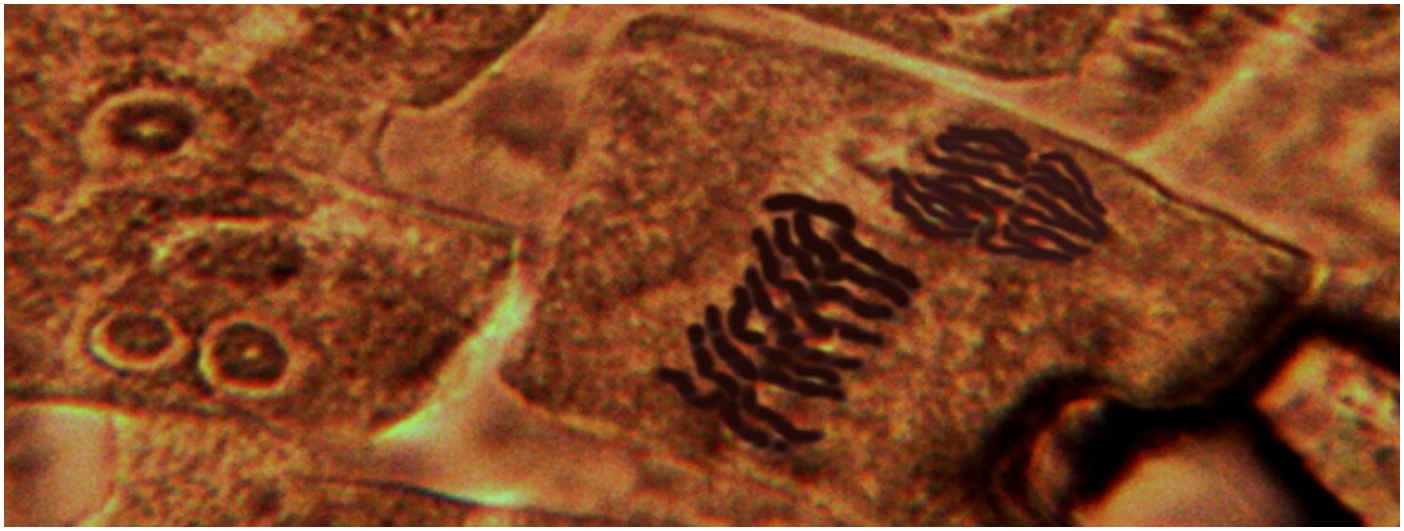

**Figure (16):** Diploid chromosomes of germinated seed of Gundelia tournefortii L.

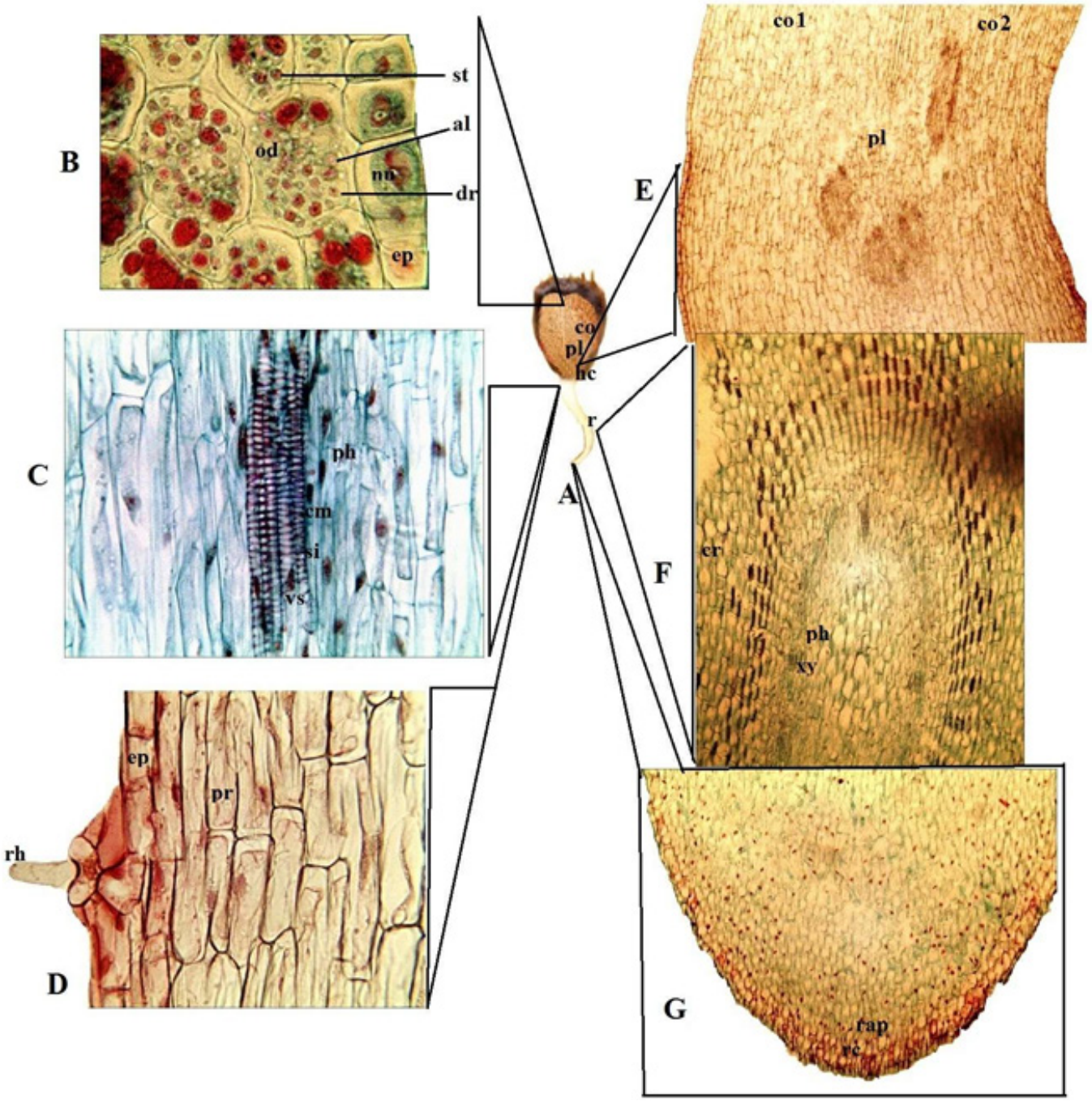


**Figure (16):** Anatomy of *Gundelia tournefortii* seed; A= whole germinated seed; B – G, different micrographs of longitudinal section portions in different places from B= cotyledon (100x) C and D = elongation or differentiation zone (40X); E= apical meristematic zone of plumule (10X); F= elongation or differentiation zone (10X); G= root cap and apical meristematic zone of root, (10X).

co=cotyledon, Pl=plumule, apical meristems, hy=hypocotyl, r=root, nu=nucleus, ep=epidermis, al=Aleurone grains, st = starch grains, dr=Druss (crystal), od=oil drops, vs=spiral thickened wall Vessels, ph=phloem, si=Sieve tubes, cm=Companion cell, pr=parenchyma cell, rh=root hair, cr=cortex, rc=root cap, rap=root apical meristem.

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