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Preventing spring freeze injury on grapevines using multiple applications of Amigo Oil and naphthaleneacetic acid

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ABSTRACT

'Edelweiss' is an important grape cultivar grown in the Midwestern part of the USA. It is one of the earliest cultivars in the vineyard to break bud, making it very susceptible to late spring freezes. 'Edelweiss' primary buds produce a significant amount of fruit, while unlike many other hybrids, the secondary and tertiary buds will have little to no yields, thus making it important to protect the primary buds from a late freeze. The objective of this research was to determine if multiple applications of Amigo Oil or naphthaleneacetic acid (NAA) achieve a greater bud delay when compared to single applications. 'Edelweiss' vines were treated in January, January and February or January, February and March. Amigo Oil was applied at 10% (v/v) and NAA at 1000 ppm with a custom built all-terrain vehicle (atv) sprayer. All treatments of oil led to a significant bud break delay ranging from 1 to 8 days as compared to the control. None of the treatments were phytotoxic to buds or negatively affected yield or fruit characteristics. Grape growers in climates with the potential of late spring freezes may consider the use of Amigo Oil or NAA as a potential means to protect their vines from freeze injury.

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1. Introduction

Grapes (*Vitis* sp.) have recently become an exciting new alternative crop planted in the Midwest United States. With the development of cold hardy cultivars capable of withstanding harsh winters, grape growing has begun to expand in many states. According to the National Agricultural Statistics, total acreage of grapes planted in the United States was 424,758 ha (USDA-NASS, 2014). The first comprehensive study to measure the full economic impact of grape (wine, juice, table, raisin) industries reported that grape and grape products contributed $162 billion annually to the U.S. economy (MKF-Research, 2007). With an increasing percentage of that economic contribution coming from Midwestern states, large crop losses due to late spring freezes can have a major economic impact on the industry. Thus, research addressing potential problems grape growers encounter in these areas is becoming increasingly important.

Grapes grown in the Midwest United States are commonly subjected to inconsistent temperatures. In Nebraska, spring freeze is a major limiting factor of grape production (Qrunfleh, 2010). Grape production in areas that are susceptible to spring freezes is risky and can occasionally cause large economic losses to the grower. The second warmest March on record for 48 of the 50 continental states was recorded in 2007, with temperatures an average of 14 °C above normal (Guinan, 2007). With the arrival of an early spring, many fruit and other crops were developmentally ahead of schedule causing them to be extremely susceptible to an oncoming freeze event. In the Midwest, the loss due to that particular freeze event was estimated to exceed one billion dollars (Guinan, 2007).

The best practice for avoiding winter and spring freeze injury is appropriate site selection (Poling, 2008; Trought et al., 1999; Young, 1940). However, many vineyards are not established in the most suitable location. To mitigate the problems associated with freeze-prone sites, many freeze protection methods have been attempted and include wind machines, overhead irrigation, and chemicals (Trought et al., 1999). Such methods are very costly and thus are not economical for small growers. Primary bud protection is essential as these buds produce 300–400% more fruit with clusters that are 135–190% larger than those produced by secondary buds (Wiggans, 1926).

One of the most effective strategies for spring freeze protection in the vineyard is to delay the onset of bud break in the spring. Some methods that have been used to delay bud break include: delayed pruning, application of cryoprotective materials, plant growth regulators, and alginate and dormant oils (Dami et al., 1997, 2000; Lavee and May, 1997). The first attempts of using oil were reported

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in the late 1960s and early 1970s (Qrunfleh, 2010). Dormant oil was used on 'Johnson Elberta' peaches (*Prunus persica*) to control insects, and found that delayed bloom also occurred (Call and Seeley, 1989). Myers et al. (1996) reported that applications of 10% soybean oil on 'Georgia Belle' peach trees increased internal CO_2 concentrations and delayed bud break by six days.

Use of dormant oils on grapevines was first reported using petroleum and vegetable-based oils (Dami et al., 2000). 'Chancellor' (an early cultivar to break bud), 'Chambourcin' (late cultivar), and 'Chardonel' (mid-season cultivar) grapevines were treated with two soybean oil-based adjuvants (Prime and Amigo Oil). Both treatments led to a significant delay in bud break in all cultivars where total delay ranged from one to twenty days (Dami and Beam, 2004). However, Prime Oil was found to be highly phytotoxic to the dormant buds. Qrunfleh (2010) also reported that Amigo Oil applied to 'Edelweiss' grapevines delayed bud break up to 12 days when compared to the non-sprayed control.

Plant growth regulators have also been used to delay bud break in grapevines. Application of exogenous gibberellic acid (GA_3) during the previous growth season delayed and inhibited bud opening the following season (Lavee and May, 1997). Nigond (1960) reported that spraying 'Aramon' vines with 1-naphthaleneacetic Acid (NAA) at 500–1000 ppm in October had no effect, but spraying the vines in January, February, and March delayed bud break by 16–27 days. Qrunfleh (2010) did a similar study in southeast Nebraska on 'Edelweiss' vines and found that NAA at 1000 ppm delayed bud break by seven days when compared to the non-sprayed control vines.

'Edelweiss' is one of the most common wine grapes planted in Nebraska. It is one of the earliest cultivars to break bud in the spring, making it highly susceptible to spring freeze events. Most vineyards in Nebraska are less than 8 hectares and growers typically cannot afford to employ freeze protection methods such as wind machines, heaters or helicopters. Thus it is necessary to find an alternative method to delay bud burst by several days that is consistent, economical, easy to apply with minimal labor and equipment, and non-toxic to grapes or humans. The objectives of this study were (1) to compare the effects of multiple applications of NAA or Amigo Oil to 14 and 15-year-old 'Edelweiss' grapevines in the field; (2) to evaluate negative phytotoxic effects to buds and on fruiting characteristics including: cluster number per shoot, cluster weight, total soluble solids (°Brix), pH and titratable acidity (TA); and (3) determine the most efficient and effective method to apply NAA and Amigo Oil to grapevines.

2. Materials and methods

2.1. 2012

The first year's experiment was designed as a pilot study to obtain a reliable variance value to set up the following year's study. The pilot study was conducted at James Arthur Vineyards near Raymond, Nebraska (40°57′12.39″N, 96°44′44.83″W). Treatments were applied to 14-year-old 'Edelweiss' (MN #78 ('Beta' × 'Witt') × 'Ontario' (Swenson et al., 1980)) grapevines. The vines were trained to a Geneva Double Curtain (GDC) trellis system with a spacing of 2.4 m × 3.7 m (vine × row). Vines were cane pruned to five buds following treatment application. Amigo Oil at 10% (v/v) (Loveland Industries, Greeley, CO) and 1000 ppm NAA (*Phyto*Technology Laboratories, Shawnee Mission, KS) were applied separately on January 26, February 25 and March 27. A power analysis was conducted on the bud burst data to determine the number of replications necessary to yield a 95% chance of observing significant differences in the following year's experiment (SAS statistical software; SAS Institute, Cary, NC).

2.2. 2013

The second experiment was conducted at the same vineyard on the same 'Edelweiss' grapevines. An incomplete randomized block design (Youden Square) was used and replicated three times. Each Youden Square consisted of a 4 × 7 blocking scheme (row × column) and contained 28 experimental units (Fig. 1). One experimental unit consisted of four vines, where data were taken from the center two vines. Blocking was done both on the row and column, accounting for the elevation change from the top of the row to the bottom and for the elevation and soil differences across the vineyards. Each row consisted of no less than 24 vines and within each row four treatments were randomly assigned. The first plant of each row was a buffer and did not receive a treatment. Vines two–five (the second–fifth vine) in each row received the first spray application. The sixth and seventh vines acted as buffer plants and the next spray treatment began with the eighth vine. This pattern continued through the four treatments. In two instances, in rows 32 and 34, a series of vines had been replanted and required the movement of two treatments laterally across the vineyard and reassigned to rows 20 and 22.

Amigo Oil was applied at 10% (v/v) until runoff (~0.7 l vine $^{-1}$) to all of the oil treatments on January 4, on February 7 for the vines requiring two applications, and finally on March 7 to vines requiring three applications. NAA at 1000 ppm was applied in the same manner on the same dates to different plants. Both applications were done with a specially constructed all-terrain vehicle (ATV) sprayer to increase spray penetration, coverage, and consistency compared to the conventionally used backpack sprayer (Fig. 2).

The vineyard was cane pruned to normal standards during the third week of March approximately 14 days after the last spray application. Four canes on the center two vines of each replication were arbitrarily selected and marked with ribbon. These canes were then pruned to five buds.

2.3. Bud break

To evaluate Amigo Oil and NAA effects on bud break, bud counts were taken every three days from May 6 to June 6 until 75% of buds had opened. Bud break was determined as stage four of the modified E–L scale of grapevine development (Coombe, 1995). Stage four indicates that the bud scales have expanded and the first leaf tissue is visible. Buds on each of the four preselected canes were counted and recorded. Grapevine buds were considered to be fully opened when 75% of the buds had reached stage four or when bud counts ceased to increase. The Julian date (beginning January 1, 2013) was recorded once the cane had reached 75% bud break. The Julian dates of bud break on each of the four canes were averaged for a mean Julian date of bud break for that experimental unit.

2.4. Fruit characteristics

Fruit was harvested on August 21, 2013. Only fruit from the four predetermined canes from each two-vine experimental unit were harvested. One hundred berry samples were collected from each experimental unit and tested for pH, soluble solids concentration (°Brix), and titratable acidity (g/L). The samples were frozen at −18 °C at harvest and thawed to room temperature on the day of measurement.

2.5. Bud phytoxicity and mortality

Once bud break reached 75% in all treatments, bud mortality was evaluated on the retained buds which failed to open. Buds were sliced open using a razor blade and assessed for live green leaf primordia in the primary bud. The percentage of dead buds per