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Suitability of Hydrogen Cyanamide + Oil Application for Dormancy Overcoming in 'Early Maycrest' Peach in a Warm-Winter Climate

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Summary

Dormancy-breaking chemical agents are usually used to compensate insufficient chill accumulation that may cause severe production problems in fruit crops. In this study we evaluated if the application of Dormex® and winter oil is efficient and suitable to enhance dormancy release in a southern Spain location. The treatment was tested at different phenological stages in the low chill peach 'Early Maycrest' (*Prunus persica* L. Batsch). Blooming and harvest times as well as blooming and fruit set percentages were evaluated during two consecutive years. The source of temperatures used to calculate chill accumulation (expressed as hours below 7 °C, Utah Model and Dynamic Model), obtained either from shade or sun, was also discussed. Trees were treated at two different phenological stages: ca. 50 % and ca. 75 % of the chilling requirements (CR) of the cultivar. The chill accumulated under field conditions was markedly different between years. The treatments only brought forward harvest time by 2 and 3 days in 2007 and 2008, respectively. However, no significant differences were found between different moments of application with regard to blooming and harvest dates and blooming and fruit set percentages. Also, no significant differences in blooming and fruit set percentages were found between the treated and control trees. The application of this treatment in extra-low-chill peach cultivars in our climatic conditions is not recommendable unless done after exceptionally warm winter conditions not fulfilling cultivar CR.

Key words. blooming – dormancy release – Dormex® – fruit set – *Prunus persica* L.

Introduction

Dormant temperate trees have a chilling requirement (CR) satisfied by exposure to low temperature (Samish 1954). CR and blooming date have been proved to be highly correlated (Ruiz et al. 2007). High prices are usually paid for the early season temperate fruits produced in warm climates. However, in mild winter areas where early-ripening temperate fruits are usually grown, CR is usually not adequately satisfied.

Hydrogen cyanamide + oil and dormancy overcoming

The application of dormancy-breaking agents can partly compensate for insufficient chill accumulation (Erez 1987). Although the physiological processes related to dormancy still remain unclear, a group of chemical products has been identified, either by chance or trial-and-error, to have a positive effect on dormancy overcoming when applied correctly. Hydrogen cyanamide has been reported to be an effective dormancy-breaking agent for peaches and nectarines (Erez 1987; Dozier et al. 1990; George et al. 1992; Lloyd and Firth, 1993), which, in combination with mineral oil, also shows a significant influence on dormancy release. Nevertheless, gaps remain regarding not only the physiology of the action of hydrogen cyanamide, but also regarding its application.

Chilling requirements and models

Knowing the CR of cultivars is crucial to the correct application of chemical breaking agents. It is generally indicated that the applications of chemical breaking agents should be accomplished when about two-thirds of the CR has been satisfied (Erez 2000). However, there are different models to measure chill accumulation which might induce changes in the date of accumulated CR threshold. The most used models are: hours below 7 °C (Weinberger 1950); the Utah Model (Richardson et al. 1974); and the Dynamic Model (Fishman et al. 1987). The Dynamic Model has been considered as the most accurate to predict rest completion in peach in warm winter areas due to the negation of high temperatures and the synergistic effect of moderate temperatures (Linsley-Noakes and Allan 1994). Apart from the variability associated with the use of the different models, the amount of accumulated chill can be highly influenced by direct solar radiation, especially in warm climates with clear skies during autumn-winter. Thus, chill accumulation calculated with sun or shade might differ by more than 20 % (Campoy et al. 2010). These differences can imply different application dates of dormancy-breaking chemicals with possible implications in the efficiency or phytotoxicity of the treatment. In extra-low-chill cultivars, such implications might be even more acute due to the narrower period

when chill is accumulated. Another question that should be clarified, for both its economic and practical relevance, is where the limit is for applying these treatments with a beneficial effect, in terms of date, the level of CR of the cultivar and the chilling accumulation of the area.

In this study we evaluated the efficiency and suitability of Dormex® and winter oil applied at different phenological stages in 'Early Maycrest' peach in warm winter climatic conditions. Blooming and harvest times as well as blooming and fruit set percentages were evaluated. The source of temperatures used to calculate the chill accumulation (expressed as hours below 7 °C, Utah Model and Dynamic Model), obtained either from shade or sun, was also discussed.

Material and Methods

Plant material

One block per treatment, with ten seven-year-old 'Early Maycrest' peach (United States Patent PP06229) trees each, was selected in 2006. All trees were cultivated in the same orchard (South-Eastern Spain: 38° N latitude, 1° W longitude and 150 m altitude) according to habitual peach orchard management. Trees were drip-irrigated with a planting distance of 4.75 m×4 m. The CR of 'Early Maycrest' peach in this area had been previously calculated following the protocol described in Ruiz et al. (2007). Fresh weight and phenological stage of flower buds were monitored until a predetermined threshold is reached. When this threshold is achieved dormancy is considered to be released. Based on two years of data, an average value of 18.85 Chill Portions (Dynamic Model, Fishman et al. 1987) was determined as the CR of 'Early Maycrest' peach.

Treatments

The experiments were conducted from autumn to spring during two consecutive years (2006–2007; 2007–2008). Blocks of 10 trees each were selected for the treatments. Treatments consisted of an application of 20 g L^{-1} of Dormex® (49 % hydrogen cyanamide) and 10 g L^{-1} of 'Oil Oro Invierno'® winter oil (83 %) at different levels of chill accumulation. The treatment date was chosen taking into account the time at which 50 % and 75 % of the chilling requirement (18.85 Chill Portions) had accumulated. Treatment 1 was applied on 13 December 2006 and on 6 December 2007, when ca. 10 Chill Portions had accumulated. Treatment 2 was applied on 19 December 2006 and on 18 December 2007, when ca. 14 Chill Portions had accumulated. In order to increase the accuracy of the phenology estimate through chilling accumulation, sun temperatures were used.

Temperature measurement and chilling accumulation

Shade air temperatures were collected hourly with Escort Junior automatic data-loggers (Escort Data Logging Systems) situated in a meteorological station in the field. Sun air temperatures were recorded each hour with TMC50-IT-A sensors and recorded with the HOBO U12 data-logger (Onset Computer Corporation, Massachusetts, USA).

Determination of blooming percentage, blooming date, fruit set, and ripening cycle

Three two-year-old branches per tree were chosen in each treatment. The total number of flower buds per branch was measured. Later, the number of flowers developed was recorded and expressed as a percentage of the total number of flower buds on those branches (blooming percentage). Blooming date was established as F50, when 50 % of flowers were open. One month after bloom, fruit set percentage (number of fruits per total remaining flowers) was calculated. Also, to determine the productivity in the different treatments, fruit set was calculated as the number of fruits per total number of flower buds (fruit/bud). Due to the high level of uniformity in each treatment, blooming and ripening dates were determined per treatment instead of per tree. The ripening cycle was determined as the number of days from F50 to harvest.

Statistics

Statistical analytical procedures were performed using the PASW Statistics 18 software for Windows (Chicago, IL). Differences concerning blooming, fruit set and fructification percentage (fruit/bud) were analyzed by ANOVA. Pearson correlation coefficients were determined.

Results

Temperature, model and chilling accumulation

The winter climatic conditions showed considerable variations between the two years studied (Fig. 1, Table 1). The late autumn and early winter of 2006–2007 were characterized by relatively high temperatures, especially in November, which delayed the onset of chill compared to 2007–2008. In 2007–2008, from December on, a normal accumulation was observed. Comparing the different models used, the delay in the onset of chilling accumulation was similar in the three models when sun temperatures where used (Fig. 1). However, when shade temperatures where used, the differences between years using the Dynamic Model were considerably minimized (Fig. 1A) in comparison to when sun temperatures were used (Fig. 1B). Sun hours were similar in 2007–2008 and 2006–2007, except in November, when the number of sun hours was 225 and 178 in 2006 and 2007, respectively. Total chill accumulation was reduced when using sun temperatures in the Utah and Dynamic Models. No important effect was found over the total chill accumulation using hours below 7 °C.

Blooming percentage, blooming date, fruit set, and ripening cycle

Application of the treatments 1 and 2 forwarded blooming time by 4 days in comparison to the control, while in 2008 blooming time was the same in both treatments and the control (Table 2). The greater the chill accumulation, the smaller was the precocity effect achieved by the application of Dormex® and winter oil in comparison to the control. No difference in blooming time was observed between the two treatments in either of the years studied.

No differences in blooming percentage were recorded between the two treatments and the control. However, in

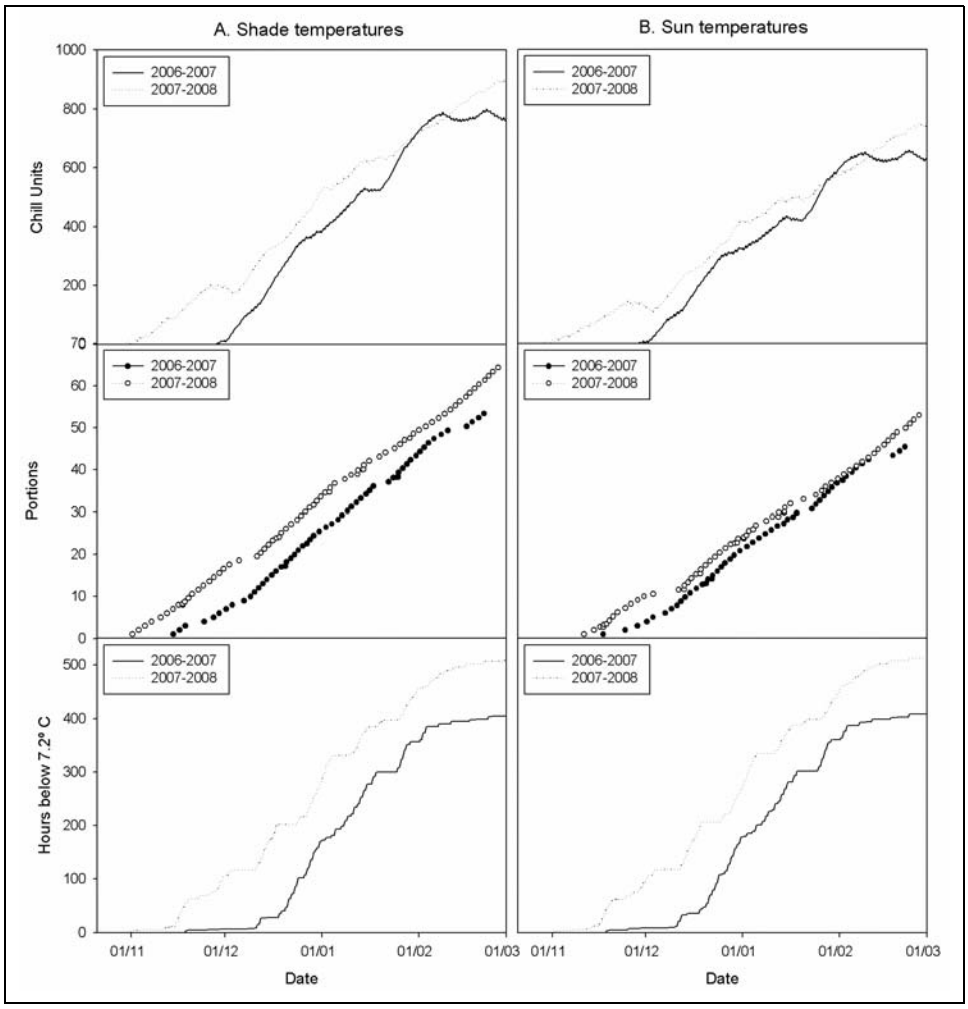


Fig. 1. Progression of chill accumulation in the period November–March in Campotéjar (Spain) between 2006 and 2008. Results are expressed in Chill Units (Utah Model) (above), Chill Portions (Dynamic Model) (centre) and hours below 7 °C (Hours-below-7 °C-Model) (below). Chill accumulation was calculated from shade temperatures (left) and sun temperatures (right).

2006–2007, all treatments gave a blooming percentage significantly higher than in 2007–2008.

No significant differences in fruit set percentage were found among treatments in either year studied, whereas the percentage was significantly lower in 2006–2007 than in 2007–2008. However, fruit/bud percentage neither showed significant differences between years nor among treatments and control, except in treatment 1 in 2006–2007 in comparison to 2007–2008. The harvest date was similar in 2006–2007 and 2007–2008 despite the difference in chilling accumulation (Fig. 1). In 2006–2007 and 2007–2008, treatments 1 and 2 were harvested on the same date. However, earlier harvest dates were obtained in treatments 1 and 2 in comparison to the control in 2006–2007 and 2007–2008 with two and three days respectively.

In 2006–2007, the ripening cycle was similar among treatments and control, but considerably shorter than in 2007–2008 (Table 2). The ripening cycle of the control was one day shorter than that of treatments 1 and 2 in

Table 1. Chill accumulated in Chill Units (Utah Model), Chill Portions (Dynamic Model) and hours below 7 °C (Hours-below-7 °C-Model) at the treatment date. Chill accumulated was calculated with sun and shade temperatures.

Treatment	Date of application	Sun temperatures			Shade temperatures		
		Chill Units	Chill Portions	H<7 °C	Chill Units	Chill Portions	H<7 °C
2006–2007							
1	13/12/2006	60.5	8.84	33	83.5	13.04	27
2	19/12/2006	115.5	12.80	48	151.5	17.02	41
2007–2008							
1	06/12/2007	140.5	10.50	118	201.5	18.60	117
2	16/12/2007	183.5	14.27	176	239.5	23.31	184

Table 2. Blooming date (F_{50}), blooming percentage, fruit set percentage, fruit/bud percentage, harvest date and ripening cycle per treatment and year.

Treatment	Description	F_{50}	Blooming[1] (%)	Fruit set[1] (%)	Fruit/Bud[1] (%)	Harvest date	Ripening cycle (days)
2006–2007							
Control		10/02/2007	92.37 aA	76.55 aB	70.66 aA	14/05/2007	93
1	Dormex®+Oil (≈50 %[2])	06/02/2007	96.14 aA	79.38 aB	76.09 aA	11/05/2007	94
2	Dormex®+Oil (≈75 %[2])	06/02/2007	92.71 aA	81.60 aB	75.89 aA	11/05/2007	94
2007–2008							
Control		21/01/2008	81.26 aB	87.80 aA	70.82 aA	11/05/2008	112
1	Dormex®+Oil (≈50 %[2])	21/01/2008	77.88 aB	88.02 aA	68.57 aB	09/05/2008	109
2	Dormex®+Oil (≈75 %[2])	21/01/2008	84.32 aB	88.92 aA	74.95 aA	09/05/2008	109

[1] Means followed, designated by different lower case letters within the same year and by the different capital letters within the same treatment, differ significantly (P<0.05) according to Tukey-b test.
[2] Chilling requirements fulfilled in field conditions at the date of treatment application according to Dynamic Model.

2006–2007, and was 3 days longer than treatments 1 and 2 in 2007–2008.

Discussion

Temperature, model and chilling accumulation

Climatic data showed noteworthy differences between years. The 2007–2008 winter could be considered as an average year in relation to the chill accumulated, while 2006–2007 was a warm year. A very warm, late autumn occurred, which led to a lower and delayed chilling accumulation. The difference in chill accumulation between years was lower when the Dynamic Model was used in comparison to the Utah Model or hours below 7 °C. This result agrees with previous studies carried out in Mediterranean climates (Ruiz et al. 2007; Luedeling et al. 2009; Viti et al. 2010; Campoy et al. 2011). Additionally, Luedeling and Brown (2011) suggested that the Dynamic Model is the most-robust and transferable unit for most growing regions. Chill accumulation differences between years were substantially reduced when sun temperatures were used in comparison to shade temperatures. The higher number of sun hours in November 2007 was associated with higher maximum temperatures (above 16 °C) that negate the chill temperatures accumulated at night. When shade temperatures were used, a significant percentage of high temperatures were reduced to moderate temperatures (12–15 °C), turning the negative effect of high temperatures into a synergistic effect in combination with low night temperatures (Couvillon and Erez 1985). This effect of shading has been used in agriculture to reduce the negative effect on dormancy overcoming in peach (Buchanan et al. 1977) and apricot (*Prunus armeniaca* L.) (Ruiz et al. 2005; Campoy et al. 2010). In spite of the higher accumulation of hours below 7 °C in 2007, higher solar radiation reduced the accumulation of Chill Portions. These results show the high variability associated with chill accumulation assessment. This variability can be crucial for the correct application of dormancy-breaking agents, whose effectiveness and phytotoxicity highly depend on the phenological state of the plant. The model and the nature of the data used may involve significant differences in the application date of these treatments. A premature application can render the treatments useless, whereas a late application can result in severe phytotoxic problems in the crop (Erez 2000). The variability associated with the use of either sun or shade temperatures is even greater in areas with high solar radiation during winter.

Effects in blooming percentage, blooming date, fruit set, and ripening cycle

The earlier chill accumulation achieved in 2007–2008 was not associated with higher blooming percentage. In 2006–2007, the year with the lowest chilling accumulation, blooming percentages were significantly higher than in 2007–2008 (Table 2). These results are not in accordance with previous results. Erez (1987) noted that chilling deficiency leads to poor-uneven bud break, poor foliage and abnormal flowers, resulting in poor fruit set, reduced leaf area and early growth cessation. In addition, it has been indicated that the moment at which chill requirements are fulfilled might be important in apricot (Campoy et al. 2010). The considerably lower CR of the studied peaches in comparison to the apricot might explain this difference.

The later chill accumulation in 2006–2007 delayed blooming-time in comparison to 2007–2008. Thus, treatments 1 and 2 were effective in advancing blooming time with respect to that of the control. Dormex® complemented part of the marginal chilling accumulated in field conditions. However, in 2007–2008, chill accumulation was higher and no effect of Dormex® and oil was found in any of the applications done. Control and treatments 1 and 2 bloomed at the same time. The lower fruit set percentage observed in 2006–2007 appears to be associated with the higher blooming percentage obtained in that year, as the fruit/bud rate was the same in the control in both years. These results contrast with the fruit set problems found in apricot in a year with late and insufficient chill accumulation in this area (Viti et al. 2010). On the other hand, Dormex® and oil treatments neither increased fruit set

nor the fruit/bud rate in either of the years. Additionally, treatment 2 showed a lower fruit/bud rate in 2008. These results showed the inefficiency of these treatments to increase blooming and fruit set percentages, uniformity and productivity. These results are not in accordance with previous works with hydrogen cyanamide in apple (*Malus domestica* Borkh) (Jackson and Bepete 1995; Costa et al. 2004); peach (Erez 1987; George et al. 1992; Siller-Cepeda et al. 1992; Lloyd and Firth 1993); and apricot and plum (*Prunus domestica*) (Son and Kuden 2005). The higher chill accumulation and the low CR of the cultivar can explain this different result. However, both treatments 1 and 2 advanced the harvest date in both years. This increase in precocity was considerably lower than that obtained in previous works (Lloyd and Firth 1993). The higher chill accumulation achieved in our area in comparison to subtropical Australia in addition to the different genotype used might explain this difference.

This difference was higher the lower the chill accumulated. As for the ripening cycle, the higher temperatures registered in spring 2007 accelerated ripening in comparison to 2008. No differences between treatments were found in either year. Contrary to expected results, control showed a shorter ripening cycle (1 day) compared to the treatments in 2006–2007, whereas the ripening cycle was longer in 2007–2008 (3 days). The lower chill accumulation in 2006–2007 together with the treatments did not shorten the ripening cycle in comparison to control. A positive effect on leafing, and subsequently on reduction of the ripening cycle, was expected, yet only occurred in the year with more chill accumulation, 2007–2008.

Almost no differences were found among the application of treatments at diverse phenological stages, measured by chill accumulation. This disagrees with previous findings. Nee and Fuchigami (1992) noted that the effectiveness of hydrogen cyanamide in overcoming rest is dependent on the growth status of the buds.

The reduced effect over the different parameters studied calls into question the annual application of these products in low-chill peach cultivars in the area studied or in warm areas with similar chill accumulation. A monitoring of chill accumulation is recommended before the application of Dormex ® and oil, which is advisable only in years with insufficient chill accumulation. These treatments could be done principally in order to accelerate harvest date, as no positive effect in productivity has been found in our experiment conditions. Thus, the initial assumption on which the work was based is rejected.

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