ISSN: 2538-2152; ECOPERSIA, 2021; 9(4):279-285.

Comparing dormancy breaking treatments in *Parkinsonia aculeata* seeds

ARTICLEINFO

Article Type
Original Research

Authors
Morteza Saberi, *Ph.D.*[1*]
Abass Harati, *Graduated Student*[2]
Farajollah Tarnian, *Ph.D.*[3]

How to cite this article
Saberi M., Harati A., Tarnian F. Comparing dormancy breaking treatments in *Parkinsonia aculeata* seeds. ECOPERSIA 2021; 9(4): 279-285.

DOR:
20.1001.1.23222700.2021.9.4.5.7

[1]Assistant Professor, Department of Range & Watershed Management, Faculty of Water & Soil, University of Zabol, Iran.
[2]Graduated Student, Department of Range & Watershed Management, Faculty of Water & Soil, University of Zabol, Iran
[3]Assistant Professor, Department of Range & Watershed Management, Faculty of Agriculture & Natural Resources, Lorestan University, Khorramabad, Iran,

** Correspondence*
Address: University of Zabol, Zabol city, Sistan & Balouchestan, Iran.
Postcode: 538-98615.
Tel:09193711759
Fax:+98-5431232088
E-mail: Mortezasaberi@uoz.ac.ir

Article History
Received: March 05, 2021
Accepted: April 25, 2021
Published: May 20, 2021

ABSTRACT

Aims: *Parkinsonia aculeata* is a valuable medicinal plant in traditional medicine adapted to tropical and subtropical arid regions and planted as an ornamental plant. Since seed germination of *P. aculeata* does not occur quickly, the current research was performed to test different dormancy-breaking treatments on germination characteristics of *P. aculeata*.
Materials and methods: The studied treatments included scarification with sandpaper, H_2SO_4 (98%), KNO_3 (0.2%), soaking the seeds in 90 °C hot water for 15 minutes, Gibberellic acid (250, 500, and 100 ppm), leaching (placing the seeds in running water for 48 hours), a combination of leaching treatment with KNO_3, and combination of leaching treatment with Gibberellic acid (250, 500 and 100 ppm). To compare the results, the distilled water was considered as a control treatment. A Completely Randomized Design (CRD) was made with 13 treatments and 4 replications.
Results: Results showed significant differences between treatments on germination percent, germination speed, length of root, length of shoot and length of seedling, and index of seed vigor ($p<0.01$). The seeds had more than 85% dormancy, and applying to leach (germination percent, 75%) and scarification treatments (70%) as well as boiling water (57.5%) had the highest effect on releasing the seed dormancy compared to control (15%).
Conclusion: Since this plant's establishment problems are the seed dormancy period, using leaching for 48 hours will help in the germination improvement of *P. aculeata*.

Keywords: Germination; Gibberellic acid; Leaching; Scarification; Seed dormancy.

CITATION LINKS

[1] Jalali A, Vatanpour H, Bagheri Khalili M, Ayatollahi M, Kamalinejad. The ...[2] Saberi M, Niknahad H, Heshmati HG, Barani H, Shahriyaei A. Investigating Morphological ... [3] Amoaghaei R. The Effect of Ga3 and Moist-Chilling on ... [4] Salehi A, Masoumiasl A, Moradi A. Evaluation of The Effective ... [5] Soltani A, Walter KA, Wiersma AT, et al., The genetics and physiology of ... [6] Morais LF, Almeida JCC, Deminicis BB, Padua FT, Morenz MJF, Abreu JBR, Araujo RP, Nepomuceno DD. Methods ... [7] Rusdy M. Improvement of seed germination and early seedling growth of ... [8] Rusdy M. A review on hardseedness and breaking dormancy in ... [9] Rodrigues-Junior AG, Mello ACMP, Baskin CC, Baskin JM, Oliveira DMT, Garcia QS. Why large ... [10] Rodrigues-Junior AG, Santos MTA, Hass J. et al. What kind of seed ... [11] Long Y, Tan DY, Baskin CC, Baskin J.M. Seed dormancy and germination characteristics ... [12] Harrison RJ, Howieson JG, Yates RJ, Nutt BJ. Long-term storage of ... [13] Howieson JG, Harrison RJ, Yates RJ, Hackney B, Loi A, Nutt BJ. Hard ... [14] Sxitus CR, Hill GD, Scoot RR. The effect of temperature and ... [15] Uzen F, Aydin I. Improving germination rate of *Medicago* and ...[16] Rana U, Nuatiyal AR. Seed dormancy in *Acacia* ... [17] Mohnot K, Chatterji UN. Chemico-physiological studies on ... [18] Egley GH. Water-impermeable seed coverings as barriers to ... [19] Teketay D. Germination ecology of twelve indigenous and ... [20] van Klinken RD, Flack L. The relationship between ...[21] Van Klinken RD, Flack L, Pettit W. Wet-season ...[22] Van Klinken RD, Lukitsch B, Cook C. Interaction between seed dormancy-release ... [23] Cochard R, Jackes BR. Seed ecology of the invasive tropical ... [24] Scott KA. Seed coat morphology of *Parkinsonia aculeata* L. and ...[25] Van Klinken RD, Campbell SD, Heard TA, McKenzie J, March N. The ... [26] Agarwal PK, Dadlani M. Techniques in seed science and ... [27] Asaadi AM, Heshmati G, Dadkhah A. Effects of ... [28] Koller D. The regulation of germination in seeds. Bulletin of Research council of...[29] Booth DT, Sowa S. Respiration in dormant and non-dormant bitterbrush seeds, Journal of Arid Environment... [30] Ghasemi Pirbaloti A, Golparvar A, Riahi Dehkordi M, Navid A. The effect of different treatments on seeds dormancy and germination of five species of medicinal plants of Chahar Mahal & Bakhtiari province ... [31] Khan J, Rauf M, Ali Z, Rashid H, Khattack MS. Different stratification ... [32] Eisavand HR, Madah Arefi H, Tavakol Afshari R. Effects of Various Treatments on Breaking Seed Dormancy of Astragalus sliquosus. Seed Sci ...

[DOR: 20.1001.1.23222700.2021.9.4.5.7]

Introduction

One of the essential medicinal species that has grown in Iran is *Parkinsonia aculeata*. This species belonged to the Leguminosae family and subfamily of Caesalpinaceae. *P. aculeata* is native to the tropical region of America and is also found in India, Pakistan, and southern Iran. This plant has been mentioned as an astringent, healing, and analgesic in traditional Iranian medicine, and its bark is used in the paper industry. In some southern regions of Iran, the leaves and shoots of the plant are used as a poultice to neutralize the effects of various scorpion venom [1]. Due to the harmful side effects of chemical drugs, using drugs of plant origin has increased. This increasing tendency causes the demand for enhancing the area under cultivation of these plants to achieve more production than before. Therefore, it is necessary to remove barriers to the cultivation and production of medicinal plants [2]. Seeds of wild plants, including medicinal plants, usually have more intense dormancy than domestic species [3, 4].

Seed dormancy is a temporary strategy in seed life that enables it to complete its germination under favorable conditions. Different types of seed dormancy, including physiological, physical, or morphological dormancy, are due to reasons such as the layers covering the embryo, undifferentiated embryo, or immature, and ultimately due to metabolic limitations [4]. It is known that legume seeds have physical dormancy [5], and many researchers have used different methods to release seed dormancy [6-13]. Rusdy [8] reviewed papers about the dormancy breaking of tropical forage legumes and found that the type of seed dormancy mainly was physical dormancy which acid scarification was the most efficient treatment to break seed dormancy, followed by sandpapering and hot water. Another study on determining the kind of seed dormancy in the legume genus Cassia, Rodrigues-Junior et al. [10] reported physical dormancy as the only kind of seed dormancy found for 53 Cassia species. Researchers studying the breaking seed coat dormancy of *Ulex europaeus* seeds concluded that treating the seeds with sulfuric acid and sandpaper increases seed germination [14]. Another research has shown a positive effect of scarifying on breaking dormancy and stimulation of germination of some alfalfa seeds [15]. A similar experiment on *Acacia farniesiana* seeds showed that the application of sulfuric acid increased the germination of the seeds, but increasing the duration of seed contact with acid increased abnormal seedlings due to damage to the structure of the seed embryo [16]. In addition to mentioned legume species, *P. aculeata* also has physical seed dormancy (>80% fresh seeds when inundated at 20 °C), and studies were tried to release the dormancy [17-22]. Cochard and Jackes [23] reported that dormancy release *P. aculeata* increased with increasing temperature in all populations. The averaged responses were significantly different between Costa Rican and Australian seed populations and between seeds collected from the soil and trees; the germination rate of scarified seeds was fastest at 35 °C in all seed populations. Van Klinken et al. [22] conducted a seed burial trial to investigate dormancy release of *P. aculeata* across the entire environmental distribution in Australia (arid to wet-dry tropics, uplands to wetlands, soil surface to 10 cm deep). Their results indicated that dormancy release was quickest for seeds buried during the wet season at relatively high rainfall, upland sites (only 3 % of seeds remained dormant after 35 d). The longest-lived seeds were in wetlands (9 % remained dormant after almost 4 years) and on the soil surface (57 % after 2 years). A wide range of mechanisms was used to release dormancy of *P. aculeata* seeds, including intense dry heat [24], physical damage to the seed coat, and artificial methods such as boiling water and acid scarification [17-19, 23], wet heat (exposure to wet, warm to hot conditions under field conditions) [22].

Although *P. aculeata* introduced as invasive species [23, 25], it has many benefits in arid zones with a harsh climate, and it is used as an ornamental tree in towns and botanic gardens and also as a hedging plant and for shade, windbreak, soil nitrogen fixation and rehabilitation purposes [25] and also for medicinal value [1]. As mentioned, the first limitation for the cultivation of plants with seed dormancy spatially in arid regions is to achieve the best method for breaking seed dormancy to improve germination and mass production. Therefore, this study aimed to compare different methods of breaking seed dormancy in *P. aculeata* seeds in Zabol city, Sistan region.

Materials and methods

In order to evaluate the effect of different treatments on breaking seed dormancy and seed germination of *P. aculeata*, an experiment was conducted at Zabol University in 2018. First, seeds were collected from the growing areas of the species in Sistan (Suburb of Zabol city) in the summer of 2018. Preliminary tests showed that *P. aculeata* seeds had initial dormancy and could not germinate under normal conditions. Therefore, according to Mohnot and Chatterji [17], Teketay [19], van Klinken [20], and Cochard and Jackes [23], different treatments were used to eliminate seed dormancy. Treatments include control (distilled water), scarifying the seed coat with sandpaper, treating the seeds with 98% sulfuric acid for 10 minutes, soaking the seeds in 0.3% potassium nitrate for 48 hours, soaking the seeds in 90 °C hot water for 15 minutes, soaking the seeds in gibberellic acid at 250, 500 and 1000 ppm for 12 hours, placing the seeds in running water for 48 hours (leaching), combining leaching treatment for 48 hours and 0.3% potassium nitrate, the combination of leaching treatment for 48 hours and 98% sulfuric acid, the combination of leaching treatment for 48 hours and gibberellic acid with 250, 500 and 1000 ppm.

Before starting the experiment, the seeds were disinfected with 10% sodium hypochlorite solution and then washed several times with distilled water. At the end of the soaking period, all seeds were washed with distilled water, and after drying, they were placed in 9 cm Petri dishes on Whatman's filter paper No. 1 for germination. Before placing the seeds, the Petri dishes were first sterilized in the oven for 48 hours at 20 ° C. Germination test was performed in an experiment in a completely randomized design with 4 replications (10 seeds per replication) in the germinator at a temperature of 25 ° C. During 15 days, germinated seeds with a root length of higher than 2 mm were counted every day, and germination percentage, germination speed, radicle, plumule, and seedling lengths, and seed vigor index were measured. Germination percentage and germination speed [26] were calculated based on the following equations.

$$GP=100\times (G/N) \tag{1}$$

GP: germination percentage, G: number of germinated seeds, N: total number of seeds

$$GR= \sum ni/ti \tag{2}$$

GR: Germination rate, ni: germinated seeds at time ti, ti: number of days after germination

$$\text{Seedling Length} = \text{Root Length} + \text{Shoot Length} \tag{3}$$

$$\text{Vigor Index} = \text{Mean of Seedling length} \tag{4}$$

[DOR: 20.1001.1.23222700.2021.9.4.5.7]

(mm) × Germination percentage

Experimental data were analyzed using SPSS software. After normalizing the data, ANOA was performed, and the mean data were compared using Duncan's multiple range tests.

Results

The analysis of variance showed that the effect of different treatments on germination percentage and germination speed, root, shoot, and seedling length, and seed vigor index of *P. aculeata* was statistically significant at a probability level of 1% (Table 1).

Mean comparisons of different treatments on germination traits of *P. aculeata*

The mean comparisons showed that all treatments used in this experiment except sulfuric acid had a higher germination percentage and germination speed compared to the control treatment. The highest germination percentage and speed were obtained by applying leaching treatments for 48 hours (75%) and scraping the seed coat with sandpaper (2.6 seeds/day), respectively. Germination percentage in the control treatment was 15 (percent), and germination speed was 0.4 (seed/day), which was significantly different from other treatments (Table 2). The maximum length of root, shoot, and seedling was also related to leaching treatments for 48 hours. Root, shoot, and seedling length showed an increase of 1.5, 3.5, and 5 cm compared to the control treatment, respectively. Treatments of hot water, gibberellic acid 250 ppm, and scarifying also improved the initial growth of seedlings, which was significantly different from the control treatment. Finally, the shortest length of root, shoot, and seedlings was obtained due to sulfuric acid (Table 2). There is also a significant difference in seed vigor in the treatments of leaching, scarification, hot water, and gibberellins. The highest seed vigor index was obtained in leaching treatment (748), while the lowest was related to sulfuric acid (4.7). The seed vigor index of the control treatment was 75 (Table 2).

Discussion

This experiment shows that the used treatments have a significant effect on increasing the germination percentage and germination speed, which is consistent with the results of van Klinken et al. [22] on the studied species and Asaadi et al. [27] on the other hard seed species. This type of dormancy is mainly related to the physical properties of the seed coat [22-23] and is controlled by external factors. In some cases, the degree of hardness of the seed coat can be due to lipids, tannins, and pectic substances present in the seed [28].

The highest germination percentage and seedling growth were obtained in leaching treatment for 48 hours. Leaching of *P. aculeata* seeds reduced mucilage formation

Table 1) Variance analysis of studied traits of H. sabdariffa species

Properties	Germination percentage	Germination speed	Root length	Shoot length	Seedling length	Seed vigor
ss	18180	25	38	204	403	2222938
df	12	12	12	12	12	12
ms	1515	2	3/2	17	33/6	185244
f	20**	89.3**	268.4**	215.5**	444.5**	72.1**

**: significant differences between treatments at 1% level

[DOR: 20.1001.1.23222700.2021.9.4.5.7]

Table 2) comparing the effects of various treatments on germination traits of *P. aculeata*

Treatment	Germination percentage (%)	Germination speed (per day)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seed vigor
Gibberellic acid (250 ppm)	45.00±2.9bcd	1.55±.06c	2.5±0.02b	4.6±0.15c	7.05±0.13b	316.4±16.3cd
Gibberellic acid (500 ppm)	32.5±4.8de	0.78±0.08f	1.0±0.04f	1.2±0.04g	2.2±0.08h	70.8±3.2g
Gibberellic acid (1000 ppm)	37.5±7.5cde	1.87±0.12b	1.5±0.07d	4.1±0.2d	5.6±0.14e	213.0±49.0e
KNO_3	32.5±2.5de	1.3±0.09d	0.5±0.05g	1.5±0.16g	2.0±0.14h	64.2±3.47fg
Scarification	70±4.0a	2.6±0.07a	1.0±0.02f	5.1±0.3b	6.0±0.29d	433.7±45.6b
Leaching	75±2.9a	2.4±0.11a	3.0±0.04a	7.0±0.09a	10.0±0.1a	748.7±34.6a
Boiling water	57.5±2.5b	1.8±0.08b	2.0±0.1c	4.7±0.06c	6.6±0.16c	381.5±12.6bc
H_2SO_4	12.5±2.5f	0.2±0.04h	0.12±0.02h	0.3±0.02h	0.4±0.04i	4.7±0.5g
Leaching + Gibberellic acid (250 ppm)	25.00±5.0ef	0.7±0.2f	0.97±0.02f	3.0±0.2f	4.0±0.16g	99.5±20.4f
Leaching + Gibberellic acid (500 ppm)	55.0±6.5b	1.3±0.08d	1.3±0.08	4.0±0.14d	5.27±0.09ef	290.0±34.5d
Leaching + Gibberellic acid (1000 ppm)	47.5±4.8bc	1.7±0.04bc	1.05±0.06f	3.25±0.03ef	4.3±0.08g	203.7±19.4e
Leaching +H_2SO_4	30.0±4.1e	1.05±0.06e	0.12±0.02h	0.5±0.4h	0.6±0.07i	17.2±1.1g
Control	15.0±2.8f	0.45±0.03g	1.5±0.04d	3.5±0.02e	5.0±0.10f	75.0±15.0fg

The different letters indicate a statistically significant difference ($p<0.01$).

around the seeds and increased seed germination compared to the control. Therefore, it seems that the factor involved in seed dormancy is inhibitory compounds (mucilage) in the seed coat. Chemical materials accumulated in the fruit and seed coat during seed development stages can remain in these areas even after harvest. These materials act as inhibitors in the germination phenomenon. These inhibitory compounds include phenols, coumarin, and abscisic acid, which can be washed and eliminated by soaking in water [29].

One of the factors affecting the seed dormancy of plant species is seed coat. In the current investigation, the successful germination of *P. aculeata* seeds under treatments of breaking dormancy confirms the effect of mechanical resistance of the seed coat against seedling emergence, which is consistent with the results of other researchers on the species [20, 22-23]. Different concentrations of gibberellic acid and 0.3% potassium nitrate increased germination percentage and germination speed compared to the control treatment. One of the reasons for the positive effect of chemical stimulants such as gibberellin and potassium nitrate on seed germination of *P. aculeata* is probably due to the balanced hormonal ratio in the seed and the reduction of growth inhibitors as abscisic acid (ABA) [30].

Gibberellic acid as a chemical stimulant can disrupt the physiological dormancy of seeds. Gibberellic acid initiates germination by inducing the synthesis of the alpha-amylase enzyme, resulting in the breaking of seed dormancy. Potassium nitrate removes dormant seeds needing light and is an effective chemical in reducing light requirements and increasing germination. Potassium nitrate helps respond to the metabolic processes of seeds. This compound may induce auxin biosynthesis and initiate the growth of the embryo [31]. Our experiment, scarifying with sandpaper, improved germination percentage and seedling growth in *P. aculeata* compared to the control. Eisvand et al. [32], working on *Astragalus siliquosus* seeds, found about 95% of dormancy is due to hard seed coat so that it is impermeable to water, and sandpaper is the best method to remove it.

Field studies indicated that wet conditions [23] and wet heat [22] had a prominent effect on releasing seed dormancy of *P. aculeata*. This study indicated that the seeds of *P. aculeata* had higher than 85% dormancy, and the treated seeds had the highest germination percentage under the effective treatments on the seed coat, including leaching, scarifying, and hot water.

Conclusion

It can be concluded that the seed dormancy of the studied species is most likely related to the physical factors of the seed coat. According to field studies [22-23] and the results of this study, seed dormancy could be quickly released by leaching for 48 hours. Leaching can be more critical in terms of being cheap with low risk and the possibility of harming the embryo compared to chemicals, especially acid. Since one of the problems of establishing this plant is the length of seed dormancy, the results of this study will help the germination of this medicinal plant.

Acknowledgments

The authors are grateful to the research Affairs of the University of Zabol for the financial support (Grant number: UOZ-GR-9718-79).

References

1. Jalali A., Vatanpour H., Bagheri Khalili M., Ayatollahi M., Kamalinejad. The antitoxicity effects of Parkinsonia Aculeate against scorpion venom (Buthotus Saulcyi): in vivo and in vitro Studies. J. Med. Plant Res. 2006; 17(5):59-69.
2. Saberi M., Niknahad H., Heshmati H.G., Barani H., Shahriyaei A. Investigating morphological characteristics and effect of different treatments on improving seed germination of two *Citrullus Colocynthis* stands in Sistan and Balouchestan. J. Rangeland 2017; 11(3):353-363.
3. Amoaghaei R. The effect of Ga3 and moist-chilling on seed dormancy breaking of *Ferula Ovina* Boiss. JWSS. 2007; 40(11):471-482.
4. Salehi A., Masoumiasl A., Moradi A. Evaluation of the effective methods of seed dormancy breaking in medicinal plant of Bilhar (*Dorema aucheri*). JWSS. 2015; 2(1):65-72.
5. Soltani A., Walter K.A., Wiersma A.T. The genetics and physiology of seed dormancy, a crucial trait in common bean Domestication. BMC Plant Biology. 2021; 21(1):1-17.
6. Morais L.F., Almeida J.C.C., Deminicis B.B., Padua F.T., Morenz M.J.F., Abreu J.B.R., Araujo R.P., Nepomuceno D.D. Methods for breaking dormancy in seeds of tropical forage legumes. AJPS. 2014; 13(5):1831–1835.
7. Rusdy M. Improvement of seed germination and early seedling growth of *Leucaena leucocephala* by cold water, mechanical and acid scarification pretreatment. Int. J. Res. 2016; 1(1):1–6.
8. Rusdy M. A review on hardseedness and breaking dormancy in tropical forage legumes. Livest. Res. Rural Dev. 2017; 29(12).
9. Rodrigues-Junior A.G., Mello A.C.M.P., Baskin C.C., Baskin J.M., Oliveira D.M.T., Garcia Q.S. Why large seeds with physical dormancy become nondormant earlier than small ones. PLOS ONE. 2018; 13(8): e0202038.

10. Rodrigues-Junior A.G., Santos M.T.A., Hass J. What kind of seed dormancy occurs in the legume genus Cassia?. Sci. Rep. 2020; 10(1):1-12.
11. Long Y., Tan D.Y., Baskin C.C., Baskin J.M. Seed dormancy and germination characteristics of *Astragalus arpilobus* (Fabaceae, subfamily Papilionoideae), a central Asian desert annual ephemeral. S. Afr. J. Bot. 2012; 83(1):68–77.
12. Harrison R.J., Howieson J.G., Yates R.J., Nutt B.J. Long-term storage of forage legumes greatly alters the hard seed breakdown pattern in situ. Grass Forage Sci. 2020; 76(1):1–10.
13. Howieson J.G., Harrison R.J., Yates R.J., Hackney B., Loi A., Nutt B.J. Hard seed breakdown patterns of unprocessed forage legume seed sown into dry soil in summer in southern Australia. Grass Forage Sci. 2021; 76(1):82–92.
14. Sxitus C.R., Hill G.D., Scoot R.R. The effect of temperature and scarification method on Ulex europaeus seed germination. New Zealand plant protection. Weeds 2003; 56(1):201-205.
15. Uzen F., Aydin I. Improving germination rate of Medicago and Terifolium species. Asian J. Plant Sci. 2004; 6(3):714-717.
16. Rana U., Nuatiyal A.R. Seed dormancy in *Acacia farnesiana*, Seed Res. 1989; 17(1):122-127.
17. Mohnot K., Chatterji U.N. Chemico-physiological studies on the imbibition and germination of seeds of *Parkinsonia aculeata* Linn. Oesterreichische Botanische Zeitschrift. 1965; 112(4):576-85.
18. Egley G.H. Water-impermeable seed coverings as barriers to germination. In 'Recent advances in the development and germination of seeds,' ed. R.B. Taylorson, (Plenum Press, New York). 1989; 187(1):207-223.
19. Teketay D. Germination ecology of twelve indigenous and eight exotic multipurpose leguminous species from Ethiopia. Forest Ecol. Manag. 1996; 80(1-3):209-223.
20. van Klinken R.D., Flack L. The relationship between wet heat and hard-seeded dormancy and germination. Weed Sci. 2005; 53(1):663-669.
21. Van Klinken R.D., Flack L., Pettit W. Wet-season dormancy release in seed banks of a tropical leguminous shrub is determined by wet heat. Ann. Bot. 2006; 98(4):875-883.
22. Van Klinken R.D., Lukitsch B., Cook C. Interaction between seed dormancy-release mechanism, environment and seed bank strategy for a widely distributed perennial legume (*Parkinsonia aculeata*, Caesalpinaceae). Ann. Bot. 2008; 102(2):255-264.
23. Cochard R., Jackes B.R. Seed ecology of the invasive tropical tree *Parkinsonia aculeate*. Plant Ecol. 2005; 180(1):13–31.
24. Scott K.A. Seed coat morphology of *Parkinsonia aculeata* L. and pattern of heat-induced fractures. Proceedings of the 15th Australian Weeds Conference, eds C. Preston, J.H. Watts, and N.D. Crossman. (Weed Management Society of South Australia, Adelaide). 2006; 268-269.
25. Van Klinken R.D., Campbell S.D., Heard T.A., McKenzie J., March N. The biology of Australian weeds 54. *Parkinsonia aculeata* L. Plant Prot. Quart. 2009; 24(3):100-117.
26. Agarwal P.K., Dadlani M. Techniques in seed science and technology. New Delhi: South Asian Publishers. 1995; 210p.
27. Asaadi A.M., Heshmati G., Dadkhah A. Effects of Different Treatments to Stimulate Seed Germination of Salsola arbusculiformis Drob. ECOPERSIA 2015; 3(3):1077-1088.
28. Koller D. The regulation of germination in seeds. Bulletin of Research council of Israel. 1981; 5D:85-108.
29. Booth D.T., Sowa S. Respiration in dormant and non-dormant bitterbrush seeds. J. Arid Environ. 2001; 48(1):35-39.
30. Ghasemi Pirbaloti A., Golparvar A., Riahi Dehkordi M., Navid A. The effect of different treatments on seeds dormancy and germination of five species of medicinal plants of Chahar Mahal & Bakhtiari province, Pajohesh & Sazandegi. 2007; 74(1):186-192.
31. Khan J., Rauf M., Ali Z., Rashid H., Khattack M.S. Different stratification techniques on seed germination of *Pistachio*. Pak. J. Biol. Sci. 1999; 4(2):1412-1414.
32. Eisavand H.R., Madah Arefi H., Tavakol Afshari R. Effects of Various Treatments on Breaking Seed Dormancy of *Astragalus sliquosus*. Seed Sci. Technol. 2006; 34(3):747-752.

[DOR: 20.1001.1.23222700.2021.9.4.5.7]