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Influence of late season foliar application of urea, boric acid and zinc sulfate on nitrogenous compounds concentration in the bud and flower of Hayward kiwifruit

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ABSTRACT

Proper management of late season mineral nutrition and improving nitrogenous reserves in kiwifruit vines can result in efficient growth and yield in the following season. This experiment investigated the influence of late season foliar application type and time on the content of total nitrogen, total protein, total free amino acid, and individual amino acids of bud and flower and consequently vegetative and reproductive growth of Hayward kiwifruit in next spring. The orchard was located in Vajargah, Guilan province, Iran, with an average annual rainfall and temperature 1147 mm and 15.7 °C, respectively. Foliar application of mineral nutrients included 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}) alone and in combined treatments as urea (0.25%) + H_3BO_3 (500 mg l^{-1}) + $ZnSO_4$ (1000 mg l^{-1}); urea (0. 5%) + H_3BO_3 (1000 mg l^{-1}) + $ZnSO_4$ (1500 mg l^{-1}); urea (1%) + H_3BO_3 (1500 mg l^{-1}) + $ZnSO_4$ (2000 mg l^{-1}). The experimental treatments were conducted in 8 years old kiwifruit vines in late growing season. To determine appropriate time for late season foliar application, fertilization was performed in middle September, early and late October, 96, 75 and 54 days before the beginning of the winter dormancy, respectively. Samples were taken from buds at two stages: before leaf abscission and again during dormancy. Flower sampling was taken at the full bloom stage. Results indicated that 33.65 and 35.75 percentages of increases in dormant bud and flower nitrogen concentrations were achieved by combined foliar application of urea (1%), zinc sulfate (2000 mg l^{-1}) and boric acid (1500 mg l^{-1}) compared to control vines. Moreover, urea (1%) + H_3BO_3 (1500 mg l^{-1}) + $ZnSO_4$ (2000 mg l^{-1}) treatment increased total protein, free amino acid and most individual amino acid concentration in analyzed tissue, however this significantly consistent elevation in almost all measured parameters was not found in other fertilization treatments. Interestingly, this treatment improved 14.51% leaf area and 22.21% fruit seed number in next growing season compared to control vines. Considering all measured parameters, late October was the best late season foliar application time. Based on our findings, late season mineral foliar application, especially urea (1%) + H_3BO_3 (1500 mg l^{-1}) + $ZnSO_4$ (2000 mg l^{-1}), in late October can improve all nitrogenous compounds concentration in bud and flower tissues, as well as increase seed number and consequently fruit weight and grower income in the next growing season.

1. Introduction

Initial growth and development of deciduous fruit trees in spring is associated with the remobilization of accumulated nutrients at the end of the previous growing season (Bushway and Pritts, 2001). The remobilization of nitrogen (N) and carbohydrate reserves are well-documented during plant new growth by providing structural components and energy supply before significant root uptake of N and photosynthesis occur in spring (Cheng et al., 2004). However, the extent of initial new growth and development is supposedly dependent on N reserves rather than carbohydrate reserves (Cheng and Fuchigami, 2002).

Nitrogen reserve roles have been highlighted in studies that focused on initial growth and development in spring (Cheng et al., 2002), including the relationship between the total N accumulated during the previous year, and the amount of N remobilized for new growth (Cheng

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and Fuchigami, 2002). Generally, N is stored as proteins and partly as free amino acids at the end of the growing season. It is well documented that leaf senescence leads to the breakdown of leaf proteins, and followed by the transfer of nitrogen compounds to the perennial plant parts to form N storage compounds like storage proteins and amino acids (Dong et al., 2000; Bazot et al., 2016). Nitrogen also supports the development of flower buds, vegetative and reproductive growth in the following season (Titus and Kang, 1982; Roubelakis-Angelakis and Kliewer, 1992). Nitrogen reserves play a critical role during the first weeks after bud break when N demand is high, soil N supply is insufficient, and canopy transpiration rate is low (Sanchez et al., 1990; Zavalloni, 2004).

Plants generally capture N from the soil through root uptake. However, plants can absorb N through leaves when applied as foliar spray (Bernard et al., 1996), particularly in urea foliar application (Rosecrance et al., 1998; Tagliavini et al., 1998). Late season mineral foliar application is a strategy in commercial fruit tree production that provide N reserves for plants (Khemira, 1995). It has been stated that N from late season urea foliar applications is converted to amino acids in the apple tree leaves, and then translocated to bark, roots, bud and other parts of the plant (Dong et al., 2002). Foliar application of urea before leaf abscission during October increased the N concentration in sweet cherries flower bud (Guak et al., 2005; Ouzounis and Lang, 2011). Therefore, it can be expected that urea foliar application enhance N in the flower bud, increase ovule life, pollination, fertilization period, and leaf area. These changes were followed by improvement in fruit set, fruit size and yield (Albrigo, 2002). Late season urea foliar application significantly increased leaf size and nitrogen level of spur leaves in sweet cherry (Mustafa and Caglar, 2016) and fruit set and yield in apple in next growing season (Zubair et al., 2017). In addition to N fertilizers, micronutrients such as zinc (Zn) and boron (B) have essential roles in increasing plant N concentration (Cakmak and Marschner, 1988). It is well established that increasing Zn and B content improve N uptake in plants due to their possible role in N compounds metabolism (Kitagishi et al., 1987; Marschner, 1995).

Given the paucity of data regarding the foliar application effect of mineral nutrients on free nitrogen metabolites concentration of kiwifruit vines, this study was conducted to find the proper fertilizer formula, and to determine the best time for late season mineral foliar application, based on total N, protein and amino acids content of bud and flower tissues to use in the following spring.

2. Material and methods

2.1. Experimental site

The experiment was conducted at a commercial orchard of Hayward kiwifruit (*Actinidia deliciosa*) located in Vajargah, Guilan province, Iran (lat. 37.02°N; long. 50.39°E) from September 2015 to May 2017. The average annual rainfall of the region was 1147 mm and the minimum, and maximum temperatures were 2.8 °C and 30.2 °C, respectively. The evaluated physic-chemical characteristics of orchard soil and vines leaf analyses are presented in Tables 1 and 2, respectively.

Table 2
Leaf mineral nutrients content of kiwifruit vines (*Actinidia deliciosa* cv. Hayward).

N	P	K (%)	Ca	Mg	Fe	Zn	Mn (mg. kg^{-1})	Cu	B
5.185	0.27	2.39	1.18	0.26	43	283	2.33	2.08	24

2.2. Experimental design

Sixty-three uniform vines 8-years of age and with 4 × 5 m spacing, 1:8 male to female ratio, trained on a T-Bar support system with “Tomori” as a pollinizer, were selected for late season mineral foliar application. All experimental vines were subjected to standard cultural practices (i.e., dormant pruning, spring soil fertilization and irrigation) during this study. The experiment was performed under a factorial experiment in a randomized complete block design with two factors, consisting of seven fertilizer treatments and three foliar applications. In this study, urea (CH_4N_2O, containing 46% N), boric acid (H_3BO_3, containing 17.5% B) and zinc sulfate ($ZnSO_4.7H_2O$, containing 22.73% Zn) were used alone and/or in combination as experimental treatments. The following experimental treatments were included:

N5000 (CH_4NO_2 5000 mg.L^{-1})
B1000 (H_3BO_3 1000 mg.L^{-1})
Zn1500 ($ZnSO_4$ 1500 mg.L^{-1})
N2500: B500: Zn1000 (CH_4NO_2 2500 mg.L^{-1} + H_3BO_3 1000 mg.L^{-1} + $ZnSO_4$ 1500 mg.L^{-1})
N5000: B1000: Zn1500 (CH_4NO_2 5000 mg.L^{-1} + H_3BO_3 1000 mg.L^{-1} + $ZnSO_4$ 1500 mg.L^{-1})
N10000: B1500: Zn2000 (CH_4NO_2 10,000 mg.L^{-1} + H_3BO_3 1500 mg.L^{-1} + $ZnSO_4$ 2000 mg.L^{-1})
C: Control vines (treated with distilled water)

The foliar application was done by spraying at three different times in middle September (September 17th), early October (October 7th) and late October (October 28th) in 2015 and 2016, 96, 75 and 54 days before the beginning of the winter dormancy, respectively, which was shown in the text as T_1, T_2 and T_3, respectively.

Four representative canes were selected from different directions of each vine. Bud samples also were collected from the middle portion of canes before and at dormancy (December 5th and February 5th, respectively). At each sampling time, four replicates of 20 similarly sized buds were dissected from the canes. In spring, five current season shoots were marked on four representative canes and flower samples were collected in the full bloom stage. In this regards, 20 flowers were randomly selected from the middle portion of current season shoots.

2.3. Total nitrogen

In order to determine the concentration of N, dried bud and flower samples were ground to a fine powder. Total N content was determined by using the Kjeldahl standard method (K-360; Buchi Labortechnik AG, Flawil, Switzerland), based on the digestion of dried plant material in a sulfuric-salicylic acid mixture (Buresh et al., 1982).

Table 1
Soil physical and chemical properties of the kiwifruit orchard located in Vajargah, Guilan, Iran.

Depth (cm)	pH	EC (dSm^{-1})	Sand	Silt	Clay (%)	Organic matter	N	P	K	Zn	B (mg. kg^{-1})	Mn	Fe	Mg
0-30	5.97	0.54	84	9	7	1.13	0.11	43	283	2.33	2.08	24	40	308
30-60	6.98	1.91	80	14	6	1.22	0.12	42	178	[a]	[a]	[a]	[a]	8

[a] Undetectable.