

Effect of Copper Oxychloride and Volck® Mineral Oil on Blooming Time, Frost Resistance and Yield in Almond cv. “Mamaei”

R. Babadaei Samani*, M. Honarvar, A.R. Javid

Department of Horticulture Science, Estahban Branch, Islamic Azad University, Estahban, Iran

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Abstract

Almond [*Prunus dulcis* (Mill.) D.A. Webb] is one of the most important cultivated fruit trees in Iran. Late frost in spring is a key limiting factor for almond productivity given that almond trees flower early in the spring in comparison with other temperate fruit trees. To decrease frost injury in “Mamaei” cultivar, this study was carried out in factorial randomized complete block design (CRBD) with four replications. Almond trees were sprayed with 5%, 10% and 15% concentrations of Volck® mineral oil mixed with a constant 3 g.l⁻¹ concentration of Copper Oxychloride at two separate times, before swelling bud stage and at the swelling bud stage. The control almond trees were sprayed with pure water. The parameters such as phenological development stages of flower bud, amount of frost injury, bud abortion, fruit set and yield were measured. The results indicated that the trees treated with Copper Oxychloride and Volck® mineral oil did not show significant effects on blooming time but had a significant effect on other parameters. The result of the mean comparison indicated that the highest percentage of bud abortion (1.84%) occurred by using 15% oil concentration and the lowest bud abortion (0.49%) occurred in the control trees. The highest yield (7.9 kg/tree) was achieved by the use of 5% Volck® mineral oil plus 3 g.l⁻¹ Copper Oxychloride during the swelling bud stage.

Keywords: Bud abortion, Development stages, Frost injury, Fruit set phenological.

Introduction

Almond [*Prunus dulcis* (Mill.) D.A. Webb], which belongs to the Rosaceae family, is one of the major stone fruits, i.e. fruits belonging to the genus *Prunus*, and it is cultivated in various parts of Iran (Rahemi 2002; Talaei 2006). Spring freeze injury in almond is one of the most important factors limiting crop productivity. Chill requirement has a much stronger effect on flowering time (Egea *et al.*, 2003) with a high positive correlation between chilling requirement and flowering time (Sanchez-Perez *et al.*, 2012).

Almond trees need lower chilling requirements for flowering and flower early in the spring in comparison with the other temperate fruits. Native genotypes and cultivars of almond are typically early flowering, which makes them susceptible to damage by late spring frost (Imani, 1997).

The minimum temperature in which almond cultivars can resist in various phenological stages may define its adaptation to specific agro-ecological zones. The temperature at which flower buds are injured depends primarily on their stage of

*Corresponding author: Email: r_samani@iauest.ac.ir

development. Buds are most hard during the winter when they are fully dormant. As they begin to swell and expand into blossoms, they become less resistant to freeze injury (Friesen and Stushnoff, 1985; Miranda *et al.*, 2005).

Dormant buds are tolerant to temperatures below zero and stay alive for a long time. Therefore, any treatment done to delay flowering in the spring would protect the young fruit and flowers against freezing (Ramin, 1999).

Chemical treatments such as urea, captan, vitamins and copper hydroxide were used to increase the cold hardiness of trees (Sauvage 1995; Sun *et al.* 2000; Zilkah *et al.* 1996).

Joolka *et al.* applied various GRs and other compounds (Gibberellic acid, ethephon, succinic acid, and urea and tree spray oil) to delay flowering and increase fruit set in Non Pareil and Drake almond trees. Emulsified soybean oil spray on almond delayed the blooming time two days later than the control trees, increased fruit set and decreased frost injury (Samani *et al.* 2006). Mineral oils are a type of refined petroleum product, and horticultural oils such as Volck® are mineral oils that have been distilled to remove impurities that can damage plants. The final formulations of these oils are combined with an emulsifying agent that allows the oil to mix with water. Volck oil has always been considered to be a dormant oil to control insects and mites (Ellis and Bradley, 1992). The damage is caused by ice formation in plant cells, which spreads both inter-and intracellularly, resulting in the disruption of cell membranes (Burke *et al.* 1976). Ice nucleating bacteria are epiphytic bacteria that can imitate ice nucleation in water at temperatures above -10°C (Lindow *et al.* 1982). These bacteria have been shown to incite frost damage to some plants (Gross *et al.* 1984). Lindow *et al.* (1978) demonstrated that the activity

of INA bacteria is sensitive to pH and heavy metals in a soluble state (e.g. copper and zinc) and cationic detergents. Dormant season applications of copper or of synthetic fungicide limit infection and prevent the spread of certain bacterial and fungal diseases. Copper oxychloride is a powder fungicide that controls various fungus and bacterial diseases in many horticultural and ornamental plants. Dawashi and Shokrollahi (1999) reported that spraying copper oxychloride increased the yield and reduced the spring freezing caused by bacteria. Thus, the application of bactericide and dormant oils can reduce the spring freezing and increase fruit set as well as control mites and other insects on fruit tree.

This study was developed to determine the optimum application time and concentration to use copper oxychloride and volck® mineral oil on almond cv. "Mamaei" in Saman region, Iran.

Materials and Methods

This study was carried out on the commercial Iranian almond cultivar 'Mamaei' at Emamamiye Station (32° 30' N, 50° 58' E, elevation 1900 m) in Saman region of Chaharmahal va Bakhtiari province, Iran. The experiment was performed in a factorial base on a completely randomized block design (CRBD) with four replications. Almond trees were sprayed with different concentrations of Volck® mineral oil (0%, 5%, 10% and 15%) mixed with a constant 3 g.l⁻¹ concentration of copper oxychloride at two different times (before swelling bud stage and at the swelling bud stage). The control almond trees were sprayed with pure water. The parameters such as phenological development of flower bud, amount of frost injury, bud abortion, fruit set and yield were measured.

Flower bud development and full blooming time were evaluated in this study. "Points" are dedicated to various phenological stages so that

higher "points" correspond to closer stages to the final stage of flower development.

To determine the fruit set percentage, the previously marked branches were used. Counting and calculating the percentage of fruit set were carried out before harvest. Fruit set percentage was determined by using the following formula:

$$\text{Fruit Set (\%)} = (\text{Total Fruit Set} / \text{Total Bloom}) \times 100$$

Marked branches were also used to determine the bud abortion percentage. Counting and calculating the percentage of aborted buds were completed at the time of flowering. The following formula gives bud abortion percentage:

$$\text{Bud Abortion (\%)} = (\text{Total Bud Aborted on Branch} / \text{Total Bud on Branch}) \times 100$$

To evaluate the frost injury, branches were exposed to -4°C in the freezing chamber in laboratory, and the damaged bud percentage was determined. The branches were transferred to the freezing chamber in the popcorn phenological stage, and after remaining at 5°C for 30 minutes, the temperature reached -4°C by reducing it by 2°C

per hour. The branches were then conserved 30 minutes in the freezing temperature. Afterwards, the temperature increased by 2°C per hour until reaching 7°C. Then, the frost injury (browning of the pistils) was evaluated after freezing treatment (Mousavi *et al.* 2014).

Yield per tree was recorded by weighting the total number of fruits per tree at harvesting time. Data were statistically analyzed with MSTAT-C software, and means were compared using Duncan's Multiple Range Test.

Results

The results showed that the use of Volck® mineral oil mixed with copper oxychloride did not significantly affect on blooming time in almond cv. "Mamaei" (Table 1).

According to the analysis of variance results (Table 1), application time and concentration of Volck® mineral oil plus copper oxychloride and the interaction of treatments (application time × concentration of Volck® mineral oil plus Copper Oxychloride) showed significant effects on bud abortion, frost injury, fruit set and yield at 1% probability level.

Table 1. Analysis of variance of application time and concentrations of Volck® mineral oil mixed with 3 g.l⁻¹ Copper Oxychloride on flowering time, bud abortion, frost injury, fruit set and yield of Iranian almond cultivar 'Mamaei'

SOV	df	Mean Square (MS)				
		Flowering time	Bud abortion	Frost injury	Fruit set (%)	Yield
Rep	3	21.3331	0.026	0.961	2.015	0.167
Time	1	32.00 ^{ns}	0.245 ^{**}	625.625 ^{**}	11.281 ^{**}	6.129 ^{**}
Concentration	3	10.583 ^{ns}	2.618 ^{**}	69.063 ^{**}	68.792 ^{**}	6.677 ^{**}
Time× Conc.	3	36.750 ^{ns}	0.068 ^{**}	232.963 ^{**}	6.262 ^{**}	2.559 ^{**}
Error	21	26.167	0.026	0.584	0.985	0.202
Total	31					

*, ** are significant at 0.05 and 0.01 of probability levels, respectively, and ns is not significant.

The results showed that the highest percentage of bud abortion occurred by using 15% Volck® oil

concentration, and the lowest bud abortion occurred in the control trees (Fig. 1).

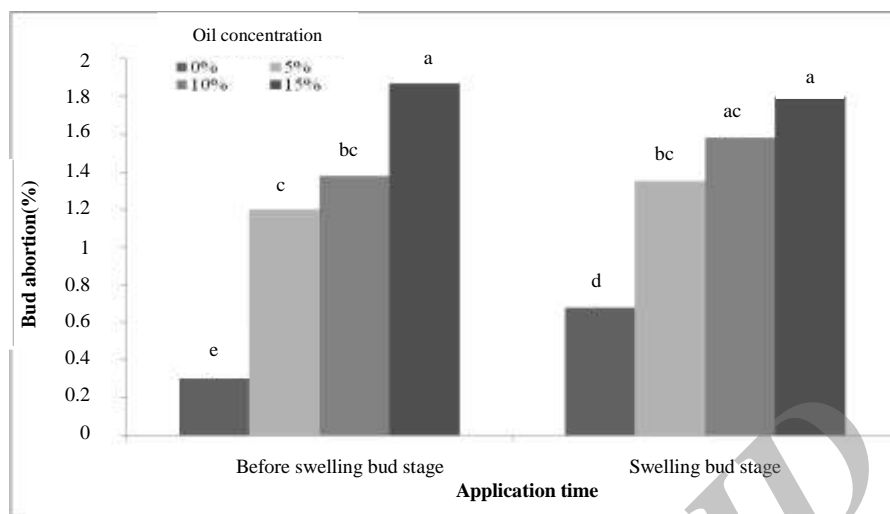


Fig. 1. Effect of copper oxychloride and volck® mineral oil on bud abortion in almond cv. 'Mamaei'

The mean comparison indicated that the lowest yield occurred by using 15% Volck® mineral oil in swelling bud stage, and the highest yield occurred

by the use of 5% Volck® mineral oil plus 3g.l⁻¹ copper oxychloride (Fig. 2).

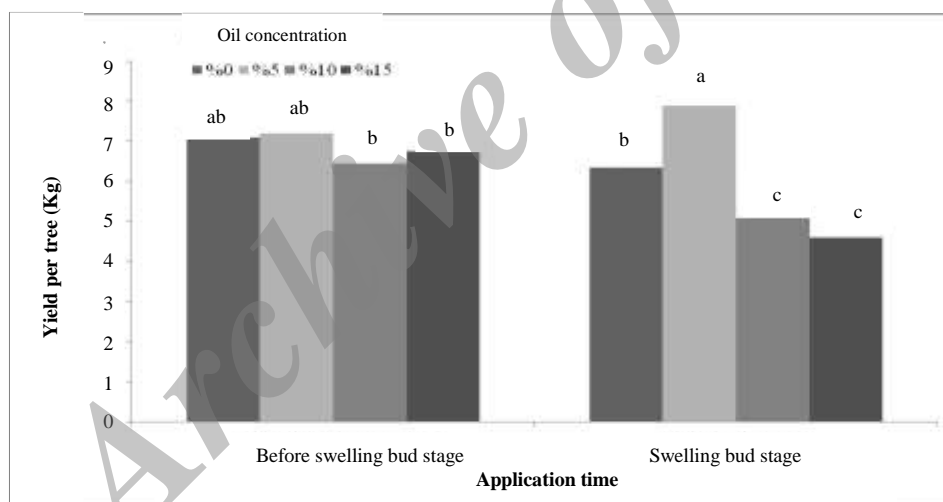


Fig. 2. Effect of copper oxychloride and volck® mineral oil on yield in almond cv. 'Mamaei'

The mean comparison indicated that increasing Volck® mineral oil concentration more than 5% decreased the fruit set and the lowest fruit set was

corresponded to 15 % Volck® mineral oil concentration in almond cv. 'Mamaei' (Fig. 3).

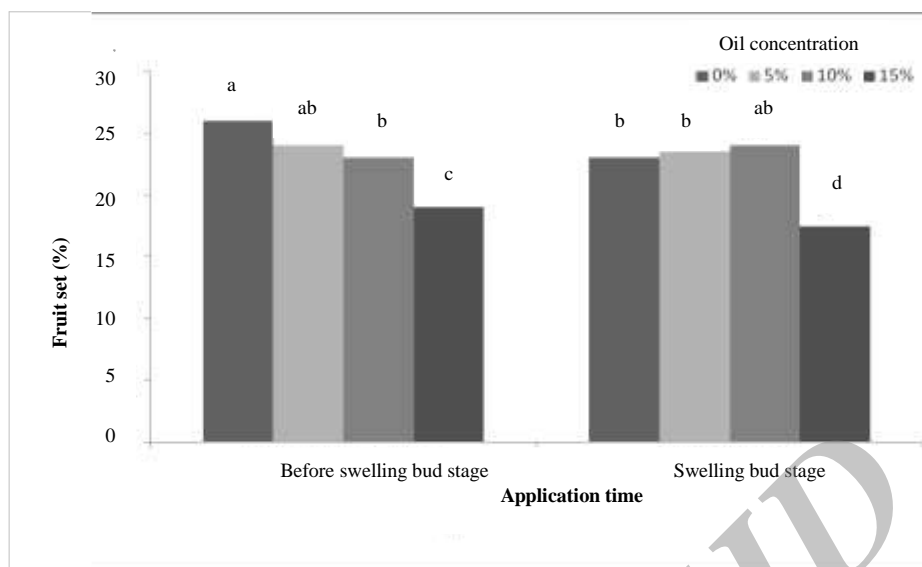


Fig. 3. Effect of copper oxychloride and volck® mineral oil on fruit set in almond cv. 'Mamaei'

The mean comparison indicated that the lowest frost injury occurred by using Volck® mineral oil before swelling bud stage, and the highest frost injury occurred by use of this compound in

swelling bud stage. The results showed that the use of this compound in swelling buds stage had no effect on reducing frost injury but had a negative impact on cold hardiness (Fig. 4).

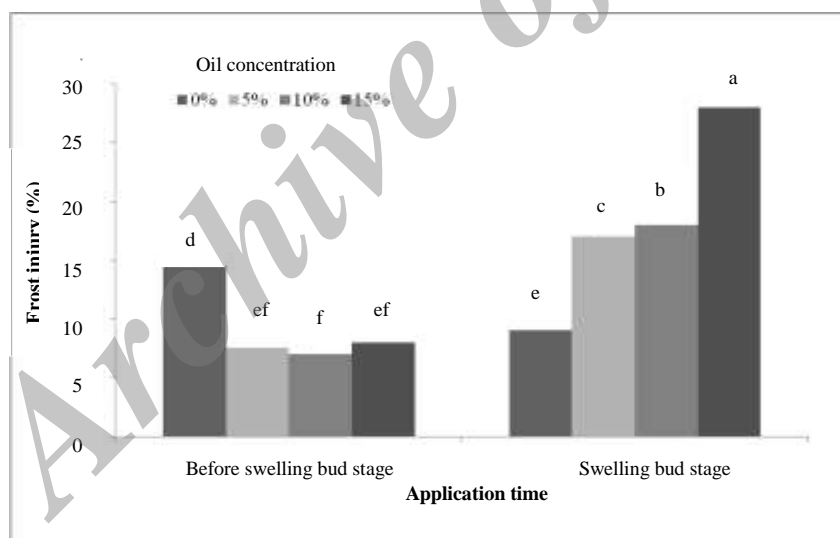


Fig. 4. Effect of copper oxychloride and volck® mineral oil on resistance to frost injury in flowers of almond cv. 'Mamaei'

Discussion

According to the results, use of Volck® mineral oil plus copper oxychloride did not significantly affect on blooming time in almond cv. "Mamaei". Deyton *et al.* (1992) reported that application of 6% to 12% petroleum oil delayed peach blooming time and caused bud death at higher concentrations.

Myers *et al.* (1996) showed that soybean oil delays bloom of peach. Soybean oil spray on apricot delayed the blooming time six days later than control trees (Alizadeh *et al.*, 1998). The use of soybean oil on almond tree delayed the blooming time two days later than control trees and increased

resistance to frost damage (Samani *et al.* 2006). Application of Volck® mineral oil increased pistachio splitting and fresh and dry weight of the crop and decreased blankness and percentage of small fruit (Kashanizadeh *et al.* 2006). Comparing the results of experiments on various plants suggest that the effect of oil on flowering is related to the type and amount of oil, application time, environmental conditions, type and cultivars of plants.

Our results showed that increasing concentrations of oil is due to the increased percentage of bud abortion, so that the highest percentage of bud abortion occurs in concentrations of 15% oil and the lowest bud abortion happened in the control tree. Renae *et al.* (2000) reported that the number of dead flower buds of peach was concentration-dependent with maximum bud kill of 53% occurring with application of 12% soybean oil. Deyton *et al.* (1992) reported that the application of 6% to 12% petroleum oil delayed peach bloom and caused bud death at higher concentrations. Meyers *et al.* (1996) also reported that soybean oil caused damage to flower buds. They observed browning of anthers and pistils two weeks after treatment. Previous researches proposed that oil spray on tree inhibited oxygen absorption by buds, resulting in dormancy breaking. Applying oil treatments has a considerable effect on CO₂ and ethylene accumulation in buds (Chayani *et al.*, 2015; Alizadeh *et al.*, 1998). According to various reports, we can conclude that increases in bud abortion are due to bud suffocation in high concentrations of oil.

As shown in the results, the lowest yield occurred by using 15% Volck® mineral oil, and the highest yield occurred by the use of 5% Volck® mineral oil plus 3 g.l⁻¹ copper oxychloride. Alizadeh *et al.* (1998) reported that soybean oil spray on apricot did not significantly affect on the

yield. Davashi and Shokrolahi, (1999) showed that the application of copper compounds such as oxychloride and bordox had positive effects on yield and reduced the spring freezing in almond. Thus, the application of bactericide such as oxychloride can reduce the spring freezing and increase the yield.

The results showed that an increase of Volck® mineral oil concentration more than 5% caused a decline in fruit set in almond cv. 'Mamaei'. The previous reports showed that the application of copper compounds such as oxychloride and bordox have positive effects on fruit set due to a decrease in freezing of flowers in almond and other fruit trees (Davashi and Shokrolahi, 1999). The application of soybean oil before the swelling bud stage significantly increased fruit set and decreased frost injury in almond cv. "Sefid" but had no significant effect on fruit drop (Samani *et al.* 2006). According to various reports, the reduction in fruit set at high concentrations of oil is the result of suffocation buds.

In accordance with the results, the lowest frost injury occurred by using Volck® mineral oil before swelling bud stage, and the highest frost injury occurred by use of this compound in swelling bud stage. The results showed that the use of this compound in swelling bud stage had no effect on reducing frost injury but had a negative impact on cold hardiness. Applying soybean oil prolongs bud dormancy due to increment of respiratory gases accumulation which subsequently delays bud break and resulted in decreased spring frost damage (Chayani *et al.*, 2015). Flower bud of peach survival was improved when trees were sprayed with 10% or 12% soybean oil prior to -4 °C spring frost (Renae *et al.*, 2000).

Conclusions

The results of this experiment verified that the use of Volck® mineral oil plus copper oxychloride had no effect on blooming time of almond cv. 'Mamaei'. Increment of Volck® mineral oil concentration of more than 5% increased the flower bud abortion and frost injury and decreased fruit set and yield of almond cv. 'Mamaei'. According to the results, the application of 5% Volck® mineral oil plus 3g.l⁻¹ copper oxychloride increased the yield in almond production. Given the results that showed positive effects of oil mixed with copper oxychloride on reduction of frost injury, it is suggested that a 3 g.l⁻¹ concentration of copper oxychloride is added to Volck® mineral oil.

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References

- Alizadeh F, Grigurian V, Valizadeh M (1998) Effect of different amount of soybean oil on blooming time of apricot. Iranian Journal of Society Horticulture Science. 1, 109-118. [In Persian].
- Bernier G, Kinet GM, Roy MS (1985) The physiology of flowering. CRC Press. Vol. I, II and III.
- Burke MJ, Gusta LA, Quamme HA, Weiser CJ, Li PH (1976) Freezing and injury to plants. Annual Review of Plant Physiology. 27,507-528.
- Chayani Sh, Ershadi A, Sarikhani H (2015) Effect of soybean oil and NAA on delaying bud break and reducing spring low temperature damage in grape cv. Fakhri. Iranian Journal of Crop Improvement. 2, 357-371.
- Dawashi A, Shokrollahi G (1999) Effect of using copper oxychloride on almond trees. Proceeding of First Iranian Almond Symposium. Shahrekord. Iran. Pp. 19.
- Deyton DE, Sams CE, Cummins JC (1992) Application of dormant oil to peach trees modifies bud-twig internal atmosphere. HortScience. 27, 1304-1305.
- Egea J, Ortega E, Martínez-Gomez P, Dicenta F (2003) Chilling and heat requirements of almond cultivars for flowering. Environmental and Experimental Botany. 50, 79-85.
- Ellis Barbara W, Bradley FM (1992) The Organic Gardener's Handbook of Natural Insect and Disease Control. Rodale Press. Emmaus, PA. Pp. 534.
- Friesen LJ, Stushnoff C (1985) Spring frost injury relative to phenophase bud development in Saskatoon berry. Hort Science. 20, 744-746.
- Gross DC, Cody YS, Proebsting EL, Rademaker GK, Spotts RA (1984) Ecotypes and pathogenicity of ice nucleation-active *Pseudomonas syringae* isolated from deciduous fruit tree orchards. Phytopathology. 74, 241-248.
- Imani A (1997) Effects of biological and physiological characteristics on yield of selected almond varieties. Ph.D Thesis. Faculty of agriculture, university of Tarbiat- Moddares. Tehran. Iran. [In Persian].
- Joolka N, Bushehri T, Bhutani V (1991) Effect of growth regulators, urea and tree spray oil on bloom delay and productivity of

- almonds. *Indian Journal of Horticulture*. 48(3), 217-221.
- Kashanizadeh S, Gholipour Y, Mohammadbeigi A (2006) The effect of Volck® mineral oil application and its spray time on the yield and quality of commercial cultivars of pistachio in Qazvin area. *Acta Horticulture*. 726, 455-458.
- Kester DE (1969) Almonds. In *Handbook of North American Nut Growers*, Assoc. (Knoxville, Tenn), pp. 302-314.
- Lindow SE, Arny DC, Barchet WR, Upper CD (1978) Bacterial ice nucleation inhibitors and reduction of frost damage to plants (Abstract). *Phytopathology News*. 12, 138.
- Lindow SE, Hirano SS, Barchet WR, Arny DC, Upper CD (1982) Relationship between ice nucleation frequency of bacteria and frost injury. *Plant Physiology*. 70, 1090-1093.
- Miranda C, Santesteban LG, Royo JB (2005) Variability in the relationship between frost temperature and injury level for some cultivated prunus species. *Hort Science*. 4(2), 357-361.
- Mousavi SS, Shiran B, Imani A, Houshmand S, Ebrahimie E (2014) Investigation of some physiological indices related to frost damage in almond genotypes with different flowering time. *Journal of Crop Production and Processing*, 4(12), 235-247. [In Persian].
- Myers RE, Deyton DE, Sams CE, (1996) Applying soybean oil to dormant peach trees alters internal atmosphere, reduces respiration, delays bloom, and thins flower buds. *Journal of American Society for Horticultural Science*. 121, 96-100.
- Rahemi AR (2002) The development of almond orchards in Iran. *Theoretical and Applied Genetics*. 591, 177-180.
- Renae E Moran, Dennis E Deyton¹, Carl E Sams, John C Cummins (2000) Applying soybean oil to dormant peach trees thins flower buds. *HortScience*. 35(4), 615-619.
- Samani RB, Mostafavi M, Khalighi A, Mousavi A (2006) Effect of different amount and application times of soybean oil spray on delaying time blooming of almond. *Acta Horticulture*. 726, 471-473.
- Sanchez-Perez R, Dicenta F, Martínez-Gomez P (2012) Inheritance of chilling and heat requirements for flowering in almond and QTL analysis. *Tree Genetics and Genomes*. 8, 379-389.
- Sauvage G (1995) Control night frost damage with vitamin E. *Fruiteelt Den Haag*. 85, 23.
- Seely SD, Damavandy H, Inderson JL (1992) Autumn applied growth regulators influence leaf retention, bud hardiness, bud and flower size, and endodormancy in peach and cherry. *Journal of American Society for Horticultural Science*. 117(2), 203-208.
- Sun F, Zhao T, Yang J, Cao X, Tang C, Meng Q (2000) Species of ice-nucleation active bacteria on the apricot and the relationship between their activity and flower frost. *Science Agricultural Sinica*, 33, 50-58.
- Talaei AR (2006) A brief outlook on Iran Horticulture. *Acta Horticulture*. 726, 29-32.
- Zilkah S, Wiesmann Z, Klein I, David I (1996) Foliar applied urea improves freezing protection to avocado and peach. *Scientia Horticulturae*. 66, 85-9.