Comparison of foliar fertilizers and growth regulators on pre-harvest drop and fruit quality of ‘Thompson Navel’ orange

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Abstract: An investigation was carried out to determine the ability of foliar fertilizers and growth regulators to prevent pre-harvest drop and enhance navel orange fruit quality. Fifteen year old trees of the Thompson Navel orange variety were sprayed with aqueous solutions of one of the following: methanol (0.13%), calcium nitrate (0.25%), zinc sulfate (1%) + urea (0.5%), fermented sugarcane extract (2.8%), salicylic acid (1 or 3 mM), citric acid (5 mM), or 2,4-dichlorophenoxyacetic acid (2,4-D) (0.002%). Results indicated that foliar treatment with 2,4-D reduced fruit drop (2.6%) as compared to the control (15.2%). Fruit decay was delayed and flavor improved by 5 mM citric acid. Weight loss was reduced after 3mM salicylic acid application, while methanol (0.13%), salicylic acid (1 and 3 mM) and citric acid (5 mM) caused a delay in fruit coloring.

Keywords: Orange; Fruit drop; Foliar treatments

1 Introduction

Citrus is one of the most widely grown fruit crops, currently being produced in more than 80 countries. The desire to increase productivity and to market the freshest fruit have made longer on-tree retention of fruits an economic necessity. Breeding has led to better color and flavors and other important characteristics such as juice content and TSS:TA ratio but the real challenge for fresh fruit handlers and postharvest technologists is to manage orchards so as to enhance the ‘garden-fresh’ characteristics of the fruit. Cultivational practices must be carefully fine-tuned to achieve this [6,19].

In some citrus cultivars, abscission of mature fruit (fruit drop) before harvest is an important cause of lost yield [2]. Thus in Kinnow mandarins, three periods of fruit drop were observed. The first extensive drop occurred during mid-May (29.1%), the second from May to mid-June (50.8%), and the third between mid-September and mid-October, i.e. the pre-harvest drop (17.3%) [19]. Pre-harvest drop occurs after the fruit have reached physiological maturity. Since this involves abscission of mature fruit, it can be a disturbing problem for growers [10]. Shortage of carbohydrate, imbalances in plant nutrition or hormones as well as insect and pathogen damage are all reported causes of fruit drop in citrus [11].

Growth regulator applications have been used successfully for many years to reduce pre-harvest drop and improve citrus fruit quality as well as in other crops [2-4,6,18,24,36,38]. The present studies were therefore undertaken aimed at evaluating the effects of foliar fertilizers and growth regulators to reduce pre-harvest drop and improve fruit quality of Thompson Navel oranges.

2 Materials and methods

This experiment was conducted under field conditions at Babolsar (36º43’N, 59º39’E), in the county of Mazandaran, Iran using fifteen-year-old Thompson Navel orange (Citrus sinensis (L.) Osbeck) trees of similar vigour, grafted onto sour orange (C. aurantium L.) rootstock and grown in sandy-loam soil. Average temperature and rainfall during the growth period were 25.4°C and 326 mm, respectively. Soil samples from up to 60cm depth were collected for the determination of orchard soil physico-chemical characteristics, as shown in (Table 1). Normal cultivational practices with regard to nutrition, weed, pest and disease control
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were utilized during the study. Trees were irrigated every two weeks and fertilized with organic manure at a rate of 40 kg per tree. Eight groups of six trees were used for the study, one for each of the following foliar treatments: methanol (0.13%) (v/v); calcium nitrate (0.25%) (w/v); zinc sulfite (1%) (w/v) + urea (0.5%) (w/v); fermented sugarcane (*Sacharum officinarum*) extract (2.8%) (v/v); salicylic acid (1 or 3 mM) (w/v); citric acid (5 mM) (w/v); 2,4-dichlorophenoxyacetic acid (0.002%) (w/v) and water (control). All treatments were applied on 9 November 2012 and repeated one month later (except 2,4-D). All spray solutions contained surfactant D-Octil (AMC Chemical, Spain) at 0.33 ml.l⁻¹. Whole trees were sprayed using a low-pressure hand-wand sprayer with approximately 3 liters of treatment solution per tree until runoff.

Fermented sugarcane extract was prepared from waste sugar-cane (approximately 20 kg fresh weight), which was chopped into small pieces and allowed to ferment for six months in a mixture of molasses and water (1:1) in a covered bucket at 32°C temperature. After six months, debris was screened and the fermented solution was stored in plastic jars at ambient temperature.

Three Fruit Traits from the study groups were recorded, (i) pre-harvest fruit drop, (ii) fruit storage quality and (iii) fruit consumer quality.

i. Fruit drop from each tree was counted at weekly intervals after second spraying until 1st January and fruit drop percentage determined using the following formula,

\[
\text{Fruit drop (\%)} = \left( \frac{\text{Total number of dropped fruits}}{\text{Total number of fruits before applied}} \right) \times 100
\]

ii. Fruit quality was assessed in ten healthy fully mature fruits without any symptoms of pest infestation or disease infection sampled from each tree. These were stored in boxes for 45 days at 23°C temperature and 80% relative humidity. Individual fruit weights were recorded during storage using an electronic balance and weight loss was calculated as percentage of water loss in comparison to initial weight.

iii. Fruit consumer quality was evaluated by a panel of consumers. The panel graded each fruit peel color on a scale of 1 (yellow) to 4 (deep orange); fruit flavor on a scale of 1 to 3, in which 1 = sour, 2 = mild and 3 = sweet.

This study had been designed as a completely randomized design with six replicates for each treatment where each replicate was represented by a single tree. The experimental data were analyzed using SPSS 16 statistical software and means were compared using Duncan’s multiple range tests.

### Table 1: Soil characteristics in shallow (0-30cm) and deep (30-60 cm) samples from the study orchard

| Depth (cm) | Physico-chemical characteristic | N total (%) | P (ppm) | K (ppm) | Zn (ppm) |
|-----------|----------------------------------|------------|--------|---------|----------|
|           | pH                               | EC (dS.m⁻¹) | Organic matter (%) |                               |          |
| 0-30      | 6.2                              | 1.6        | 1.4    | 0.14    | 43       | 195      | 1.6     |
| 30-60     | 5.8                              | 1.5        | 0.4    | 0.04    | 17       | 152      | 1.2     |

*Fermented sugarcane extract was prepared from waste sugarcane (approximately 20 kg fresh weight), which was chopped into small pieces and allowed to ferment for six months in a mixture of molasses and water (1:1) in a covered bucket at 32°C temperature.*

### Figure 1: Effect of foliar-applied methanol (M), calcium nitrate (CN), zinc sulfate + urea (ZS+U), fermented sugarcane extract (FSE), salicylic acid 1 and 3 mM (SA1 and SA3), citric acid (CA), 2,4-dichlorophenoxyacetic acid (2,4-D) and water (Con) on pre-harvest fruit drop (%) of ‘Thompson Navel’ orange. Differences in column headings denote statistically significant treatment effects (P< 0.05)

3 Results

Thompson Navel oranges were shown to respond well to application of chemicals in reducing premature fruit drop, weight loss, fruit decay and loss of fruit flavor. Methanol, Ca(NO₃)₂, ZnSO₄ + urea, fermented sugarcane extract, salicylic acid (1 mM) and 2,4-D all significantly reduced fruit drop as shown in Figure 1. For example, fruit drop for the controls was 15.2%, while only 2.6% after application of 2,4-D.

In terms of fruit storage quality only 3 mM salicylic acid reduced fruit weight loss. The greatest fruit weight loss (4.3%) was recorded in plants treated with citric acid.
acid (Figure 2). Results of foliar treatment on fruit decay are shown in Figure 3. There were no significant differences among fruits from control and fermented sugarcane extract groups on fruit decay. Application of methanol, Ca(NO₃)₂, ZnSO₄ + urea, salicylic acid, citric acid and 2,4-D resulted in significantly reduced fruit decay compared to control (Figure 3).

The data presented in Figure 4 show that pre-harvest spraying of methanol, salicylic acid and citric acid delayed peel coloring compared to control, Ca(NO₃)₂ and fermented sugarcane extract treatments. Also, foliar application of citric acid significantly improved the fruit sweetness (Figure 5).

According to Table 2, there was a significant positive correlation among peel color with fruit decay and fruit flavor with weight loss.

4 Discussion

Fruit of Navel oranges and some its hybrids are prone to fruit abscission during the maturation process. Applying synthetic auxins can efficiently reduce fruit abscission [1]. It is also clear from the present results that foliar application of 2,4-D could reduce fruit drop. This agrees with the findings of Modise et al. (2009) who observed foliar application of 2,4-D at 20 mg.l⁻¹ reduced the rate of fall in Navel oranges as compared to control. According to Akhlaghi Amiri et al. (2012b), the effects of plant growth regulators in reducing the rate of premature fruit drop of ‘Satsuma’ mandarin were significant compared to control, with 2,4-D at 60 mg.l⁻¹. It seems that pre-harvest fruit drop may be caused by low non-structural carbohydrate
Fruit weight loss

Table 2: Similarity coefficients among fruit traits of 'Thompson Navel' orange

| Trait          | Fruit drop | Fruit weight loss | Fruit decay | Peel color |
|----------------|------------|-------------------|-------------|------------|
| Fruit drop     | -0.148     | 0.147             | 0.001       | 0.489**    |
| Fruit weight   |            |                   |             |            |
| loss           |            |                   |             |            |
| Fruit decay    | 0.147      |                   |             |            |
| Peel color     | -0.145     | 0.025             | 0.489**     | -0.406**   |
| Fruit flavor   | -0.040     | 0.309*            | -0.406**    | -0.234     |

* P < 0.05, ** P < 0.01

concentrations, low plant nutrients and low IAA concentrations [25]. The present results are in agreement with previous work which speaks of the efficacy of foliar based growth regulators or nutrients in arresting citrus fruit drop. Yasin Ashraf et al. (2013) observed that foliar applications of 2,4-D, salicylic acid, K$_2$SO$_4$, and ZnSO$_4$ alone or in combination significantly reduced fruit drop in 'Kinnow' mandarin. Akhlaghi Amiri et al. (2012a) reported that 2,4-D, 2,4-D + urea and 2,4-D + ZnSO$_4$ significantly reduced abscission in 'Thompson Navel' orange compared to control while auxin significantly increased it. They found that abscission had a significant negative correlation with auxin and a significant positive correlation with hydrolytic enzymes. Therefore, these treatments delayed reduction of auxin level, and decreased production or activation of hydrolytic enzymes and postponed breakdown of cell walls in the abscission zone, thus resulting in significant reduction in pre-harvest drop in comparison to control.

The present results reveal the benefits of foliar application of fermented sugarcane extract and suggest it may be useful to decrease fruit drop and therefore may be a valuable resource in organic agriculture. Russo (2001) suggested that fermented waste solution may be used as a foliar spray to promote growth of leaf and root biomass while nursing seedlings of the tropical fruit Vochsia guatemalensis. Fermented sugarcane extracts contain inorganic compounds such as minerals (calcium, copper, iron, magnesium, manganese, zinc, phosphorus, potassium and nitrogen), in addition to sucrose, reduced sugars, organic non-sugar- nitrogenous substances and organic acids [12,23,33]. Overall, sugar cane extract can improve the nutrient buildup in the plant system as well as the rhizosphere. The same findings were obtained by Amro (2015) who reported that foliar spray of algal extract in combination with zinc sulfate enhanced valencia orange yield and fruit quality, effects that may be attributed to its enriched composition of minerals, vitamins and growth regulators like IAA and cytokinins.

In this study, salicylic acid at 3 mM concentration reduced fruit weight-loss. Zheng and Zhang (2004) and Khademi and Ershadi (2013) showed that salicylic acid decreased the respiration rate and fruit weight loss in mandarin and peach, respectively. Ilic et al. (2001) reported that salicylic acid decreased transpiration and this was associated with reduced activity of enzymic cell wall hydrolysis. On the other hand, weight loss can also be due to increased metabolic activity and salicylic acid, as an electron donor, produces free radicals which prevent normal respiration [37]. With the exception of fermented sugarcane extract, all treatments were effective in reducing fruit decay. Sugar et al. (1992) found that application of ammonium nitrate to pear trees 3 weeks before harvest and calcium chloride during the growing season reduced the severity of fungal decay. In the present study, no decay was evident on fruits treated with citric acid. It has been demonstrated that citric acid is more effective than acetic and lactic acids for inhibiting growth of thermodhilic bacteria [32]. Similarly, Pao and Petracek (1997) reported that infusion of 0.5% w/v citric acid extended shelf life of both peeled whole and chunked orange fruits and, the extension of shelf life resulted primarily from the inhibition of spoilage bacteria. Jiang et al. (2004) found that treatment with 0.1 M citric acid markedly extended the shelf life and inhibited disease development on fresh-cut Chinese water chestnut (Eleocharis dulcis). Similarly useful effects of salicylic acid on preventing fungal decay on strawberry [7], lemon [20], mandarin [41] and mango [39] have been reported. Increasing evidence suggests that a plant’s endogenous salicylic acid plays an important role in activation of defense responses against pathogen attack [8]. Salicylic acid is an important component in the signal transduction pathway and is also involved in local and systemic resistance to pathogens. Exogenous application of salicylic acid, at nontoxic concentrations, could enhance the resistance of fruits to pathogens [35]. Furthermore, fruits treated by fermented sugarcane extract showed a high decay incidence compared to other treatments. Fermented sugarcane extract contains substances such as sucrose, glucose and fructose [23], which might enhance microbial survival leading to increased fruit decay.
Fruit appearance to the consumer is indicative of nutritive value of fruit and plays an important role in consumer satisfaction, influencing further consumption. Sensory ratings of fruit by panelists and physical measurements of fruit properties are useful methods in the evaluation of fruit quality [9]. The use of methanol, salicylic acid and citric acid delayed peel coloring as compared with control. In addition, decreased fruit metabolic activities seems to result in decreased fruit water loss and carbohydrate depletion rate, consequently delaying fruit senescence. These effects appear to be associated with the suppression of the fruit respiration rate and ethylene production. Ethylene is necessary for chlorophyll degradation in citrus peel [28]. Furthermore, ethylene production was reduced or inhibited by alcohol (ethanol and methanol) and salicylic acid. The mechanism for this is that by blocking the conversion of 1-aminocyclopropane-1-carboxylic acid (ACC) to ethylene, fruit ripening is inhibited [8,13,21].

Citric acid significantly increased fruit sweetness in comparison to control. Fruit flavor is a complex combination of soluble and volatile compounds, and organic acid: sugar ratio of the fruit. Monoterpenes and simple organic acids such as citric and malic acids, stand out as important flavor and aroma compounds [19,26,30]. In citrus, citric acid is the major form of the acid followed by malic acid, and these acids are converted back to sugars during ripening. Citric acid content decreased steadily after the first month in storage [19,26]. Zhao et al. (2009) reported that treatment of Chinese jujube fruits with 0.5% citric acid could slow down the decline of soluble sugar. We suggest that the utilization of external citric acid causes accumulation of this acid and its conversion to sugar could be the reason for observed higher amounts of sugar in treated fruits. On the other hand, Malundo et al. (1995) and Silva et al. (2012) observed adding citric acid to fresh tomato and banana significantly resulted in products of good acceptability. Also, the effect of citric acid on essential oil content of basil is already reported [15], which could be considered another possible factor affecting flavor of fruits in our study.

Fruits that have colored earlier are more prone to decay. During ripening and storage, resistance of the fruit to the pathogen decreases and preliminary mycelium enter an active stage, and initiate decay. Moreover, during prolonged fruit storage a series of physiological processes occurs which leads to senescence of the vegetal tissue and a parallel increased susceptibility to weak pathogens [8]. Also, there appeared an inverse relationship between fruit flavor and fruit decay with sweeter fruit having less fruit decay percent. This result is in contrast to other reports and warrants further study. A similar correlation has been observed between the sugar content of nectarine and plum fruits and their susceptibility to Botrytis cinerea infection. As usual, young unripe fruit doesn't provide the pathogen with the nutrition and energy required for its development. Since, during ripening and storage, a conversion of insoluble carbohydrates to soluble sugars occurs, it is no wonder that the sensitivity of ripe fruit to rotting has been attributed to the tissue sugar content [8].

5 Conclusion

The application of growth regulators and nutrients in the orange fruit orchard can be helpful in controlling pre-harvest fruit drop and leads to improvement of some fruit quality traits, hence increasing yield and giving good returns to the grower. Since, methanol, CaNO₃, ZnSO₄ + urea, fermented sugarcane extract and salicylic acid (1 mM) were effective in controlling pre-harvest fruit drop in citrus, these may be effectively substitute for 2,4-D herbicide which has environmental side-effects but is commonly used for controlling fruit drop in many countries. Based on the positive results, we expect to achieve better results by a combination of these compounds in optimal concentrations. However, further work is required to find these optimal combinations that could create a better framework for practical applications on specific fruit trees.

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