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EFFECTIVE HYDROGEN CYANAMIDE (DORMEX®) APPLICATION FOR BUD BREAK, FLOWERING AND NUT YIELD OF PISTACHIO TREES CV. MATEUR IN WARM GROWING AREAS

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SUMMARY

Climate change characterized by global warming is expected to have an incidence on fruit trees' development and production. The severity of these effects depends on lack of chilling. The current study focused on the research of an optimal dose of hydrogen cyanamide (Dormex®) treatment which can advance the bud break of female pistachio trees (*Pistacia vera* L.) to ensure better blooming synchronization with pollinators. A field experiment was conducted in northern Tunisia (36°49′N, 9°48′E) on mature pistachio trees. Two hydrogen cyanamide treatments at 2% and 4% Dormex® were applied with reference to the control untreated trees. The flowering time, vegetative growth, starch content, productivity and nut characters were followed. Results show that 4% Dormex® advanced the normal bud break by 15 days and flowering by 11 days and improved natural pollination by synchronization of male and female flowers. Consequently, fresh yield and nut quality as split and blank rates and nut weight were improved. However, shoot growth, leaf area and starch content in current shoot seemed unaffected by hydrogen cyanamide applications. In conclusion, hydrogen cyanamide could be used as 4% Dormex® and sprayed 45 days before bud break to improve pistachio productivity and prevent anomalies of lack of chilling due to global warming that could be more frequent in the Mediterranean areas.

INTRODUCTION

In a mild winter climate like that of the Mediterranean region, flowering and cropping of fruit trees depended highly on winter chill (Campoy *et al.*, 2011; Viti *et al.*, 2010). Fruit tree cultivars have specific genetic chilling requirements to break dormancy (Alonso *et al.*, 2005; Egea *et al.*, 2003; Ruiz *et al.*, 2007). Lack of chilling in warm winter regions results in abnormal patterns of bud break and development in fruit trees (Ben Mimoun, 2008; Campoy *et al.*, 2012; Crossa-Raynaud, 1955; Erez, 1987, 1999; Erez and Couvillon, 1987; Legave *et al.*, 1982; Viti *et al.*, 2010). Several dormancy-breaking agents were used to stimulate bud break of deciduous fruit trees in warm areas lacking sufficient chilling accumulation (Campoy *et al.*, 2010; Jackson and Bepete, 1995; Mohamed, 2008; Seif El-Yazal and Rady, 2012; Theron *et al.*, 2011). The agents included growth regulators, gibberellins, cytokinins mineral oils and potassium nitrate. However, hydrogen cyanamide (Dormex®) is considered as an efficient solution for

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breaking dormancy and having synergistic effect on bud break, flowering, yield and fruit quality (Bartolini *et al.*, 1997; Erez, 1987; Jackson and Bepete, 1995; Seif El-Yazal and Rady, 2012).

The rest-breaking effect is both dosage- and time-dependant, with stronger effects at higher concentrations and later applications (Erez and Lavee, 1974). Timing of application of cyanamide cannot be safely done as in the case of oil–dinitro-o-cresol (DNOC), but should be allowed 30 days before bud swell (Erez, 1995). George *et al.* (1992) found that early applications of cyanamide on peach are usually more effective in advancing floral and vegetative bud break than applications closer to normal blooming. High concentrations of cyanamide on stone fruit species lead to a marked advancement of leafing over bloom, which may have negative effects on fruit set due to sink competition (Erez, 1995). Erez (1987) discourages applications of cyanamide within less than four weeks of bud swell, especially where maximal level of bloom is desired as in the case of small fruits and nuts. The range of 2–4% Dormex® was successfully applied on many fruit trees (Bartolini *et al.*, 1997; Erez, 1995; Shulman *et al.*, 1986).

Pistachio (*Pistacia vera* L.) is a main nut crop well adapted to severe conditions. It is widely planted in arid and warm regions of Tunisia. Such conditions make the trees exhibit reduction and irregularity in opened flower and vegetative buds. Incompletely developed leaflets and leaves with a reduced number of leaflets and extremely poor pollen production by male inflorescences were the symptoms produced by pistachio trees in response to insufficient chill (Crane and Takeda, 1979). Moreover, failed synchronization between flowering periods of male and female genotypes was noted in the main pistachio production zone and led in part to low productivity (Ghrab *et al.*, 2002, 2008). Yield production of pistachio tree cv. Mateur seemed to be highly correlated to chilling accumulation in the arid Mediterranean climate of Tunisia, as lack of chilling threatened pistachio productivity (Elloumi *et al.*, 2013).

The evaluation of rest-breaking agents on pistachios was studied by several authors. Procopiou (1973) proved that the oil–DNOC combination could be successfully used on pistachios to improve bloom. Pontikis (1989) used hydrogen cyanamide in a four-year study, where he reported similar yield reactions. Küden *et al.* (1995) found that Armobreak and cyanamide combinations showed the best improvement in the bud break of both vegetative and flower buds of three pistachio cultivars. Beede and Ferguson (2002) found that mineral oil applications showed the greatest advancement in vegetative growth, bloom and rate of kernel filling. Recently, Rahemi and Asghari (2004) showed that volk oil and hydrogen cyanamide, as well as their combinations, can be successfully used for pistachio trees to advance blooming and increase kernel weight, lateral bud break as well as percentage of flower buds developing into fruit clusters. They attributed this increase in yield entirely to improved synchronization of male and female flowers.

The effectiveness of application of rest-breaking agent was related to climatic conditions, mainly the amount of chill accumulated before winter oil treatment (Fuchigami and Nee, 1987; Zhang and Taylor, 2011). Time of application seemed to highly affect these results (Lloyd and Firth, 1993; Nee and Fuchigami, 1992; Wood, 1993). Bound and Jones (2004) found that hydrogen cyanamide advanced flowering when applied 30 or 40 days before the estimated bud burst.

This research focused on the effect of hydrogen cyanamide (Dormex®) on bud break, shoot growth and yield in pistachio trees cv. Mateur in warm production regions and to determine the most effective concentration of Dormex® applied 40 days before the estimated bud break.

MATERIAL AND METHODS

Plant material and experimental field

The field experiment was conducted in the region of M'Hamdia (36°49′N, 9°48′E) in northern Tunisia. The production area was characterized by the semi-arid Mediterranean climate with mild winter. The annual average rainfall and reference evapotranspiration (ETo) was 439 and 1250 mm, respectively. The soil is silty-clay, saline and poor in organic matter. Chilling accumulation was calculated as chill unit (CU) according to Utah model (Richardson *et al.*, 1974). Average chilling accumulation was about 535 CU with extreme values of 294 and 805 CU. During the experimental study, winter chill accumulation was 696 CU.

Fifteen-year-old pistachio trees cv. Mateur planted at 5 m × 7 m spacing and grafted on *Pistacia vera* were used. Pest control and fertilization practices were the same as used commonly by pistachio growers, and no weeds were allowed to develop within the orchard.

Hydrogen cyanamide (Dormex®) treatments

The chemical rest-breaking agent Dormex® was evaluated on pistachio trees cv. Mateur. The following three treatments were investigated: (i) an untreated control; (ii) 2% Dormex® and (iii) 4% Dormex®. The hydrogen cyanamide treatments were carried out by spraying on the whole tree in combination with an adjuvant Agral. Treatment application was done approximately 45 days before bud break (February 23). The experimental design consisted of three blocks and four trees per treatment in each block.

Measurements

Four one-year-old shoots per tree distributed over four cardinal points were marked during dormancy. The four selected one-year-old shoots were evaluated in terms of bud break and flowering percentage, number of new shoots, new shoot length and leaf area. The fruit drop was estimated by determining the fruit-set and the final fruit number per cluster at harvest. The number of clusters per tree was determined. At harvest, the fresh nut yield was measured separately for each tree. Nut weight and split and blank rates were determined on three samples of 100 nuts per tree.

For starch analysis, current shoots were sampled during dormancy one year after Dormex® treatments and oven-dried at 70 °C for 48 h and then crushed separately. Starch content was determined following Nielson's (1943) method, modified by Pesis *et al.* (1978).

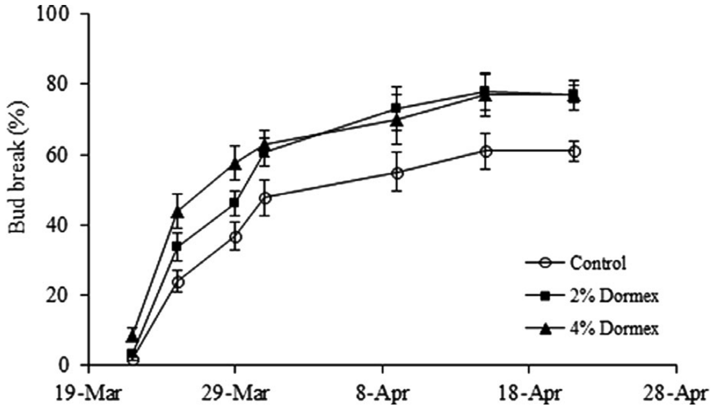

Figure 1. Bud break rate (mean ± SE) of pistachio tree cv. Mateur in response to hydrogen cyanamide treatments (2% and 4% Dormex®).

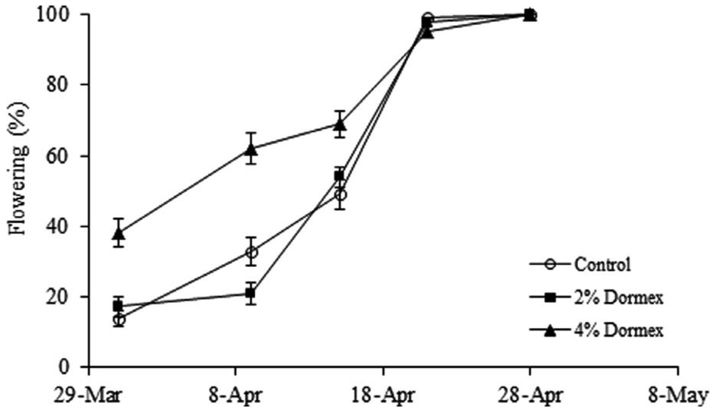

Figure 2. Flowering rate (mean ± SE) of pistachio tree cv. Mateur in response to hydrogen cyanamide treatments (2% and 4% Dormex®).

Data analysis

Data collected were subjected to analyses of variance, and treatment means were separated by Duncan's multiple range tests ($p < 0.05$) using the SPSS software program.

RESULTS

Bud break and flowering

The effects of hydrogen cyanamide treatments on bud break and flowering of pistachio trees cv. Mateur were consistent (Figures 1 and 2). Hydrogen cyanamide application (4% Dormex®) advanced the average date of bud break, and 50% bud break was reached on March 29th compared with April 13th for the control (Figure 1). Moreover, the hydrogen cyanamide treatments (2% and 4% Dormex®) significantly increased the percentage of floral bud break by 20% compared with the control with a maximum rate of 80% (Figure 1).

Table 1. Vegetative growth and starch content in one-year-old shoot monitored under different hydrogen cyanamide treatments.

	Shoot number	Shoot growth (cm)	Leaf area (cm^2)	Starch content (mg g^{-1} DW)
Control untreated	2.79*	11.73*	52.7*	7.2*
2% Dormex®	2.92*	12.94*	60.6*	7.6*
4% Dormex®	3.50*	13.18*	53.2*	7.9*

*Mean values within columns are not significantly different according to Duncan's test at $p < 0.05$.

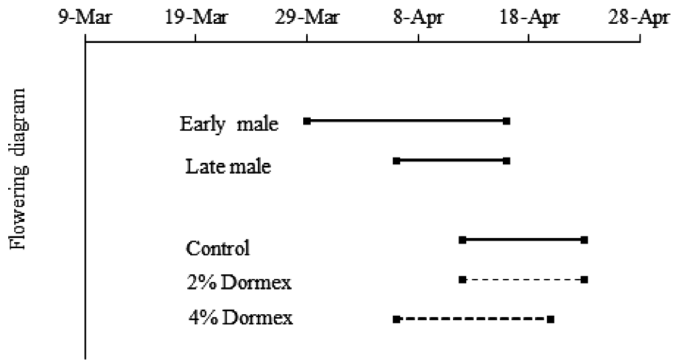

Figure 3. Flowering diagram of male pollinators and female tree cv. Mateur under hydrogen cyanamide treatments (2% and 4% Dormex®).

The phenological observation revealed a positive effect of hydrogen cyanamide application on flowering of pistachio trees cv. Mateur, mainly with 4% Dormex® (Figure 2). Fifty percent flowering was observed by April 5th and April 16th on the 4% Dormex®-treated trees and the control, respectively. However, 2% Dormex® did not show differences compared with the control. The flowering diagram showed that 70% of the flowering period of female trees treated with 4% Dormex® synchronized with the flowering period of male trees (Figure 3). No synchronization was observed for 2% Dormex® and control, inducing a need for artificial pollination to reach a good fruit set.

Vegetative growth

The application of hydrogen cyanamide induced an insignificant increase of vegetative growth observed for shoot number and length as well as leaf area and starch content of one-year-old shoot (Table 1).

Yield compounds

Application of hydrogen cyanamide led to increase in yield compounds ($p < 0.05$) as compared with the untreated control (Table 2). 4% Dormex® seemed to be an effective treatment that significantly improved the number of clusters per tree, fresh yield and nut quality as split rate.

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Table 2. Yield compound and fruit quality recorded for different hydrogen cyanamide treatments.

	Rate of fruit fail	Clusters tree^{-1}	Yield (kg tree^{-1})	Blank rate	Split rate
Control	0.40*	32†	0.95†	0.12*	0.22‡
2% Dormex®	0.46*	36†	0.90†	0.09*	0.30†
4% Dormex®	0.51*	55*	1.65*	0.12*	0.38*

Mean values shown with different symbols within columns are significantly different according to Duncan's test at $p < 0.05$.

DISCUSSION

The significant effect of hydrogen cyanamide in inducing earlier bud break and flowering with 4% Dormex® treatments is in agreement with previous reports (Erez, 1987; Erez and Lavee, 1974; Rahemi and Asghari, 2004). An advance of 15 days in bud break date was obtained with 4% Dormex® treatment compared with the control trees. Rahemi and Asghari (2004) reported similar results on pistachio with hydrogen cyanamide applied eight weeks before the bud break, and the best results were obtained by combining the concentration of 4% and 7% of Dormex® and volk oil, respectively. Hydrogen cyanamide gave good results on several other fruit species in response to lack of chilling in growing areas with warm winter (Erez, 1987; Jackson and Bepete, 1995; Mohamed, 2008; Theron *et al.*, 2011). An advance in bud break occurred in peach trees treated with 2% hydrogen cyanamide (Dozier *et al.*, 1990). Murisier *et al.* (1990) also showed that spraying grapevine with hydrogen cyanamide resulted in homogenous bud break and prevention of impact of lack of chilling.

Advanced bud break induced earlier flowering, since floral buds in pistachio flowered before the development of vegetative buds (Maggs, 1973). The hydrogen cyanamide application (4% Dormex®) permitted advanced flowering by 11 days in reference to untreated trees and this provided better synchronization of male and female flowers and efficient natural pollination. These results prove that hydrogen cyanamide could be an effective dormancy-breaking agent, which agrees with previous findings (Fuchigami and Nee, 1987; Jackson and Bepete, 1995; Theron *et al.*, 2011). The chances of effective cross-pollination increased greatly by synchronization of flowering, which should have a positive effect on yield potential (Jackson and Bepete, 1995). The beneficial effect of hydrogen cyanamide on flowering time was also confirmed on other fruit trees such as peach (Dozier *et al.*, 1990; Lloyd and Firth, 1993).

The positive effects of hydrogen cyanamide treatments on bud break and flowering were, however, not observed on vegetative growth. The shoot number and length presented insignificant improvement after application of hydrogen cyanamide. Similar results showing no effect of hydrogen cyanamide on vegetative growth were observed for Kiwi (Powell, 1987). However, Rahemi and Asghari (2004) and Dozier *et al.* (1990) found increase in the vegetative growth of pistachio trees in response to 4% Dormex® application.

The application of 4% Dormex® led to an important number of clusters per tree and, consequently, the highest fresh yield. Moreover, there was improvement in fruit quality as the split rate was achieved. These results agree with a previous research, which showed that the treatment with hydrogen cyanamide (4% Dormex®) significantly increased the performance of pistachio compared with the control (Rahemi and Asghari, 2004). Similar results were found with other fruit species such as peach and grapevine (Murisier *et al.*, 1990; Powell, 1987). Jackson and Bepete (1995) found that hydrogen cyanamide applications significantly increased fruit yield in most of the apple cultivars studied.

CONCLUSION

Hydrogen cyanamide (Dormex®) was effective when sprayed as 4% on the pistachio tree cv. Mateur. It increased bud break and flowering, inducing better synchronization with male pollinators and consequently greater chances for effective cross-pollination. When Dormex® was applied in appropriate dose (4%), it significantly increased fresh yield and nut quality. It could be recommended to increase pistachio productivity for the growers in the production areas mainly in warm regions by reducing production cost induced by artificial pollination. The last practice is widely adopted in the pistachio growing areas of Tunisia as a result of heterogeneous material, with no synchronization of male and female flowers from different genotypes. Experiments oriented to test other rest-breaking agents and cultural practices could be interesting with the global warming and climate change projected in the future (Luedeling *et al.*, 2009, 2011). These rest-breaking agents could play a major role in pistachio production in warm regions and during low chill years.

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