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# Late season mineral foliar application improves nutritional reserves and flowering of kiwifruit

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ABSTRACT

Proper management of late season mineral nutrition in kiwifruit orchards is necessary to maintain sufficient carbohydrate and mineral reserves for efficient growth and yield in the following season. The present study was conducted in order to investigate the influence of urea (0.25%, 0.5% and 1%), zinc sulfate (1000, 1500 and 2000 mg $l^{-1}$) and boric acid (500, 1000 and 1500 mg $l^{-1}$) foliar application, both alone and combined, on physiological and biochemical characteristics and mineral nutrients concentration in leaf and bud tissues and, flowering of kiwifruit cv Hayward in Guilan, Iran during two years. In order to determine the best application time in late season, foliar application was applied at three different times: September 17, October7 and October 28. Leaf and bud samples were collected three weeks after the last foliar application. Although combined foliar application of urea (1%), zinc sulfate (2000 mg $l^{-1}$) and boric acid (1500 mg $l^{-1}$) significantly increased leaves chlorophyll concentration and boron, zinc, soluble carbohydrate and starch content of leaf and bud tissues in the fall, however this consistent elevation in almost all measured parameters was not found in other experimental fertilization treatments compared to control vines. Likewise, bud break, and flowering shoot percentage, and total number of flowers and abnormal flowers percentage was significantly improved in the following growth season by urea (1%), zinc sulfate (2000 mg $l^{-1}$) and boric acid (1500 mg $l^{-1}$) treatment in comparison with control group. There were no significant differences among the treated and non-treated vines regarding shoots growth, leaf abscission and the beginning of winter rest of the kiwifruit vines. Considering all measured parameters, we conclude October 28 was the best spraying time. These results suggest that urea (1%), zinc sulfate (2000 mg $l^{-1}$) and boric acid (1500 mg $l^{-1}$) treatment on October 28 can be used as a proper way to improve mineral and carbohydrate reserves of kiwifruit orchards to use in next growing season.

## 1. Introduction

Kiwifruit (*Actinidia deliciosa* cv. Hayward) is considered a commercial horticultural crop in the northern provinces of Iran (Fattahi et al., 2010). Kiwifruit vines require both organic and inorganic nutrients for their proper vegetative growth and fruit yield (Zuccherelli and Zuccherelli, 1990). It is well established that the month following bud break, and two or three weeks after fruit set, are the critical periods in kiwifruit vines' life cycle, which nutrients and carbohydrate reserves should be available for vines (Clarck and Smith, 1992). Foliar fertilizer application is a relatively new agricultural technique which is considered as an immediate method of spraying water-dissolved fertilizer directly to plant leaves (Solanki et al., 2015). Foliar application is perfect not only for gaining higher crops yield, but also for correction of nutrient deficiencies and addition of macro and micro nutrients (El-Sheikh et al., 2007). Deciduous fruit trees accumulate nitrogen (N) and carbohydrates in perennial tissues in the end of the growing season, and then use them for differentiation and development of flower buds and supporting initial growth in the following spring (Titus and Kang, 1982; Loescher et al., 1990). Furthermore, the type of N and other fertilizers and the application time can influence both the growth and yield at the following year, and also the different forms of reserves in the tree (Cheng et al., 2004; Neilsen et al., 2006). On the one hand, it seems that foliar application must be well-organized at late summer or early autumn to ensure provision of an optimum nutrient supply and reserves for the next growing season (Harris et al., 1999). On the other hand, several studies have emphasized the critical role of macro and micro nutrients concentration in the spray solution which has an impact on application and improvement of vegetative and reproductive traits (Nyomora et al., 1997; Sanchez and Righetti, 2005; Keshavarz et al.,

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2011; Hasani et al., 2015).

Foliar application of N compounds has been suggested as an alternative to supplying N to the soil of woody perennial plants in late season through minimizing nitrate leaching and increase of N reserves in above the ground organs (Khemira, 1995). Urea, white crystalline solid containing 46% N, is one of the common and accessible resources for the growers in foliar application (Shamsudin et al., 2012). Rapid absorption, low phytotoxicity, and high solubility, have made urea an excellent source of N for crop production (Bondada et al., 2001). Furthermore, it has been observed that spraying urea at late season has positive impacts on deciduous fruit trees (Titus and Kang, 1982). Previous researchers have found a positive correlation between N concentration and levels of chlorophyll, photosynthesis, carbohydrates and protein synthesis (Vos et al., 2005). Applying N at late summer or early fall causes the transfer of N to storage organs, and therefore affects tree growth, flowering and yield in the following growth season (Titus and Kang, 1982). In kiwifruit vines, applying relatively small amounts of pre-harvest N was an effective technique for enhancing N storage and remobilization in the following spring (Tagliavini et al., 2000).

Among micronutrients, zinc (Zn) and boron (B) have essential roles in plants nutrition (Ali et al., 2015). Both Zn and B are essential elements for plants and are known to be involved in photosynthesis, N-fixation, respiration and other bio-chemical activities (Cakmak and Marschner, 1988; Goldbach et al., 1991). Foliar application of Zn and B was found to be the best method for Zn and B absorption during early fall and prior to bud break in spring (Weinbaum, 1988; Nyomora et al., 1999). It has been shown that B fall foliar application in pear trees and grapevines enhanced the B concentration in buds in the dormant time (Sanchez et al., 1998; Christensen et al., 2006). Fall B fertilization has even improved both fruit-set and yields in almond trees compared to spring fertilization (Nyomora and Brown, 1999).

The main purpose of late season foliar application is improving carbohydrate and mineral storage content in order to achieve a higher quality and quantity of flower and fruit in spring season. However, in the current study we mainly focus on autumn changes, and therefore a little of spring data is presented in this paper. Given the paucity of data on the fall regarding the foliar application of mineral nutrients on kiwifruit vines, series of experiments were conducted with two main objectives: First, to find the proper fertilizer formula, and second, to determine the best time for fall foliar application, based on mineral elements and carbohydrates concentration in vines to use in the following spring.

## 2. Material and methods

### 2.1. Experimental site

This research was conducted on kiwifruit orchard located in Vajargah, Guilan province, Iran, with latitude of 37°02′N; longitude of 50°39′E and 10 m altitude from September 2015 to May 2017. The average annual rainfall and temperature of the region are 1147 mm and 15.7 °C, respectively. Some physico-chemical characteristics of orchard soil are presented in Table 1.

### 2.2. Plant materials and experimental design

The experiment was carried out on 8-years old vines of 'Hayward' kiwifruit. Vines were on their own roots and trained on a T-Bar support system with a plant distance of 4 × 5 m and the ratio was 1:8 males to females. All vines had been subjected to same standard cultural practices (i.e., dormant pruning, spring soil fertilization and irrigation) in both years of experiment. A total of sixty-three uniform vines were selected and this research was done as factorial experiment in a randomized complete block design with two factors, consisting of seven fertilizer treatments and three times of foliar application. To determine the proper fertilizer formula, urea, boric acid ($H_3BO_3$) and zinc sulfate ($ZnSO_4{\cdot}7H_2O$) were selected for fall foliar application on kiwifruit vines. The experiment included the following seven foliar application treatments:

1. Urea (0.5%)
2. $H_3BO_3$ (1000 mg $l^{-1}$)
3. $ZnSO_4$ (1500 mg $l^{-1}$)
4. Urea (0.25%) + $H_3BO_3$ (500 mg $l^{-1}$) + $ZnSO_4$ (1000 mg $l^{-1}$)
5. Urea (0.5%) + $H_3BO_3$ (1000 mg $l^{-1}$) + $ZnSO_4$ (1500 mg $l^{-1}$)
6. Urea (1%) + $H_3BO_3$ (1500 mg $l^{-1}$) + $ZnSO_4$ (2000 mg $l^{-1}$)
7. Control group (treated with distilled water)

To determine the best application time, foliar application was applied at three different times, September 17, October 7 and October 28. To prevent the undesirable sunlight effects, vines were sprayed in the early morning.

**Table 1**
Physical and chemical properties of the orchard soil from depth of 0–30 cm.

| Soil parameters | Value |
|---|---|
| Particle size distribution | |
| Sand (%) | 84 |
| Silt (%) | 9 |
| Clay (%) | 7 |
| Texture | |
| pH | 5.97 |
| EC (dSm$^{-1}$) | 0.54 |
| Organic matter (%) | 1.94 |
| Macro and micro nutrients | |
| N (%) | 0.1 |
| P (mg kg$^{-1}$) | 43 |
| K (mg kg$^{-1}$) | 283 |
| B (mg kg$^{-1}$) | 2.08 |
| Zn (mg kg$^{-1}$) | 2.33 |
| Cu (mg.kg$^{-1}$) | 1.6 |
| Fe (mg kg$^{-1}$) | 40 |
| Mn (mg kg$^{-1}$) | 24 |

### 2.3. Leaves and buds sampling

Three weeks after the last foliar application (November 20), leaf and bud samples were collected from the middle section of current season growth shoots from four directions of each vine. These samples were kept in a −20 °C freezer for future chlorophyll, soluble carbohydrate and starch analysis. In addition, sub-samples of collected plant materials were dried at 70 °C for 48 h to detect mineral nutrients.

### 2.4. Total chlorophyll content

The chlorophyll content of the leaves was extracted based on Hiscox and Israelstam method (1979). One hundred milligram of leaf tissue was placed in test tubes containing 7 ml dimethyl sulphoxide (DMSO). Test tubes were incubated at 65 °C for 20 min in a water bath. The extracted liquid was transferred to another tube and made up to a total volume of 10 ml with DMSO. Chlorophyll extract was then transferred to a microplate and the absorbance was read using an Epoch Microplate Spectrophotometer (BioTek Instruments, Inc., USA) at 663 and 645 nm against DMSO blank for chlorophyll a and b, respectively. Finally, total chlorophyll (a + b) concentration was determined using equation derived by Arnon (1949):

$$\text{Total chlorophyll (g l}^{-1}) = 0.0202(A_{645}) + 0.00802\ (A_{663}) \quad (1)$$

The total chlorophyll concentration of the extract was calculated from this equation and then was converted to mg $g^{-1}$ fresh weight (FW).