Seed washing, exogenous application of gibberellic acid and cold stratification enhance germination of sweet cherry (*Prunus avium* L.) seeds

T. Javanmard1, Z. Zamani1, R. Keshavarz Afshar2\*, M. Hashemi3 and P. C. Struik4

1Department of Horticultural Sciences, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran.

2Department of Agronomy and Plants Breeding, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran.

3Stockbridge School of Agriculture, University of Massachusetts Amherst, USA.

4Centre for Crop Systems Analysis, Plant Sciences Group, Wageningen University, Droevendaalsesteeg, 6708 PB Wageningen, The Netherlands.

\*Author to whom correspondence should be addressed;

Tahereh Javanmard

Email address: javanmard.t@gmail.com

Fax: +98-263-3418604

Tel: +98-912-6063843

**Abstract**

Seed germination of sweet cherries is a very slow and lengthy process, causing problems in its breeding efforts. In this study new seeds from ripe fruit of sweet cherry (*Prunus avium* L.) cv. Lambert were collected and after removing endocarps, selected breaking dormancy treatments including seed washing, application of exogenous Gibberellic (GA3) and cold stratification were evaluated for enhancement of seed germination percentage and rate. Germination percentage and germination rate of sweet cherry seeds responded positively to all breaking dormancy treatments. Results indicated that seed washing is necessary for dormancy breaking of sweet cherry seeds. Application of GA3 up to 500 ppm significantly improved the percentage and rate of germination. The highest germination percentage was obtained by cold stratification for a period of 6 weeks whereas germination rate improved by longer period of stratification. The highest germination percentage (44.3%) was obtained from application of 500 ppm GA3 combined with 6 weeks cold stratification which was not statistically different than those obtained from higher hormonal application and longer period of storing seeds in cold condition. Interaction of the highest hormonal level and 6 weeks cold stratification resulted in highest rate of germination (2.77 seeds per day). Interactive effect of all three breaking dormancy methods was only significant for germination rate but not for germination percentage.

**Keywords:** chilling requirement; pre germination treatment; seed dormancy; water soaking.

1. **Introduction**

Sweet cherry (*Prunus avium*) is an important fruit species in temperate zones. Sweet cherry orchards are usually established by planting rootstocks that are used to produce grafted trees. Rootstocks are grown from seedlings in nurseries. For propagating rootstocks it is often necessary to stimulate cherry seeds to enhance their germination. However, the seeds of most *Prunus* species, including *Prunus avium*, show deep dormancy which needs to be overcome. *Prunus* seed dormancy can be broken in various ways and the best method depends on the species (Heidari et al., 2008). Seed dormancy is an adaptive mechanism that *Prunus* species use to protect seedlings from frost damage during harsh winter. The dormancy mechanism inhibits seed germination even when moisture, oxygen and temperature conditions are favorable until seeds met the required cold stratification (Frisby and Seeley, 1993). Therefore, it is a major challenge to obtain abundant germinated seeds for breeding purposes (Schmidt and Ketzel, 1994).

There is a large diversity of methods to break dormancy and methods often differ in duration of pretreatments, both within and among various cherry species (Çetinbaş and Koyuncu, 2006; Finch-Savage et al., 2002; Garcia-Gusano et al., 2004). Traditionally, cold stratification has been used to break seed dormancy in *Prunus* (Seeley et al., 1998; Garcia-Gusano et al., 2004). In some studies cold stratification was complemented by other treatments such as Gibberellic acid (GA3) for faster breaking of dormancy and to accelerate seed germination (Bretzloff and Pellett, 1979; Iglesias and Babiano, 1997). GA3 is one of the hormones proposed to control primary dormancy by inducing germination (Iglesias and Babiano, 1997). Seed washing is another effective treatment as it removes potential inhibitors from seed coats therefore enhances germination (Gosling, 2007). The effect of seed washing on dormancy breaking of different plants such as hawthorn (Mirzadeh Vaghefi et al., 2010), and jackfruit (Maiti et al., 2003) has been reported.

The aim of this research was to evaluate effectiveness of several methods capable of stimulating and enhancing seed germination of *Prunus avium*.

**2. Materials and methods**

**2.1. Preparation of plant material**

Ripe fruits of *Prunus avium* L. cv. Lambert were collected in June. After removing the fleshy fruit parts, mature seeds from open-pollinated sweet cherries, were washed and dried for 3 days at room temperature. Outer shells of seeds were removed as earlier experience indicated that removing the hard shells (i.e. the stony endocarps) from *Prunus* seeds resulted in more and faster germination (Garcia-Gusano et al., 2004; Heidari et al., 2008).

**2.2. Experimental details**

To evaluate the response of sweet cherry (*Prunus avium*) seeds to different dormancy breaking treatments, a three-factorial experiment was conducted in June 2011. The treatments consisted of two levels of seed washing (no washing and seed washing for 24 hr), four levels of GA3 concentration (0, 250, 500 and 1000 ppm) and three levels of duration of the cold stratification period (4, 6 and 8 weeks). A randomized complete block design with four replications was employed to analyze the data.

Seeds were sterilized with 1% NaClO (sodium hypochlorite) solution for 20 minutes, rinsed three times with distilled water prior to implementing any experimental treatment. Half of the seeds were placed under running Tab water for 24 hours and the other half were left unwashed. Subsequently, seeds in each washing method were separately divided into four groups for being treated with exogenous GA3 (Merck, Germany).

Each replication comprised of twenty seeds, placed in petri dishes. The seeds of each replication were placed in freezer bag containing abundant wet perlite. Bags were placed in a dark cold chamber at 4±0.5 ºC for 4, 6, and 8 weeks representing of the cold stratification period. After cold stratification, freezer bags containing seeds plus wet perlite were placed in a growth chamber with 13±0.5○C temperatures until day 21.

**2.3. Data collection**

Germination test was performed according to methods of the International Seed Testing Association (ISTA, 1996). The number of germinated seeds was counted periodically. Seeds were considered germinated when the tip of the radicles had grown free of the seed coat (Wiese and Binning, 1987). Germination process was evaluated in intervals of two days. The initial percentage of germination was recorded at the end of each stratification period before taking seeds into the growth chamber. Germination percentage was quantified from the number of germinated seeds at the 21st day in growth chamber (13±0.5○C) divided by the number of seeds in each replication (20 seeds).

Germination rate was calculated using the number of germinated seeds at two days intervals:



where *n* denotes the days in growth chamber

**2.4 Data analysis**

Before analyzing the data, germination percentages were transformed using:

y = arcsin√p/100

where p denotes the germination percentage.

The data are presented as mean ±SE (standard error). The protected LSD test was performed for the separation of means (*P < 0.05*). All statistical analysis was performed with SAS software (SAS 9.1, SAS Institute Inc., Cary, NC, USA).

**3. Results**

Germination percentage and germination rate of sweet cherry seeds responded positively to all breaking dormancy treatments (P ≤ 0.01) (Table 1). Washing seeds increased germination percentage and rate of cherry seeds by more than 50%. Application of GA3 up to 500 ppm dramatically improved the percentage and rate of germination. Application of 500 ppm GA3 enhanced germination percentage from 2.7% to 33.5% and germination rate from 0.05 to 1.39 seeds per day. However, further increase in GA3 concentration from 500 ppm to 1000 ppm could only improve germination rate with no effect on germination percentage. The highest germination percentage was obtained by cold stratification for a period of 6 weeks whereas germination rate improved by longer period of stratification (Table 1).

The effect of GA3 application on germination percentage and rate of germination of sweet cherry was more pronounced when it was accompanied with washing treatment. Washing cherry seeds for 24 hours in combination with application of GA3 could significantly enhanced both seed germination percentage and rate of germination (Fig 1 A and B). Interaction of washing treatment and 500 ppm GA3 resulted in highest germination rate (47%) among all treatments. Combination of these two treatments also led to the highest germination rate which was 2.58 seeds per day (Fig 1 A and B).

Influence of GA3 on germination percentage and rate of sweet cherry was also intensified when it was accompanied with cold stratification treatment (Fig 2 A and B).

The highest germination percentage (44.3%) was obtained from application of 500 ppm GA3 combined with 6 weeks cold stratification (Fig. 2A) which was not statistically different than those obtained from higher hormone application and longer period of storing seeds in cold condition. Interaction of the highest hormonal level and 6 weeks cold stratification resulted in highest rate of germination (2.77 seeds per day) which did not differ significantly from 1000 ppm GA3 + 8 weeks cold stratification (2.66 seeds per day) or 500 ppm GA3 + 8 weeks cold stratification (2.44 seed per day) (Fig 2B). The interactive effect of washing treatment and cold stratification as well as the three way interaction between the breaking dormancy methods were only significant for germination rate but not for germination percentage (Table 1 and 2). Regardless of applied treatment, rate of germination was positively correlated (P≤ 0.01,   
R2= 0.89) with germination percentage in sweet cherry seeds: fast germination will be associated with high germination percent (Fig. 3).

4. **Discussion**

Successful seed germination constitutes the first essential step for successful crop establishment (Radosevich et al., 1997).Many *Prunus* species, including *P. avium*, have two different types of dormancy: internal or embryo dormancy and external or endocarp dormancy (Ghayyad *et al*., 2010). The results of the present study indicated a clear promoting effect of washing treatment on breaking the dormancy of sweet cherry seeds. Similarly, Nadjafi et al. (2006) reported that washing for a period of 14 days resulted in increased germination rate and percent of *Ferula gummosa* seeds. Washing is a standard procedure that is used to enhance the germination of dormant seeds (ISTA, 1996). Washing seeds under Tab water or soaking seeds in water helps softening the seed coats, removing inhibitors, reducing the time required for germination and increasing the germination percentage (Kumar et al., 2012). Results of the present investigation are in agreement with previous reports on enhancing seed germination by washing (Mirzadeh Vaghefi et al., 2010, Maiti et al., 2003).

The positive effect of washing treatment on germination percentage and rate of sweet cherry seeds was more pronounced when it was accompanied with GA3 application. Some research indicated that application of exogenous GA3 resulted in seed dormancy release (Grappin et al., 2000; Karam and Al-Salem, 2001; Pipinis et al., 2012). In dormant seeds, gibberellins content is low but gradually increases prior to or at dormancy break (Nagar and Anil, 2000; Karssen et al., 1989).The physiological role of GA3 in regulating dormancy regulation is not precisely known (Suttle, 2004). It has been shown; however, that gibberellins-mediated hydrolysis of storage materials precedes growth processes in the embryo axis (Arias et al., 1976). Also, exogenous gibberellins promote the expression of hydrolase and protein-kinase genes, which are associated with mobilizing storage materials and sprouting (Alvarado et al., 2000). In addition, GA3 has an active role in hydrolytic enzyme synthesis in seeds and consequently releasing nutritional substances and finally transporting of the substances to growing embryo (Kucera et al., 2005). The effect of GA3 application on seed dormancy breaking strongly depends on its concentration. Among the GA3 concentrations tested in this study, 500 ppm resulted in the highest germination percentage and further increase to 1000 ppm did not significantly differ to 500 ppm. Similar results have been reported on other species, including *Ferula gummosa* (Nadjafi et al., 2006) and *Sesamum indicum* (Kyauk et al., 1995).

Cold stratification is an important treatment commonly applied to enhance seed germination of different plant species (Bewley and Black 1994; Hartmann et al. 1997). In this study cold stratification up to 6 weeks clearly increased germination percentage and rate of germination of sweet cherry seeds. The efficacy of stratification treatment on seed germination has been demonstrated in other *Prunus* species like *Prunus persica* (Mehanna et al., 1985, Frisby and Seeley, 1993) and *Prunus dulcis* (Garcia-Gusano et al., 2004). The enhancement effect of cold stratification on breaking dormancy is due to some physiological changes which occur at low temperatures and act as germination cues. Most likely these changes can be attributed to adaptations to the natural environmental conditions of this species (Manjkhola et al., 2003). Our results agreed with those reported earlier by Yang *et al*. (2007), Nadjafi *et al*. (2006), Fang *et al*. (2006), in other plants. Frankland and Wareing (1962) suggested that cold stratification increases gibberellin and decreases inhibitor concentrations in seeds, which in turn, may improve germination. In order to accelerate the effect of cold stratification, it can be combined with some other dormancy breaking treatments such as hormone applications (Mehanna et al. 1985; Martinez-Gomez and Dicenta, 2001). According to the results of this study, cold stratification in combination with GA3 application was more effective in seed dormancy breaking than cold storage alone.

**Conclusions**

In summary, germination percentage and germination rate of sweet cherry seeds responded positively to all breaking dormancy treatments. Just washing cherry seeds with Tab water increased both germination percentage and germination rate by more than 50%. Although application of 500 ppm GA3 could enhance germination percentage from to 33.5%, a combination of the two treatments was even more effective and improved the germination percentage and germination rate to 47% and 2.58 seeds per day, respectively. Interaction of GA3 and cold stratification was also very effective in breaking dormancy where 500 ppm GA3 and 6 weeks cold stratification improved germination rate to 44.3 The highest germination % (61.2) was obtained from seed washing + 500 ppm GA3 + 6 weeks cold stratification whereas the highest rate of germination (3.8 seeds per day) was observed in seed washing + 1000 ppm GA3 + 8 weeks of cold stratification.

|  |  |  |  |
| --- | --- | --- | --- |
| Table 1  Effects of seed washing, GA3 concentration and duration of cold stratification period on germination percentage and rate of sweet cherry (*Prunus avium*) var. Lambert. | | | |
| **Treatment** | | **Germination percentage** | **Germination rate** |
| washing | No washing | 12.81 (±1.63)b | 0.56 (±0.11)b |
|  | 24 hr washing | 26.46(±3.55)a | 1.17(±0.22)a |
|  | LSD | 2.1701 | 0.0935 |
| GA3 | 0 ppm | 2.71(±0.67)c | 0.05 (±0.02)c |
|  | 250 ppm | 8.13(±1.41)b | 0.10 (±0.02)c |
|  | 500 ppm | 33.54 (±4.29)a | 1.39 (±0.22)b |
|  | 1000 ppm | 34.17(±3.72)a | 1.91 (±0.30)a |
|  | LSD | 3.069 | 0.1323 |
| Cold stratification | 4 weeks | 8.91(±1.55)b | 0.14(±0.02) c |
|  | 6 weeks | 23.75(±3.97)a | 1.16(±0.23) b |
|  | 8 weeks | 26.25 (±3.93)a | 1.30(±0.24)a |
|  | LSD | 2.6579 | 0.1145 |
| **Source of Variation** | |  |  |
| Washing treatment (A) | | \*\* | \*\* |
| GA3 concentration(B) | | \*\* | \*\* |
| Cold stratification period (C) | | \*\* | \*\* |
| A×B |  | \*\* | \*\* |
| A×C |  | Ns | \*\* |
| B×C |  | \* | \*\* |
| A×B×C |  | Ns | \*\* |
| Values are means ± standard error of four replicates. Within columns, means with similar letter are not significantly different at (P ≤ 0.05).  ns: statistically not significant.  \* Statistically significant at P ≤ 0.05.  \*\* Statistically significant at P ≤ 0.01. | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 2  Interactive effect of seed washing, GA3 concentration and duration of cold stratification period on germination percentage and germination rate of sweet cherry (*Prunus avium*) var. Lambert. | | | | |
| Treatment | | | Germination percentage | Germination rate  (seeds per day) |
| Washing | GA3 | Cold stratification |  |  |
| No washing | 0 ppm | 4 weeks | 0.00(±0.00) | 0.00(±0.00) |
|  |  | 6 weeks | 2.50(±1.44) | 0.03(±0.01) |
|  |  | 8 weeks | 2.50(±1.44) | 0.03(±0.01) |
|  |  |  |  |  |
|  | 250 ppm | 4 weeks | 2.50(±2.50) | 0.03(±0.03) |
|  |  | 6 weeks | 7.50(±2.50) | 0.11(±0.04) |
|  |  | 8 weeks | 8.75(±1.25) | 0.10(±0.02) |
|  |  |  |  |  |
|  | 500 ppm | 4 weeks | 10.00(±2.04) | 0.14(±0.03) |
|  |  | 6 weeks | 22.50(±1.44) | 0.95(±0.08) |
|  |  | 8 weeks | 27.50(±2.50) | 1.66(±0.22) |
|  |  |  |  |  |
|  | 1000 ppm | 4 weeks | 12.50(±1.44) | 0.27(±0.05) |
|  |  | 6 weeks | 27.50(±3.23) | 1.93(±0.16) |
|  |  | 8 weeks | 30.00(±2.04) | 1.53(±0.16) |
|  |  |  |  |  |
| Washing | 0 ppm | 4 weeks | 1.25(±1.25) | 0.01(±0.01) |
|  |  | 6 weeks | 5.00(±2.04) | 0.04(±0.02) |
|  |  | 8 weeks | 5.00(±2.04) | 0.20(±0.14) |
|  |  |  |  |  |
|  | 250 ppm | 4 weeks | 3.75(±2.39) | 0.05(±0.03) |
|  |  | 6 weeks | 8.75(±2.39) | 0.12(±0.04) |
|  |  | 8 weeks | 17.50(±4.33) | 0.21(±0.04) |
|  |  |  |  |  |
|  | 500 ppm | 4 weeks | 20.00(±2.89) | 0.30(±0.03) |
|  |  | 6 weeks | 61.25(±3.15) | 2.48(±0.13) |
|  |  | 8 weeks | 60.00(±5.40) | 2.84(±0.24) |
|  |  |  |  |  |
|  | 1000 ppm | 4 weeks | 21.25(±2.39) | 0.32(±0.05) |
|  |  | 6 weeks | 55.00(±5.40) | 3.63(±0.31) |
|  |  | 8 weeks | 58.75(±2.39) | 3.80(±0.11) |
| Values are means ± standard error of four replicates. Means are separated by LSD (P ≤ 0.05). | | | | |

**References**

Alvarado V., Nonogaki H., Bradford K.J. (2000). Expression of endo-beta-mannanase and SNF-related protein kinase genes in true potato seeds in relation to dormancy, gibberellin and abscisic acid. In: Viemont J.D., Crabbe J. (eds.), Dormancy in plants: From whole plant behavior to cellular control. CABI Publishing, Wallingford, UK, pp. 347-364.

Arias I., Williaas P.M., Bradbeer J.W. (1976). Studies in seed dormancy. IX. The-role of gibberellin biosynthesis and the release of bound gibberellin in the post-chillingaccumulationof gibberellins in seeds of *Corylus avellana* L. Planta, 151: 135-139.

Bewley J.D., Black M. (1994). Seeds: Physiology of Development and Germination. Second Edition. Plenum Press, New York.

Bretzloff L.V., Pellett N.W. (1979). Effect of stratiﬁcation and gibberellic acid on the germination of Carpinus caroliniana Walt. Hort. Sci, 14: 621–622.

Çetinbaş M., Koyuncu F. (2006). Improving germination of Prunus avium L. seeds by gibberellic acid, potassium nitrate and thiourea. Hort. Sci, 33(3): 119–123.

Fang S., Wang J., Wei Z., Zhu Z. (2006). Methods to break seed dormancy in Cyclocaryapaliurus (Batal) Iljinskaja. Sci. Hort, 110: 305–309.

Finch-Savage W.E., Clay H.A., Dent K.C. (2002). Seed maturity affects the uniformity of cherry (*Prunus avium* L.) seed response to dormancy-breaking treatments. Seed Sci. Technol, 30: 483–497.

Frankland B., Wareing P.F. (1962). Changes in endogenous gibberellins in relation to chilling of dormant seeds. Nature, 194: 313 –314.

Frisby J.W., Seeley S.D. (1993). Chilling of endodormant peach propagules: seed germination and emergence. J. Am. Soc. Hort. Sci, 118: 248–252.

Garcia-Gusano M., Martinez-Gomez P., Dicenta F. (2004). Breaking seed dormancy in almond (*Prunus dulcis* Mill.). Sci. Hort, 99: 363- 370.

Ghayyad M., Kurbysa M., Napolsy Gh. (2010). Effect of endocarp removal, gibberellin, stratification and sulfuric acid on germination of mahaleb (*Prunus mahaleb* L.) seeds. American-Eurasian J. Agric. Environ. Sci, 9 (2): 163-168.

Gosling P. (2007). Raising trees and shrubs from seed. Forestry commission practice guide, publication. Forestry commission, pp. 18-28.

Grappin P., Bouinot D., Sotta B., Miginiac E., Jullien M.( 2000). Control of seed dormancy in Nicotiana plumbaginifolia: Post-imbibition abscisic acid synthesis imposes dormancy maintenance. Planta, 210: 279-285.

Hartmann H.T., Kester D.E. (1967). Plant Propagation: Principles and Practice. Englewood Cliffs, N.J. Prentice Hall, 559 pp.

Heidari M., Rahemi M., Daneshvar M.H. (2008).Effect of mechanical, chemical scarification and stratidication on seed germination of *Prunus* *scoparia* (Spach.) and Prunus webbii (Spach.) Vierh. American-Eurasian J. Agric. Environ. Sci, 3 (1): 114-117.

Iglesias R.G., Babiano M.J. (1997). Endogenous abscisic acid during the germination of chickpea seed. Physiol. Plantarum, 100: 500–504.

ISTA. (1996). International rules for seed testing. Seed Sci. Technol, 13: 299–513.

Karam N.S., Al-Salem M.M. (2001). Breaking dormancy in Arbutus andrachne L. by stratification and gibberellic acid. Seed Sci. Technol, 29:51-56.

Karssen C.M., Zagorski S., Kepczynski J., Groot S.P.C. (1989). Key role for endogenous gibberellins in the control of seed germination. Ann. Bot, 63: 71-80.

Kucera B., Cohn M.A., Leubner-Metzger G. (2005). Plant hormone interactions during seed dormancy release and germination. Seed Sci. Res, 15: 281-307.

Kumar R., Misra K. K., Misra D. S., Brijwal M. (2012). Seed germination of fruit crops: a review. HortFlora Res. Spect, 1(3): 199-207.

Kyauk H., Hopper N.W., Brigham R.D. (1995). Effects of temperature and pre-soaking on germination, root, length and shoot length of sesame (*Sesamum indicum* L.), Environ. Exp. Bot, 35: 345–35.

Manjkhola S., Dhar U., Rawal R.S. (2003). Treatments to improve seed germination of Arnebiabenthamii: an endangered medicinal herb of high altitude Himalaya. Seed Sci. Technol, 31: 571 –577.

Maiti C.S., Wangchu L., Sen S.K. (2003). Effect of pre-sowing seed treatments with different chemicals on seed germination and seedling growth of jackfruit (Artocarpus heterophyllus L.). Env. Ecol, 21: 290-292.

Martinez-Gomez P., Dicenta F. (2001). Mechanism of dormancy in seeds of peach (*Prunus* *persica* (L.) Batsch) cv. GF305. Sci. Hort, 91: 51-58.

Mehanna H.T., Martin G.C., Nishijuma C. (1985). Effects of temperature, chemical treatments and endogenous Hormone content on peach seed germination and subsequent seedling growth. Sci. Hort, 27: 63–73.

MirzadehVaghefi S.S., Jamzad Z., Jalili A., Nasiri M. (2010). Study on dormancy breakage and germination in three species of Hawthorn (*Crataegus aminii*, *C*. *persica* and *C*. *babakhanloui*). IJFPR, 17: 547-559.

Nadjafi F., Bannayan M., Tabrizi L., Rastgoo M. (2006).Seed germination and dormancy breaking techniques for *Ferula gummosa* and *Teucrium polium*. J. Arid Environ, 64: 542-547.

Nagar P.K., Anil K. (2000). Changes in endogenous gibberellin activity during winter dormancy in tea (*Camellia sinensis* (L.) O. Kuntze). Acta Physiol. Plant, 22: 439-443.

Nejatali S., Ezoldin H., Taherian K. (2001). Study the cultivation and propagation methods of Ferula gummosa. Journal of Pajoohesh and Sazandegi, 53: 90–97.

Pipinis E., Milios E., Mavrokordopoulou O., Gkanatsiou Ch., Aslanidou M., Smiris P. (2012). Effect of pretreatment on seed germination of *Prunus mahleb* L. Not. Bot .Agrobo, 40 (2):183-189.

Radosevich S., Holt J., Ghersa C. (1997). Weed ecology. Implications for management. 2nd Edn., John Wiley and Sons, Inc., New York.

Seeley S.D., Ayanoglu H., Frisby J.W. (1998). Peach seedling emergence and growth in response to isotherma and cycled stratiﬁcation treatments reveal two dormancy components. J. Am. Soc. Hort. Sci, 123: 776–780.

Schmidt, H. Ketzel A. (1994). Raising sweet cherry seedlings by using *in vitro* techniques. In H. Schmidt and M. kellerhals (Eds): Progress in Temperate Fruit Breeding, Kluwer Academic Publisher. Netherlands, pp. 381-383.

Suttle J. C. (2000). The role of endogenous hormones in potato tuber dormancy. In: Viémont J-D, Crabbe J (eds) Dormancy in Plants. From Whole Plant Behaviors to Cellular Control. CABI Publ, Wallingford, pp. 211–226.

Wiese A.M., Binning L.K. (1987). Calculating the threshold temperature of development for weeds. Weed Sci, 35: 177–179.

Yang Q.H., Ye W.H., Yin X. (2007). Dormancy and germination of *Areca triandra* seeds. Sci. Hort, 113: 107-111.