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Effects of Dormex (Hydrogen Cyanamide) on the performance of three seedless table grape cultivars grown under greenhouse or open-field conditions

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Abstract. Greenhouse cultivation of table grapes is still limited to some experimental trials at Lebanese coast. One major constraint facing this type of cultivation is the lack of enough chilling hours causing irregular bud-break and yield reductions. Dormex, with Hydrogen Cyanamide as active ingredient, is an effective mean for dormancy release adopted in warm winter regions. The work investigated separate and combined effects of two factors: greenhouse cultivation and Dormex application on vine buds (following winter pruning) on three-year old seedless cultivars (ARRA15, ARRA18, and ARRA19). Control consisted of non-treated plants grown in open-field. Results showed that Dormex application under greenhouse induced budburst uniformity, increased budburst percent (by 60%), number of flowers and fruits per shoot (by 83%) and vine productivity (by 90%) in all cultivars compared to control. Bud formation was increased under greenhouse and was reduced by Dormex treatment. Under greenhouse, elongation of current season shoots was delayed and shoot length was reduced in treated plants, harvest was earlier by 7, 14, and 30 days in non-treated plants of ARRA18, ARRA19 and ARRA15 respectively and full fruit set (100%) occurred for all plants. Dry weight of shoots was improved by Dormex application in both cultivation systems. All ARRA cultivars responded similarly to experimental factors except ARRA 19 under greenhouse where shoot length was enhanced in all plants while bud formation only in treated plants. Finally, treating vine by Dormex under greenhouse was found as efficient tool to improve bud break and advance harvest under the specific Lebanese coastal conditions.

Key words: bud break, greenhouse, Hydrogen Cyanamide, seedless cultivars.

INTRODUCTION

The diversity of micro-climates in Lebanon is an asset for new introduced table grape cultivars which are characterized by a higher productivity compared to local ones. Lebanese farmers are becoming increasingly interested in diversifying into popular seedless cultivars targeting high value local and export markets. However, excess production of such cultivars could negatively affect their prices at local market especially when the quality of products intended for export is affected by inadequate storage facilities (DAI, 2014). Consequently, it is of great practical significance to change the grape growth period and promote the grape to go on the market ahead of time through greenhouse cultivation pattern. According to Qin (2013) under greenhouse yield is higher, quicker and easier to manage compared to open-field cultivation. Also, the fruit is of good quality, and fruit maturity and harvest period can be easily controlled.

Recently, greenhouse cultivation has been rising at Lebanese coast; however it is still limited to some experimental trials and has not yet reached commercial volumes. One major constraint facing this cultivation technique in coastal regions is the lack of enough chilling hours that cause irregular bud-break. When grapes do not receive sufficient winter chilling to release buds from dormancy, a delayed and erratic bud-break may result causing reductions in shoots and clusters number per vine and irregular ripening (Lavee et al., 1984; Hashim-Maguire, 2015). Inadequate winter chilling could also reduce fruit yield and fruit quality (Dokoozlian & Williams, 1995).

There are three successive phases of bud dormancy in grapevines; paradormancy that is regulated by physiological factors within the plant but outside the dormant structure, endodormancy that is regulated by physiological factors within the bud itself and ecodormancy that is imposed by environmental factors after endodormancy release ending when warm temperatures cause ecodormant buds to burst (Balandier et al., 1993; Egea et al., 2003). Shoot growth begins with budburst and initially the growth is slow, but soon it enters a phase of rapid growth which typically continues until just after fruit set (Goldammer, 2015).

On the other hand, early studies have pointed out the efficient role of Hydrogen Cyanamide (HC) as a plant growth regulator that supplements chilling and causes earlier and more uniform bud-break (George et al., 1992; Cline, 2003) improves yield (Carreno et al., 1999; Abdalla, 2007; Hussein, 2009) and ameliorates growth uniformity (Hashim-Maguire, 2015; Silvestre et al., 2017). Under experimental conditions, applying 1.25% HC, 2.50% HC (Dokoozlian & Williams, 1995) and 1.5% HC (Botelho et al., 2007) has improved bud sprouting in vine cuttings. Similar trend was reported by Pérez & Lira (2005) and Mohammed & Gouda (2017) in open-field conditions where the application of 5% HC has maximized and advanced bud-break by 26–40 days. Improvement and advances in bud-break were also found by Ben Mohamed et al. (2010), Ben Mohamed et al. (2012) and Khalil-Ur-Rehman et al. (2017) following Dormex (HC as active ingredient) treatment. Additionally, HC improved main shoot length (Ahmed et al., 2014), advanced harvest dates and ameliorated fruiting buds percentage, berry set, clusters number per vine, cluster weight and cluster dimensions (Ahmed et al., 2014; Mohamed & Gouda, 2017).

Moreover, de Almeida et al. (2017) reported positive effects of HC application on grape vines covered by plastic films, however previous trials regarding its potential effects under greenhouse are lacking from literature. Consequently, the experiment was as a first trial conducted in Lebanon to evaluate the effects of Dormex (3.5% HC) application under greenhouse as an attempt to attain more uniform and earlier production, consequently to provide newly introduced seedless ARRA cultivars off-season at the Lebanese market.

MATERIALS AND METHODS

The study was carried out in an experimental field situated at the Lebanese coast (140 m above sea level) where three years old seedless cultivars (ARRA15: white variety, ARRA18: black variety and ARRA19: red variety) were grown in open-field conditions or under greenhouse spaced at 3 x 3 meters apart, trained on pergola system and drip irrigated (30 L per vine per 2 weeks). Vines of all cultivars were grafted on the same rootstock: 1103P and were pruned in mid-November leaving 6 buds per cane. Vines received around 400 chilling hours in open-field, and 90 chilling hours under greenhouse during the period of bud dormancy.

Dormex solution containing 3.5% HC was applied 12 days after pruning (Aly et al., 2015) and 12 days later by wiping the buds with cotton immersed in Dormex solution. Experimental treatments were: greenhouse/without Dormex, greenhouse/with Dormex, open-field/with Dormex and open-field/without Dormex (control).

Date of budburst, fruiting, flowering and harvest were determined through daily visual monitoring on-site. Budburst percent was evaluated on the main cane. Buds on the main cane were assigned as a, b, c, d, e and f. The bud position 'a' being the position of the first bud emerging at the base of the main cane. Measurements carried out were: length of current season's shoot (cm) (evaluated weekly as soon as shoots have emerged), number of buds (formed on current season's shoots), bud burst uniformity (distribution pattern of bursted out and non-bursted out buds on current season's shoots), number of flowers and number of clusters per shoot, fruit set (%), average weight of individual cluster (g) and fruit yield (Kg per vine). Additionally, shoots were collected and oven-dried at 105 °C until constant weight for determine their dry weight (g). A full factorial design was adopted with 4 treatments and 9 replicates per treatment (9 vines). Statistical analysis was done using STATISTICA program. Factorial ANOVA and Chi-square test were applied considering a $P_{value} < 0.05$.

RESULTS

Dormex application increased budburst percent by around 74% under greenhouse and around 31% in open-field with no significant differences among cultivars Fig. 1. Dormex induced significantly lower average length of current season's shoots of all cultivars grown in open-field, and under greenhouse, with the lowest values obtained in ARRA15 and ARRA18 grown under greenhouse Fig. 2. In non-treated plants, shoot elongation in time Fig. 3 was not affected by cultivation system, while in treated plants it was lower under greenhouse except for ARRA19. In addition, average dry weight of shoots Fig. 4 was significantly enhanced by Dormex application mainly in ARRA15 (by 59%) and ARRA18 (by 49%) in open-field and in all cultivars under greenhouse (by around 68%). The highest dry weight of shoots was recorded for ARRA19 in the treatment greenhouse/with Dormex (2,141.6 g).

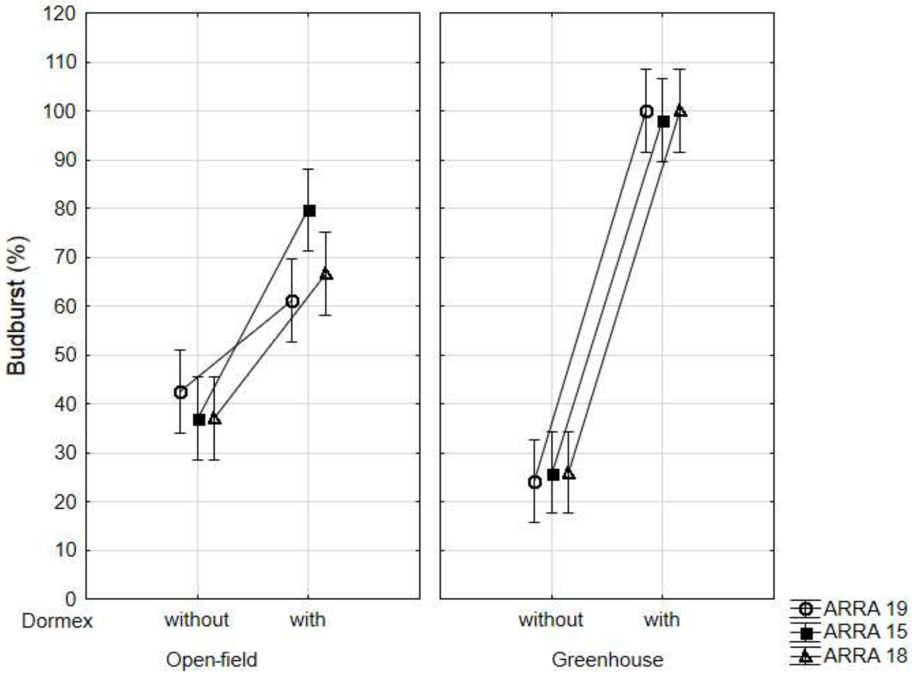

Figure 1. Averages of budburst in percentage (middle markers).

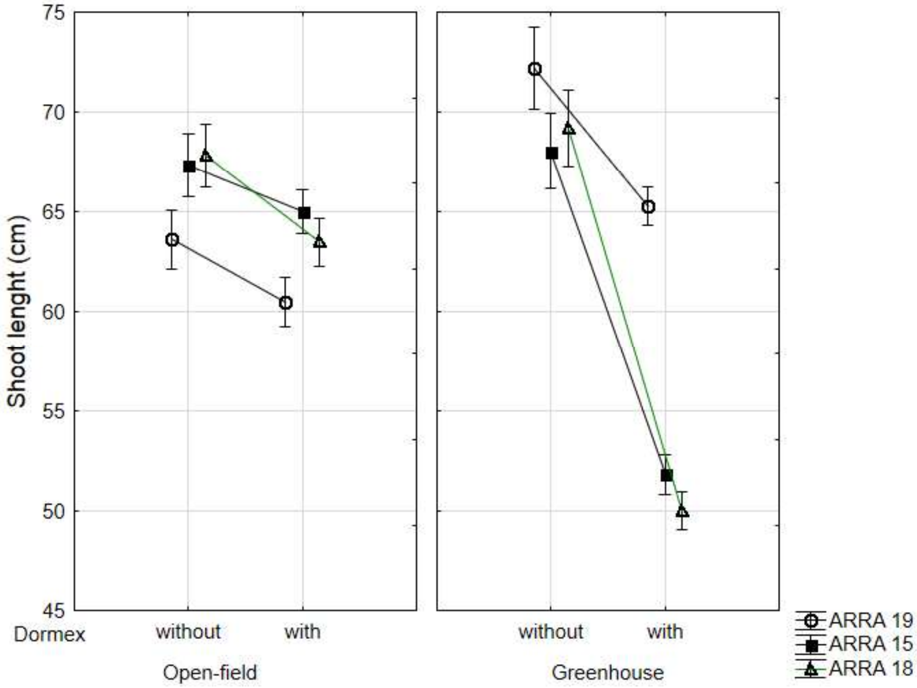

Figure 2. Averages of shoot length in cm (middle markers).

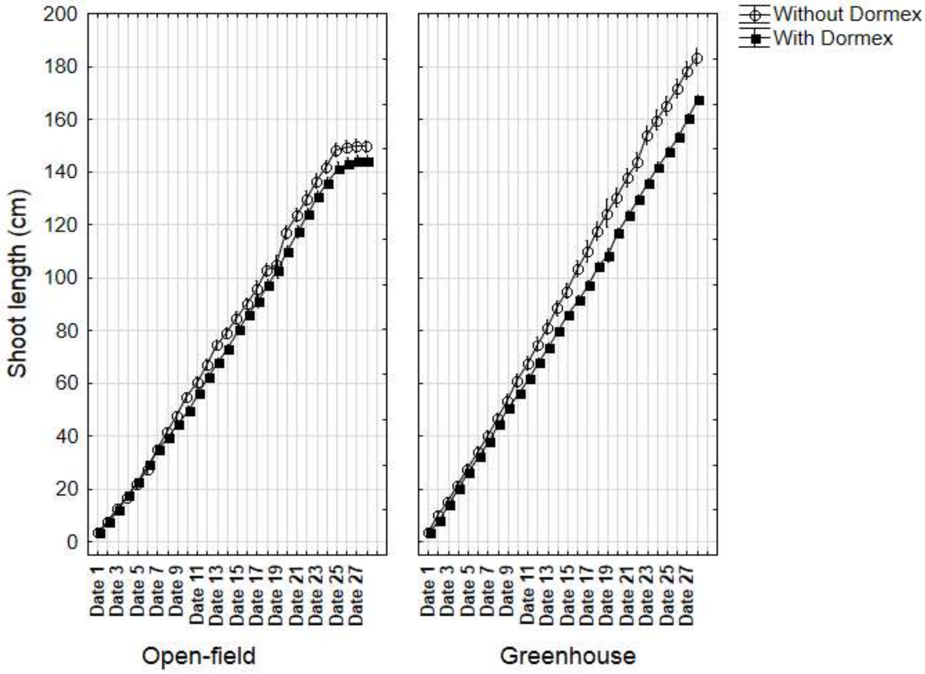

Figure 3. Averages of shoot length in cm (middle markers).

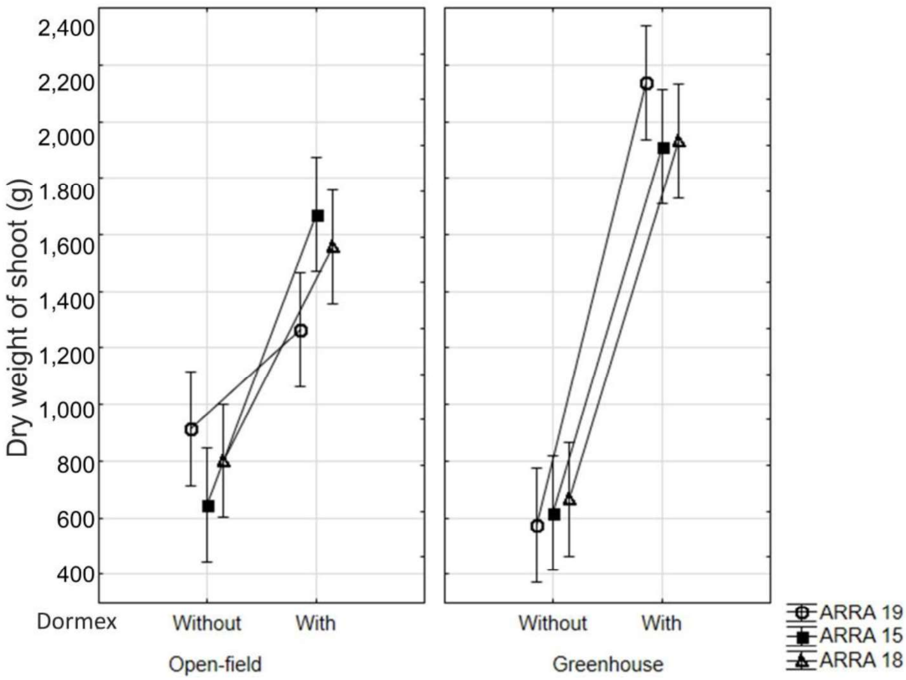

Figure 4. Averages of dry weight of shoots in grams (middle markers).

Average number of buds on current season's shoots was higher under greenhouse compared to open-field in treated (greenhouse/with Dormex: 31, 31 and 39 buds compared to outdoor/with Dormex: 13, 13, and 13 in ARRA15, ARRA18 and ARRA19 respectively) and non-treated plants of all cultivars (greenhouse/without Dormex: 34, 34 and 33 buds compared to open-field/without Dormex: 20, 30 and 17 in ARRA15, ARRA18 and ARRA19 respectively). However, Dormex reduced bud formation in both systems for all cultivars except for ARRA19 under greenhouse (32 and 39 buds in greenhouse/without Dormex and greenhouse/with Dormex respectively).

When comparing the effect of cultivation systems, it was observed that budburst was higher in open-field compared to greenhouse in non-treated plants, while it was the opposite case following Dormex application Fig. 5. Moreover, Dormex induced a more uniform and full budburst (100%) under greenhouse (around 27 buds on the 6 bud positions), while it only improved buds formation in open-field (on all positions with maximization only on the first two positions) with no significant effect on budburst uniformity.

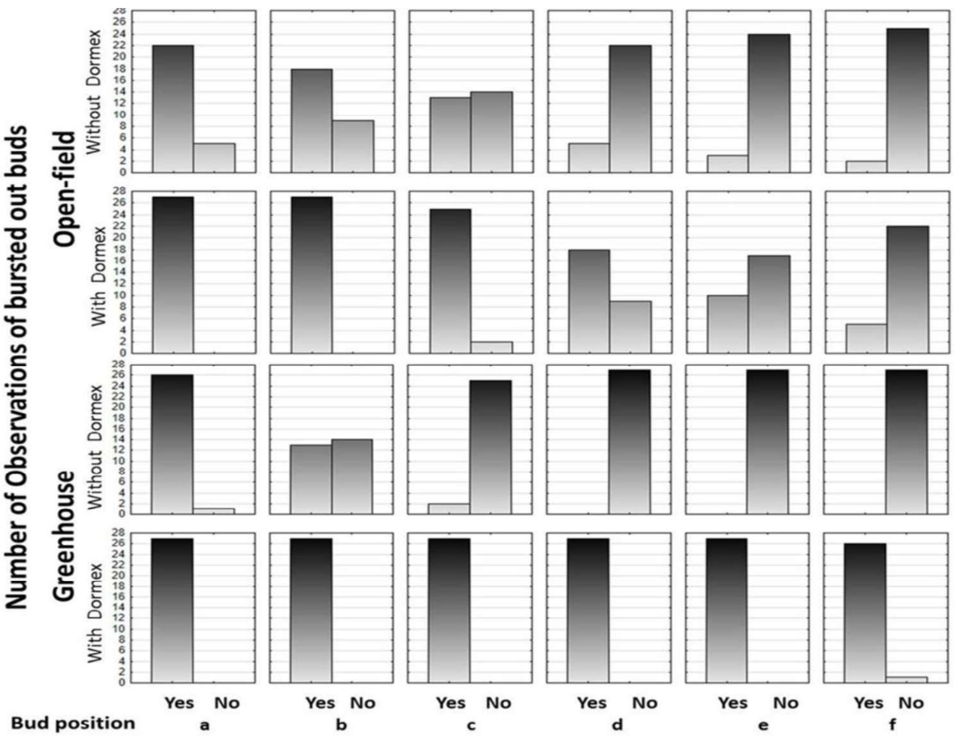

Figure 5. Observed bursted out buds frequencies for the different levels of the experimental factors(a, b, c, d, e and f: position of buds on main shoot).

In general, the dates of flowering and fruit set were advanced under greenhouse compared to open-field. Also, budburst and harvest dates were advanced under greenhouse by one week in treated plants of all cultivars. On the other hand, in non-treated plants budburst was advanced by one week for all cultivars and harvest was advanced by one, three and four weeks for ARRA18, ARRA19 and ARRA15 respectively. Under greenhouse, there was no significant effect of Dormex on various phenological dates while in open-field conditions it induced earlier harvest by 2 and 3 weeks in ARRA19 and ARRA15 respectively Fig. 6.

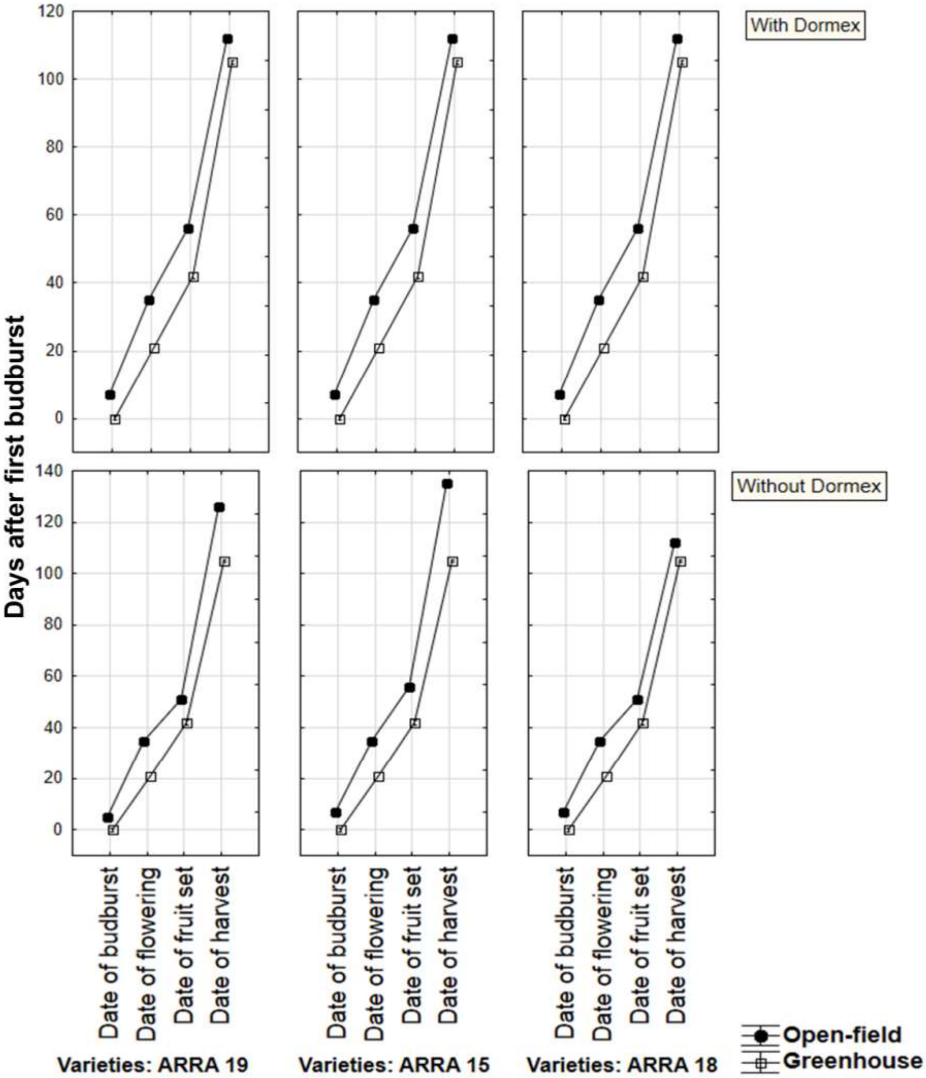

Figure 6. Average days (middle markers) to budburst, flowering, fruit set, harvest dates (days after first budburst).

Fruit set was significantly improved under greenhouse in non-treated plants of ARRA 19 (by 22%) and in treated ones of ARRA 15 (by 46%) and ARRA 19 (by 35%) compared to open-field. Dormex treatment did not positively influence fruit set despite the cultivation systems, in fact it had a negative effect on fruit set of ARRA15 in open-field (decrease by 46%). Moreover, it has a significant positive effect on flowers and fruits number per shoot only under greenhouse where averages of both indicators were both increased (1 flower and 1 fruit in greenhouse/without Dormex compared to

6 flowers and 6 fruits in greenhouse/with Dormex). The highest average cluster weight and average yield per vine were obtained in the treatment greenhouse/with Dormex (708 g, 671 g, 743 gand 26 kg per vine, 25 kg per vine, 27 kg per vine for ARRA19, ARRA15, and ARRA18 respectively). In the remaining treatments, average cluster weight did not exceed 237 gand yields were negligible. As a result, application of Dormex under greenhouse improved plant productivity by 99% for all cultivars.

DISCUSSION

Advanced harvest under greenhouse was related to the earlier budburst and fruit maturity on vines confirming the findings of Novello et al. (2000) and Kamiloğlu et al. (2011). Under greenhouse, the air temperature increases and induces a faster accumulation of growing degree days, which in turn, stimulate an earlier vine budbreak (Novello & de Palma, 2008). The greater shoot development in non-treated plants of ARRA 19 under greenhouse were similarly observed by Novello et al. (2000) on protected 'Matilde' table grapes.

Improvement in budburst percent as a result of Dormex application that was reached in this study (4 times higher) was superior to the one obtained on "Superior Seedless" (2 times higher) in the study of Ben Mohamed et al. (2012a). In fact, hydrogen cyanamide favors the decarboxylation process (Slocum & Flores, 1991) and causes a strong inhibition of the enzyme catalase (Amberger, 1961). Catalase activity is at maximum in dormant buds and decreases with low winter temperature (Nir et al., 1986; Or et al., 2001). Additionally, Dormex counteracted the impact of lacking chilling hours on plants by favoring the allocation of assimilates towards plant shoots and inducing a normal metabolic activity (Ben Mohamed et al., 2012a) in shoot cells. It also might have lowered down and reduced shoot growth at the expense of budburst. However, it did not affect the date of budburst which contradicted earlier findings regarding this indicator (Pérez & Lira, 2005; Ben Mohamed et al., 2012; Hashim-Maguire, 2015; Khalil-Ur-Rehman et al., 2017).

Chilling exposure is a critical factor influencing the response of grapevines to HC which could not play any significant role on bud-break and fruit maturity under conditions where grapevines receive sufficient chilling 800 h at 7 °C (Jensen & Bettiga, 1984; Williams, 1987). In the current work the efficiency of Dormex (3.5% HC) on bud break was high under greenhouse where vines received 90 chilling hours compared to a lower efficiency in open-field with 400 chilling hours. In addition, a high efficiency of Dormex (4% HC) in breaking dormancy and promoting yield was found earlier by Ahmed et al. (2014) when vines had received 200 or 210 chilling hours.

The lowest shoot elongation, thus the more equilibrated distribution of assimilates in shoots caused complete and uniform budburst and improved flower and fruit number in treated vines under greenhouse while in open-field the growing stems have diverted sugars away from axillary buds (Kebrom, 2017). The exceptional low reduction in shoot length and the improvement in budburst in treated ARRA19 plants under greenhouse compared to ARRA 15 and ARRA 18 could reflect a variety-dependent response to Dormex (Lavee et al., 1984).

At the level of each axillary bud and at the plant level, many endogenous and developmental signals have to be integrated to determine bud fate and to establish the number and position of the growing new shoots on the plant. Such regulation is also strongly dependent on environmental factors (Khayat & Zieslin, 1982; Moulia et al., 1999; Battey, 2000; Cameron et al., 2006; Kim et al., 2010; Huché-Thélier et al., 2011; Demotes-Mainard et al., 2013; Djennane et al., 2014; Pierik & Testerink, 2014).

CONCLUSION

Greenhouse cultivation has shortened the phenological cycle of plants reaching an earlier maturity of fruit clusters and consequently earlier yields. In parallel, improvement in bud-break and the more equilibrated allocation of assimilates in new shoots following Dormex application has resulted in a maximization of yields on shoots of current season. Consequently, there was complementarity in the effects of Dormex and greenhouse and this combination of cultural practices was an efficient way to reach the objectives of the study that were basically focused on resolving the problem of insufficient chilling hours' requirements on the Lebanese coast and would help in spreading table grapes cultivation in warm winter regions and to produce off-season table grapes. Finally, Dormex is prohibited in some countries because of its hazardous effects. Therefore, it is better to use it at recommended concentration and to take all safety measure when applying it.

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