ISSN 1644-0692
www.acta.media.pl

Acta Sci. Pol. Hortorum Cultus, 15(6) 2016, 265-277

CHEMICAL APPLICATIONS AFFECTED DORMANCY BREAKING IN 'MODI' APPLE CULTIVAR UNDER SUBTROPICAL CONDITIONS

Burhanettin İmrak, Ayzin B. Küden, Ali Küden, A. Kadir Sarıer, Berken Çimen

University of Çukurova, Balcali, Adana, Turkey

Abstract. The winter chill is essential for most fruit crops. Fruit trees require a certain number of chill hours, also called chill units, each winter to produce fruits in the next summer. Insufficient chilling accumulation during winter period usually results in blooming disorders and decreases the fruit yield of deciduous fruit trees. Dormancy can be broken by using chemicals, such as Dormex. In recent years Dormex has been forbidden in some countries, including Turkey since it was found to be carcinogenic to human beings. This situation raised a necessity to find alternative chemicals to Dormex to be used in subtropical climate regions. For this purpose, six years old trees of 'Modi' apple scions (*Malus sylvestris*, Mill) grafted on Malling-Merton M9 rootstocks were sprayed with 6% Erger (total nitrogen, 15.0%; ureic nitrogen, 6.1%; nitric nitrogen, 5.8%; ammoniacal, 3.1%; water soluble calcium oxide, 4.7%), hydrogen cyanamide 4% (Dormex) and potassium nitrate 8% (KNO_3) for breaking dormancy of the buds during 2011–2013. Calculating the chilling hours below 7°C and chill unit (CU) values during the experimental winter periods, 497 to 828 h and 357 to 467 CU of chilling durations were obtained under subtropical conditions of Adana (36°56 12'04"N. 35° 33'53.46"E). Modi broke endodormancy of the buds on 20 February 2012 with the accumulation of 375 CU and 550 h. The effects of dormancy breaking agents on bud break, fruit set and fruit quality were investigated. Erger markedly advanced bud-break and increased the final fruit set, quality and yield in comparison with the other treatments and control.

Key words: *Malus sylvestris*, Mill., Erger, bud break, chilling accumulation, fruit quality and yield

Corresponding author: Burhanettin İmrak, Department of Horticulture Research and Experimental Center, Faculty of Agriculture, University of Çukurova, 01330, Balcalı, Adana, Turkey, e-mail: bimrak@cu.edu.tr

INTRODUCTION

Apple is one of the most economical deciduous fruit crops in Turkey. Apples are grown in many regions of Turkey but approximately 50% of all commercial apple production comes from three provinces; Isparta, Karaman and Nigde. These provinces are located in the southern part of Central Anatolia and the Northern Mediterranean Regions. Commercial apples are also grown in Antalya, Eregli, Denizli, Yalova and Amasya [Tüik 2014].

In apple production of Turkey, 90% of the production is consumed as fresh, 5% is processed into juice, canned products, vinegar or dried products. Turkey took 3rd place in the world apple production while apple exportation was at the 16th place in the world [FAO 2013]. The main reason for low apple exportation is the use of old apple varieties which are not exportable anymore [Küden and İmrak 2014]. Apple exportation of the country could be increased by using high chilling requirements new varieties.

Fruit trees require a certain number of chill hours or chill units. This is very important for both pome and stone fruits grown in subtropical climates to satisfy their winter chilling requirements [Erez 2000].

Winter chill is essential for most of the plants that fall dormant in the winter in order to break their dormancy. In some areas with low chilling duration, such as tropical locations, production is only possible under certain conditions by using effective cultural applications, such as using low chill cultivars, evaporative cooling, dormancy avoidance and using dormancy break agents [Rai et al. 2015].

Many fruit cultivars and species require cold temperatures during winter, and warm temperatures to break endodormancy [Blandier et al. 1999, Bound and Jones 2004, Khün et al. 2009]. The effective temperatures to accumulate chilling requirements have been reported to range from 0°C to 7°C. Temperatures lower than 0°C or higher than 7°C are not effective in this respect [Javanshah et al. 2006]. Fruit trees develop their vegetative and generative buds in summer and in winter, already developed buds go dormant in response to both shorter day lengths and cooler temperatures [Byrne and Bacon 1996].

In recent years, global warming and climate change affect almost all countries' fruit growing. İn addition, it causes loss of vigour, reduces fruit bearing ability, reduces size of fruits, produces less juice content, results in low colour, reduces shelf-life and increases the attack of pests resulting in the low yield and poor quality of some apple varieties [Jangra et al. 2013].

When chilling requirements are not completely fulfilled, trees display irregular and temporally spread out flowering, leading to anomalous growth and inhomogeneous crop development. Many farmers cultivate apple varieties without knowing their chilling requirements which results in several problems, such as irregular flowering and growth, low yield, small fruit size and fruit shape deformity [Ameglio et al. 2004].

A major problem in the cultivation of most deciduous fruit trees in subtropical regions is the lack of chilling hours to break bud dormancy, unless the trees were exposed to sufficient chilling in winter. Dormancy breaking agents must be applied to break bud dormancy [Dorenboos et al. 1953]. Up to now, to overcome such problems, many chemicals have been used to induce bud break of deciduous fruit trees in areas with

insufficient chill units. Hydrogen cyanamide (Dormex), potassium nitrate (KNO_3) and mineral oil have a synergistic effect on bud break and some chemical constituents of many deciduous fruit trees [Sagredo et al. 2005, De-Oliveira et al. 2008, Morsi and El-Yazal 2008, Sabry et al. 2011, Seif El-Yazal et al. 2014]. El-Sabagh et al. [2012] stated that dormancy breaking treatments were found to be effective by changing the polyamine and nitrogen amount in buds.

In Egypt, bud break values normally reach 50% and the dormancy-breaking agents (DBA) are applied to the trees to overcome the adverse effect of insufficient chilling years.

Hydrogen cyanamide (Dormex^{TM}) were used to break bud species, responses are usually associated with the action of amino acids and plant hormones [Guevara et al. 2008, Seif El-Yazal et al. 2012].

The most common DBA is Dormex, potassium nitrate, mineral oil, calcium nitrate and thiourea, few studies have measured endogenous hormones and amino acids. On the other hand, many DBA were applied and shown to be the most effective with deciduous fruit trees management [Rufato et al. 2009, Germchi et al. 2010, 2011, Hawerroth et al. 2010, Khayat et al. 2010, Ben Mohamed et al. 2012 a, b, Eshghi et al. 2012].

Couturier et al. [2010] stated that amino acids are the currency of nitrogen exchange between sources and sink tissues in plants, and constitute a major source of the components used for cellular growth and differentiation.

Seif El Yazal and Rady [2012] indicated that nitrogen compounds, including amino acid, were noticed at low levels in buds during dormant stage, but reached maximum levels just prior to bud break. Also recent research has shown that changes in amino acid profiles are associated with buds dormancy breaking [Judd et al. 2010].

Many researchers have been working on the dormancy breaking of apple depending on a very low chilling requirement known as Anna (100 h). Dormex is a commercial product that have been used by many researchers and this chemical had been reported to have the most evident results [Seif El Yazal et al. 2013, 2014]. However, the usage of Dormex is prohibited in Turkey and some other countries because of its carcinogenic effects. Therefore, it became necessary to investigate the alternative chemicals to Dormex for use in breaking dormancy. These substances usually emerge as a commercial products.

Considering all these knowledge and necessity we established the present study, in order to investigate the dormancy breaking effect of Erger together with Dormex and potassium nitrate on Modi apple variety which can't break their dormancy in the warm years.

MATERIALS AND METHODS

This study was carried out for two years (2011–2013). The capacity of Erger (total nitrogen – 15.0%, ureic nitrogen – 6.1%, nitric nitrogen – 5.8%, ammoniacal – 3.1%, water soluble calcium oxide – 4.7%), Dormex (hydrogen cyanamide) and potassium nitrate (KNO3) for breaking of dormancy in buds of 'Modi'^{TM} apple (*Malus sylvestris*, Mill.) trees were noted. The six years old 'Modi' apple trees (*Malus sylvestris*, Mill)

grafted on Malling-Merton M9 rootstock were randomly, uniformly selected for this study during 2011–2012 and 2012–2013 seasons, at the experimental orchards of a private company called ÖZLER in Abdioglu Village in Adana (36°56 12'04"N. 35° 33'53.46"E) at an altitude of 100 m. The selected trees were labeled and sprayed in December 2011 and 2012. Each tree was designed as one replicate and each treatment included twelve trees.

Foliar-spray applications (4 l $tree^{-1}$; twelve trees per treatment) were conducted as follows: for the first treatment, foliage were sprayed with commercial "Erger", molecular weight 42.04 g mol^{-1}, density 1,25 g ml^{-1}, conductivity E.C. -1‰ (m^S cm^{-1}) 0.526 and formulation (Total nitrogen (N): 15.0%; Ureic nitrogen (N): 6.1%, Nitric nitrogen (N): 5.8%; Ammoniacal (N): 3.1%; Water soluble calcium oxide (CaO): 4.7%).

For the second treatment, foliage were sprayed with hydrogen cyanide, commercially known as "Dormex'' (molecular weight 42.04 g mol^{-1} and formulation 49% hydrogen cyanamide, density 1.065 g L^{-1}). The third treatment was the foliar application of 8% (w/v) potassium nitrate [KNO3; containing 13% (w/w) N and 44% (w/w) K]. The fourth treatment was the control-received tap water. All spray treatments were applied (Dormex 4%, KNO3 8%, Erger 6%), on December 15 (45 days before the end of dormancy duration) using 20L Knapsack Sprayer. Triton B [0.1% (v/v)] was added as a wetting agent to each spray solution experimental line.

Phenological observations. Bud break dates were recorded at 50% of bud break in each tree (n = 12) for all treatments. The final fruit set was calculated six weeks after full bloom stage as number of fruits per hundred spur and lateral buds [Westwood 1978].

Calculation of the chilling requirements of the Modi Apple cultivar and the chilling durations in Adana. Different simulation models of winter chill accumulation have been developed which are based on either field observations or controlled temperature experiments. The most widely used models to calculate chill units are as follows: chilling hours model, Utah model and Dynamic model [Linkosalo et al. 2008]. In determination of the chilling requirements of the experimented Modi apple cultivars, cuttings of 25 to 30 cm were taken from 1 or 2 years old shoots every 2 days and put in a water tank to observe endodormancy release dates in the controlled room temperatures (±24°C). Dormancy release was determined when 50% of the buds reached the green tip stage in 21 days [Luedling et al. 2011].

The chilling requirements of the Modi apple cultivar were calculated from daily maximum and minimum temperatures of 24h by using a computer program prepared by Miller and Küden in 1989 according to the Richardson's chill unit, using asymcur curve model [Anderson et al. 1982, Anderson 1987, Küden et al. 1997]. Besides the standard method of hours below 45°F for chilling accumulation, Richardson's chill unit model was also used to calculate the CU of the cultivar and also for the calculation of the chilling durations of the region [Anderson et al. 1987].

Chilling hours <1000 contribute to low yield of poor quality. For breaking dormancy, trees must not only fulfil their chilling requirement but also heat requirement [Campoy et al. 2011].

Pomological analysis and yield. The effects of the dormancy breaking chemicals on fruit quality, weight (gr), length (mm), diameter (mm), firmness (kg/inch^2), fruit yield and yield per unit (kg da^{-1}), were determined. Ham-Held magness-pressure tester of 5–15 inch plunger according to İmrak [2016], total soluble solids (TSS, %) was determined by hand refractometer. Titrable acidity (%) was determined by the titration with 0.1N NaOH [İmrak 2016]. Treatments were applied to increase the total yield and the amount of exportable size of fruits. The study was conducted in ÖZLER fruit packing house and orchards.

Experimentation and data analysis. Experiments were carried out as a complete randomized design. Each treatment consisted of three replicates and each replicate included ten trees. DATA were subjected to ANOVA using SAS 9.0 software. Means comparison were performed by using the LSD test at a significance level of $\alpha = 0.05$.

RESULTS

Bud break and fruit set. According to the results, there were no differences in dormancy breaking (50.5–52.2%) and fruit set rates (89.81–91.22%) of the applications, due to sufficient chilling accumulation during 2011–2012 winter period of Modi apple variety. Therefore, in this period, the effects of dormancy breaking agents on bud break rate and fruit set comparison could not be determined (data not show). On the other hand, chilling accumulation during 2012–2013 winter period was low and the effects of the treatments on bud break rate were obvious. Table 1 shows that all tested substances significantly increased the percentages of floral bud break and fruit-set, while decreasing the percentages of dormant buds in comparison with control trees. In this period, the best results were obtained from Erger treatments with 51.3%. The other treatments results were detected respectively, Dormex (50.2%), KNO_3 (38.2%) and control (33.8%) broke dormancy in lower levels. Similar results were detected from the fruit set value. The highest fruit set was obtained from Erger (87.32%) and Dormex (83.64%) treatments, followed by KNO_3 with 64.85% and control (tap water) with 59.36% (tab. 1).

Table1. Effect of chemicals on bud break and fruit set rates in 'Modi' apple trees

	Bud break rate (%)		Fruit set (%)	
Treatments	2011–2012	2012–2013	2011–2012	2012–2013
Erger (6%)	52.2a	51.3a	91.22a	87.32a
Dormex (4%)	51.5a	50.2a	90.90a	83.64b
KNO_3 (8%)	51.3a	38.2b	89.92a	64.85c
Control	50.5a	33.8c	89.81a	59.36d
LSD 5%	2.25	3.85	1.38	3.98

Chilling accumulation and requirement. The chilling accumulation of the experimental area (Abdioğlu village 50 m elevation) was calculated according to the hours below 45°F and CU (Chill Unit). Chilling duration in 2011–2012 period was founded to be sufficient to break dormancy (828 h and 467 CU), while in 2012–2013 winter period chilling accumulation was calculated to be insufficient for release from dormancy (497 h and 357 CU) (tab. 2). In order to calculate the chilling requirements of Modi apple cultivar, the cuttings of 25 to 30 cm were taken from 1 or 2 years old shoots every 2 days and put in a water tank to observe endodormancy release dates at controlled room temperatures of ±24°C during 2011–2012 winter period. Dormancy release was determined when the 50% of the buds reached the green tip stage in 21 days [Weinberger 1950]. It was observed that the cuttings taken on 20th of February in 2012 broke dormancy and chilling requirement of Modi apple variety, calculated as 375 CU and 550 h (tab. 2).

Table 2. Chilling accumulation of the experimental area in 2011–2013 winter periods

Months	2012 (2011–2012 period)		2013 (2012–2013 period)	
	hours below 45°F	chill unit (CU)	hours below 45°F	chill unit (CU)
November	42	38	0	19
December	135	106	119	107
January	209	143	216	123
February	272	129	76	66
March	170	71	86	42
Total	828	467	497	357

Fruit quality (pomological characteristics) and yield. Although there were no significant differences between treatments in terms of fruit weight, the highest fruit weight was observed from control trees due to low fruit set (fig. 1A). In other treatments average fruit weight was determined as, KNO_3 (170.6 g), Erger (160.0 g) and Dormex (163.2 g). Also, no significant differences were observed according to a one-way ANOVA test in terms of fruit diameter (fig. 1 B), firmness (fig. 1 C) and fruit juice pH (fig. 1 E). Fruit firmness changed between 83.77 and 86.88 (fig. 1 N). Fruit diameter was higher in control trees then other treatments with no statistically significant difference. The pH values of fruit juice ranged between 3.7 and 3.8. On the other hand, significant differences were determined in terms of total soluble solids and total acidity according to a one-way ANOVA at a confidence level of 99%. The highest TSS was observed in Erger treatment (17.67%) followed by Dormex (17.00%). The lowest TSS content was obtained from fruits of control (16.00%) treatment (fig. 1D). In terms of total acidity, KNO_3 (7.80%) and control (7.17%) treatments gave the highest results whereas Erger (5.90%) and Dormex (5.93%) were the lowest (fig. 1 F).

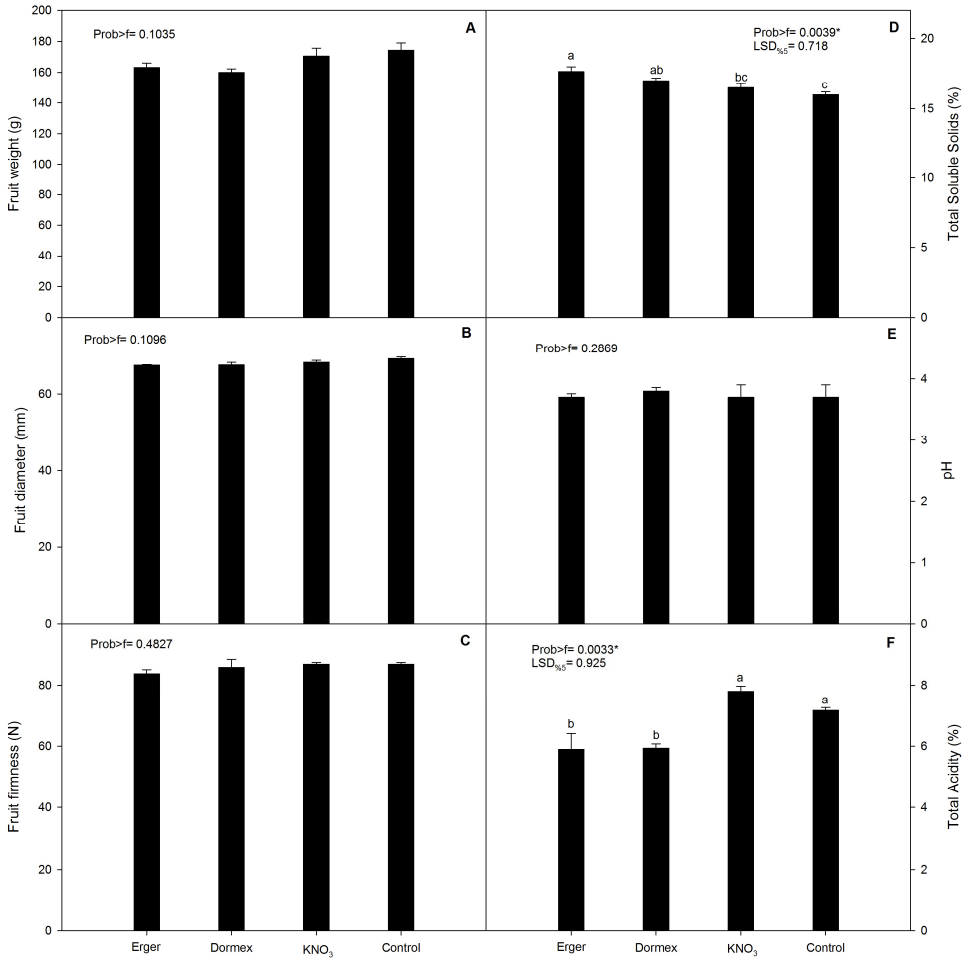

Fig. 1. Effects of applications on fruit quality parameters of Mody Apple. A – fruit weight (g); B – fruit diameter (mm); C – fruit firmness (N); D – total soluble solids (%); E – pH; F – total acidity. The bars show the standard deviation

Average yield was found to be 2480 kg da^{-1}in control group, 2487 kg da^{-1} in KNO_3 and 2541 kg da^{-1} in Dormex. The highest yield was obtained from Erger treatment (2600 kg da^{-1}) comparing with control group, but this increase (120 kg da^{-1}) in yield was not statistically important. However, positive effects of dormancy breaking agents were observed in 'low' chilling period during 2012–2013 winter period and significant increase in yield were also observed (tab. 3). We also compared the effects of the treatments on yield and the lowest yield was obtained from KNO_3 (165 kg da^{-1}) and the highest yield from Erger treatment with 726 kg da^{-1} in 2012–2013. At the same period plants treated with Dormex yielded 664 kg da^{-1} and resulted in higher yield than control

treatment (tab. 3). Applying Erger increased the amount of the exportable quality fruit with 29.30% per acre compared to the control, Dormex (25.60%) and KNO_3 (12.20%), respectively (tab. 2). When we evaluated the effects of the treatments on the yield, in 2011–2012 period no statistically important differences were determined. The average yield value in treatments and control was estimated as 7.3 kg tree^{-1} and 2409 kg da^{-1}. The average yield of exportable quality of fruits (60 mm ≥) was 548 kg da^{-1}.

Table 3. The effects of the applications on the amount of total and exportable fruit quality (2013)

Yield (2012–2013)	Erger (6%)	Dormex (4%)	KNO_3 (8%)	Control
kg tree^{-1}	7.5	7.1	5.8	5.3
kg da^{-1}	2475	2343	1914	1749
Yield increase in comparison with control (kg da^{-1})	726	664	165	–
60 mm ≥ Fruit size (kg da^{-1})	581	543	389	410
Export Quality (kg da^{-1})	1894	1800	1525	1339
Exportable fruit differences comparing the control (kg da^{-1})	555 %29.30	461 %25.60	186 %12.20	

DISCUSSION

Many researchers have examined the effect of chilling on budbreak, but most of these studies have been conducted at higher latitudes or with very low chilling requirement cultivars. Moreover, many different dormancy breaking agents were used and compared. But the most common agent is Dormex.

Chemicals gave positive effects for both bud break and fruit set in low chilling year. El-Sabagh et al. [2012], Williams et al. [2002] and Sagredo et al. [2005] reported that the best results were obtained from Dormex treatment compared with KNO_3 and mineral oil + Dormex treatments to break dormancy in deciduous fruit trees. In our study, Erger (6%) gave better result than Dormex (4%). Similar results were reported by Shaltout et al. [1983] in apricot and plum cultivars. Sagredo et al. [2005] stated that Dormex (4%) and mineral oil (1%) combination gave the best result in dormancy breaking in 'Golden Delicious' apple trees. Seif El Yazal et al. [2012] reported that Dormex was found to be the best effective treatment (4%) in dormancy breaking of Anna apple variety.

Some results are not reliable because they did not calculate the chilling accumulation of experimental area and chilling requirement of the cultivar. Therefore, ın the present study, we calculated chilling accumulation experimental area and requirements of Modi apple cultivar, in order to compare which treatment is better for bud break. Also, Modi cultivar was specially selected since chilling requirements is not very low, such as Anna (100 CU), Vistabella (250 CU).

Kumar et al. [2012] stated that apple varieties having chilling requirement lower than 450 CU were early varieties. According to the results, Modi apple variety was known as a low chilling requirement variety. Chilling requirement of Modi apple variety was found to be similar to the chilling requirements of early apple varieties of Anna,

Golden Dorset, Vistabella, Mondial Gala (100–450 CU) reported by Küden et al. [2007] and İmrak et al. [2009]. Differences depending on the years were similarly reported by Ruız et al. [2007], who studied chilling requirements of three apricot cultivars for 4 years.

Chilling accumulation of the experimental area was sufficient in 2011–2012 winter period and there were no differences between the treatments in terms of phenology, quality and yield values. But the 2012–2013 period gave the real results to compare effects of treatment on dormancy breaking. Erger and Dormex gave the better results for all parameters than the KNO_3 and Control. Also, yield and quality parameters obtained similar result in 2011–2012 period which is the period that has sufficient chilling accumulations. Exportable fruit quantity (kg da^{-1}) was found to be higher, 29.30% with Erger treatment in insufficient chill accumulation period (2012–2013) than the control. The results were found to agree with previous researches about apple fruit quality parameters and yield [İmrak 2016, Özkaya et al. 2006].

Untreated trees (control) with budbreak agents studied showed the lowest yield (kg da^{-1}). The fruit set and yield was greater in all bud break inductors treated trees than in control. The highest yield was obtained from Erger treatment with 2475 kg da^{-1}. The increase of yield was dependent on dormancy breaking agent effect. There was a relation between budbreak intensity and fruit set, also yield. Regarding our results, foliar application with Erger and other substances increased the budburst, fruit set and yield. This result is found to be in agreement with other researches which studied dormancy breaking substance in different apple cultivars [Hawerroth et al. 2010, Seif El-Yazal and Rady 2013, Seif El-Yazal et al. 2014]

CONCLUSIONS

In the present study, we tried to describe if the other chemicals could be used as alternatives to Dormex in Modi apple cultivar without any decreases in fruit yield and quality. As a conclusion, the key results obtained in this study are listed below according to the data recorded in this study.

1. Recently, global warming and climate change affect almost all countries. This effect is seen more seriously under subtropical conditions. In these countries temperate fruits cannot meet their chilling requirements even if the chilling requirements were low. Hydrogene Cyanamide (Dormex) was used as the dormancy breaking agent many years ago and is still being used. However, it was forbidden since it was found to be carcinogenic for human beings. Several alternative commercial dormancy breaking chemicals have been tested until today. Erger is one of these agents. It includes organic materials and was found to be very active/efficient in dormancy breaking experiments in comparison with other dormancy breaking agents especially Dormex.

2. In this study on Modi apple Erger was found to be the best dormancy-releasing chemical. It was followed by Dormex and KNO_3. Erger especially increased the amount of exportable quality fruits (29.30%), advanced earlier bud break, fruit set, fruit quality in Modi apple variety compared with the untreated trees (control) and other applica-

tions. Thus, Erger gave recommendable results compared with the other applications in Modi apple.

REFERENCES

Ameglio, T., Alves, G., Bonhomme, M., Cochard, H., Ewres, F. (2004). Winter functioning of walnut: involvement in branching processes. In: L'Arbre, Biologieet development, Montreal (CAN), Isabelle Quentin, 230–238.

Anderson, J.L., Richardson, E.A. (1987). The Utah chill unit/flower bud phenology models for deciduous fruit: Their implication for production in subtropical areas. Acta Hortic., 199, 45–50.

Anderson, J.L., Richardson, E.A., Kesner, C.D. (1982). Validation of chill unit and flower bud phenology models for 'Montmorency' sour cherry. Acta Hortic., 184, 71–78.

Balandier, P., Bonhomme, M., Rageau, R., Capitan, F., Parisot, E. (1999). Leaf bud endodormancy release in peach-tree evaluation of temperature models in temperate and tropical climates. Agric. Forest Met., 67(1–2), 95–113.

Ben Mohamed, H., Vadel, A.M., Geuns, J.M.C., Khemira, H. (2012 a). Carbohydrate changes during dormancy release in Superior Seedless grapevine cuttings following hydrogen cyanamide treatment. Sci. Hortic., 140, 19–25

Ben Mohamed, H., Vadel, A.M., Geuns, J.M.C., Khemira, H. (2012 b). Effects of hydrogen cyanamide on antioxidant enzymes' activity, proline and polyamine contents during bud dormancy release in Superior Seedless grapevine buds. Acta Physiol. Plant, 34, 429–437

Bound, S.A., Jones, K.M. (2004). Hydrogen cyanamide impacts on flowering, crop load, and fruit quality of red 'Fuji' apple (*Malus domestica*). New Zealand J. Crop Hortic. Sci., 32, 227–234

Byrne, D.H., Bacon, T. (1996). Chilling Accumulation, its importance and estimation. http://aggiehorticulture.Tamu. Edu /Stone Fruit

Campoy, J.A., Ruiz, D., Egea, J. (2011). Dormancy in temperate fruit trees in a global warming context: a review. Sci. Hort., 130, 357–372.

Couturier, J., De Fay, E., Fitz, M., Wipf, D., Blaudez, D., Chalot, M. (2010). PtAAP11, a high affinity amino acid transporter specifically expressed in differentiating xylem cells of poplar. J. Exp. Bot., 26, 1–12

De-Oliveira, O.R., Peressuti, R.A., Skalitz, R., Biasi, L.A., Zanette, F., Costacurtaantunes, M. (2008). Dormancy broken of 'Hosui' pear trees with mineral oil in two training systems. Rev. Bras. Frutic., 30, 409–413.

Doorenbos, J. (1953). Review of literature on dormancy in buds of woody plants. Mededel. Landbouwh. Wagen., 53, 1–23.

El-Sabagh, A.S., Othman, S.A., Abdal, A.N. (2012). Performance of anna apple cultivar grown on two different rootstocks in response to hydrogen cyanamide winter spraying. World J. Agric. Sci., 8(1), 01–12.

Erez, A. (2000). Bud dormancy; phenomenon, problems and solutions in the tropics and subtropics. In: Temperate fruit crops in warm climates, Erez, A. (ed.). Kluwer Academic, Dordrecht, The Netherlands, 17–48.

Eshghi, S., Safizadeh, M.R., Jamali, B., Sarseifi, M. (2012). Influence of foliar application of volk oil, Dormex, gibberellic acid and potassium nitrate on vegetative growth and reproductive characteristics of strawberry cv. 'Merak'. J. Biol. Environ. Sci., 6, 35–38

FAO (2013). Fao Stat. http://faostat.fao.org/site/291/default.aspx. Web Page.

Germchi, S., Khorshidi, B.M.B., Hassan, P.D., Yarnia, M., Faramarzi, A. (2010). Effect of thiourea on dormancy breaking and performance of Agria minitubers in greenhouse and laboratory. J. New Agric. Sci., 18, 65–72

Germchi, S., Behroozi, F.G., Badri, S. (2011). Effect of thiourea on dormancy breaking and yield of potato (*Solanum tuberosum* L.) minitubers Marfona cv. in greenhouse. Int. Conf. Environ. Agric. Eng., 15, 19–24

Guevara, E., Jimenéz, V.M., Herrera, J., Bangerth, F. (2008). Effect of hydrogen cyanamide on the endogenous hormonal content of pea seedlings (*Pisum sativum* L.). Braz. J. Plant Phys., 20, 159–163.

Hawerroth, F.J., Petri, J.L., Leite, G.B., Herter, F.G. (2010). Budbreak in 'Imperial Gala' and 'Fuji Suprema' apples by use of Erger and calcium nitrate. Rev. Brasil. Fruticult., 32(2), 343–350.

İmrak, B., Küden, A., Sarıer, A.K., Küden, A.B. (2009). Apple growing in greenhouse under subtropic conditions. Tabad Res. J. Agric. Sci., 2(1), 187–193.

İmrak, B. (2016). Effects of different colored net cover on 'Galaxy Gala' apple fruit quality and photosentetik Parameters. Altarım, 15(1), 29–38

Judd, M.J., Meyer, D.H., Meekings, J.S., Richardson, A.C., Walton, E.F. (2010). An FTIR study of the induction and release of kiwifruit buds from dormancy. J. Sci. Food Agric., 90, 1071–1080

Jangra, M.S., Sharma, J.P. (2013). Climate resilient apple production in Kullu valley of Himachal Pradesh. Int. J. Farm Sci., 3, 91–98.

Javanshah, A., Alipour, H., Hadavi, F. (2006). A model for assessing the chill units received in Kerman and Rafsanjan areas. Acta Hortic., 726, 221–225

Khayat, M., Rajaee, S., Shayesteh, M., Sajadinia, A., Moradinezhad, F. (2010). Effect of potassium nitrate on breaking and dormancy in strawberry plants. J. Plant Nutr., 33, 1605–1611

Kühn, N., Ormeño-Nuñez, J., Jaque-Zamora, G., Pérez, F.J. (2009). Photoperiod modifies the diurnal expression profile of VvPHYA and VvPHYB transcripts in field-grown grapevine leaves. J. Plant Physiol., 166, 1172–1180

Küden, A., İmrak, B. (2014). Apple growing in Turkey. New approaches in apple and cherry growing and breeding techniques. Workshop book, May, 22–24, Adana, Turkey, 37–41.

Küden, A., Küden, A.B., İmrak, B., Sırış, Ö., Tümer A. (2007). Modern elma ve kiraz yatiştiriciliği entegre projesi (TOGTAG-3064) Sonuç Raporu., 13.

Küden, A.B., Küden, A., Kaşka, N. (1997). Cherry growing in the subtropics proceedings of the fifth ınternational symposium on temperate zone fruits in the tropics and subtropics. Acta Hort. Sci., 441, 71–74.

Kumar, A., Yasir-Mir, M.D. (2012). Assessment of chilling requirement of different varietiess of apple in South Kashmir. Progr. Hortic., 44(1), 84–88.

Linkosalo, T., Lappalainen, H.K., Hari, P. (2008). A comparison of phenological models of leaf bud burst and flowering of boreal trees using independent observations. Tree Physiol., 28, 1873–1882.

Luedeling, E., Brown, P.H. (2011). A global analysis of the comparability of winter chill models for fruit and nut trees. Int. J. Bio. Met., 55, 411–421.

Morsi, M.E., El-Yazal, M.A. (2008). Effect of potassium nitrate, garlic and onion extracts on bud break, growth, yield and some chemical constituents of apple (*Malus sylvestris*, Mill) trees. Fayoum J. Agric. Res. Dev., 22, 82–93.

Özkaya, O., Dündar, Ö., Küden, A. (2006). Effect of preharvest gibberellic acid treatments on postharvest quality of sweet cherry. J. Food Agric. Environ., 4, 189–191.

Rai, R., Joshi, S., Roy, S., Singh, O., Samir, M. (2015). Implications of changing climate on productivity of temperate fruit crops with special reference to apple. J. Hortic., 2, 135. doi:10.4172/2376-0354.1000135

Rufato, L., Kretzschmar, A.A., Brighenti, A.F., Macedo, T.A., Mendes, M.S. (2009). Bud break in different cultivars of apple ilva LC trees in two regions of Santa Catarina State, Brazil. In: XI International Symposium on Plant Bioregulators in Fruit Production. ISHS Acta Hortic. 884. doi: 10.17660/ActaHortic.2010.884.85

Ruiz, D., Campoy, J.A., Egea, J. (2007). Chilling and heat requirements of apricot cultivars for flowering. Environ. Exp. Bot., 61, 254–263.

Sabry, G.H., El-Helw, A.H., Abd El-Rahman, A.S. (2011). A study on using jasmine oil as a breaking bud dormancy for flame seedless grapevines. Rep. Opin., 3, 48–56.

Sagredo, K.X., Theron, K.I., Cook, N.C. (2005). Effect of mineral oil and hydrogen cyanamide concentration on dormancy breaking in 'Golden Delicious' apple trees. South Afr. J. Plant Soil, 22(4), 251–256.

Seif, El-Yazal, M.A., Rady, M.M. (2012). Changes in nitrogen and polyamines during breaking bud dormancy in 'Anna' apple trees with foliar application of some compounds. Sci. Hortic., 136, 75–80.

Seif El-Yazal, M.A, Rady, M.M. (2013). Foliar-applied Dormex^{TM} or thiourea-enhanced proline and biogenic amine contents and hastened breaking bud dormancy in 'Ain Shemer' apple trees. Trees, 27, 161–169.

Seif, El-Yazal, M.A, Seif, El-Yazal, S.A., Rady, M.M. (2013). Foliar-applied dormancy-breaking chemicals change the content of nitrogenous compounds in the buds of apple (*Malus sylvestris* Mill. cv. Anna) trees. J. Hortic. Sci. Biotech., 87, 299–304.

Seif El-Yazal, M.A., Seif El-Yazal, S.A, Rady, M.M. (2014). Exogenous dormancy-breaking substances positively change endogenous phytohormones and amino acids during dormancy release in 'Anna' apple trees. Plant Growth Reg., 72, 211–220

Shaltout, A.D., Unrath, C.R. (1983). Rest completion prediction model for Starkrimson delicious apples. J. Am. Soc. Hortic. Sci., 108(6), 957–961.

Tüik (2014). Turkey Statistical Agency. http://www.tuik.gov.tr/

Weinberger, J.H. (1950). Chilling requirements of peach varieties. Proc. Am. Soc. Hortic. Sci., 56, 122–128.

Westwood, M.N. (1978) Dormancy and plant hardiness. In: Temperate zone pomology. Freeman, San Francisco, pp. 299–319.

Williams, J.G., Maust, B.E., Miller, E.P. (2002). Hydrogen cyanamide accelerates vegetative bud break and shortens fruit development period of Blueberry. Hort. Sci., 37, 539–542.

WPŁYW CZYNNIKÓW CHEMICZNYCH NA PRZERWANIE STANU UŚPIENIA JABŁEK ODMIANY 'MODI' W WARUNKACH SUBTROPIKALNYCH

Streszczenie. Chłód zimowy jest istotny dla większości owoców. Drzewa owocowe wymagają pewnej liczby godzin chłodnych (jednostkek chłodu) każdej zimy, aby wyprodukować owoce następnego lata. Niewystarczająca kumulacja ochłodzenia podczas zimy zwykle powoduje zaburzenia w kwitnieniu oraz zmniejsza plon owoców liściastych drzew owocowych. Okres uśpienia można przerwać przy użyciu środków chemicznych, takich jak Dor-

mex. W ostatnich latach Dormex został zakazany w niektórych krajach, łącznie z Turcją, gdyż stwierdzono jego rakotwórczy wpływ na ludzi. Sytuacja ta wywołała konieczność znalezienia alternatywnych środków chemicznych do zastosowania w subtropikalnych regionach. W tym celu sześcioletnie drzewa jabłoni 'Modi' (*Malus sylvestris*, Mill) zaszczepione na podkładkach Malling-Merton M9 w latach 2011–2013 opryskano 6% Ergerem (całkowity azot – 15.0%; azot mocznika – 6.1%; azot azotanowy – 5.8%; amoniak – 3.1%; tlenek wapnia rozpuszczalny w wodzie – 4.7%), cyjanamidem wodoru 4% (Dormex) i azotanem potasowy 8% (KNO_3), aby przerwać okres uśpienia pąków. Obliczono godziny chłodu poniżej 7°C oraz wartości jednostek chłodu (CU) podczas eksperymentalnych okresów zimowych w warunkach subtropikalnych w Adana (36°56 12'04"N. 35° 33'53.46"E), otrzymując 497 do 828 godzin i 357 do 467 CU. Okres uśpienia pąków jabłoni 'Modi' został przerwany 20 lutego, przy kumulacji 375 CU i 550 godzin. Badano wpływ środków przerywających uśpienie na pąki, zawiązki i jakość owoców. Erger zdecydowanie przyspieszał pękanie pąków i zwiększał ostateczne zawiązywanie owoców oraz plon w porównaniu z innymi środkami i z kontrolą.

Słowa kluczowe: *Malus sylvestris* Mill., Erger, pękanie pąków, kumulacja chłodu, jakość i plon owoców

Accepted for print: 26.09.2016

For citation: İmrak, B., Küden, A.B., Küden, A., Sarıer, A.K., Çimen, B. (2016). Chemical applications affected dormancy breaking in 'Modi' apple cultivar under subtropical conditions. Acta Sci. Pol. Hortorum Cultus, 15(6), 265–277.