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SOIL SCIENCE

Leaf mineral concentration of peach after the use of resistance inducers

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ABSTRACT: *This research studied the effect of the inducers acibenzolar-S-Methyl, potassium phosphite, and potassium silicate on the leaf mineral concentration of peach. The experiment was carried out in Tezontepec, Puebla, in the years 2017 and 2018. The treatments consisted of the foliar application of the resistance inducers acibenzolar-S-Methyl, potassium phosphite, and potassium silicate. Inducers were applied at commercially recommended dose. The experimental design was in randomized blocks with four replicates. Foliar quantification of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, copper and silicon was carried out. The use of resistance inducers increases the leaf concentrations of calcium. The interaction of resistance inducers and years of application modified the foliar concentration of magnesium, phosphorus and sulfur in peaches.*
Key words: *Prunus persica, phosphorus, potassium phosphite, resistance induction.*

Concentração mineral da folha do pessegueiro após o uso de indutores de resistência

RESUMO: *O objetivo desta pesquisa foi estudar o efeito dos indutores acibenzolar-S-Metil, fosfito de potássio e silicato de potássio sobre o teor de minerais foliares do pessegueiro. O experimento foi realizado em Tezontepec, Puebla, nos anos de 2017 e 2018. Os tratamentos consistiram na aplicação foliar dos indutores acibenzolar-S-Metil, fosfito de potássio e silicato de potássio. Os indutores foram aplicados na dose comercialmente recomendada. O delineamento experimental foi em blocos casualizados com quatro repetições. Foi realizada a quantificação foliar de nitrogênio, fósforo, potássio, cálcio, magnésio, enxofre, cobre e silício. A interação de indutores de resistência e anos de aplicação modificou a concentração foliar de magnésio, fósforo e enxofre nas folhas de pessegueiro.*
Palavras-chave: *Prunus persica, fósforo, fosfito de potássio, indução de resistência.*

Resistance inducers are compounds of biotic or abiotic origin that, when applied to plants, induce the expression of genes that encode enzymes and metabolites related to the defense responses of plants against pathogens. It activates different defense pathways that lead to the production of reactive oxygen species, phytoalexin biosynthesis, reinforcement of the plant cell wall-associated with phenylpropanoid compounds, callose deposition and synthesis of defense enzymes (BAENAS et al., 2014).

The inducers acibenzolar-S-Methyl, potassium phosphite and potassium silicate, significantly reduce some diseases, since they activate enzymes such as peroxidase (POD), chitinase (CHT) and phenylalanine ammonium lyase (PAL) (DATNOFF et al., 2007; WALTERS et al., 2013; HAILEY & PERCIVAL, 2014). However, the use of inducers implies energetic attrition on the part of the plant. Energy diverted toward the production of defense is not available for other needs; thus, trade-offs should typically be inevitable (KARASOV et al., 2017). An important factor to consider is the nutritional status of the plant during the application of inducers, because if the nutrients

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are limiting, the allocation of a nutrient to defense may be accompanied by a reduction in the allocation to growth.

Various nutrients, when limited, are likely to influence the relationship between growth and defense. For example, defense responses involving salicylic acid, auxin, glucosinolates, and methyltransferases depend directly, or indirectly, on sulfur (S) availability and may involve the positive regulation of genes related to sulfur metabolism (KRUSE et al., 2007). The application of the inducers can modify the nutritional status of peach. Therefore, this research studied the effect of the inducers acibenzolar-S-Methyl, potassium phosphite, and potassium silicate on the leaf mineral concentration of peaches.

The experiment was carried out in commercial orchard with 8-year-old 'Atlax' peach trees grafted on criollo rootstock, established in a plantation scheme of 5 x 4 m, cultivated under rainfed conditions, during the 2017 and 2018 production cycle. The orchard is located in Tezontepec, Puebla, México at 19° 31' 32" N, 97° 31' 15" W and altitude of 2450 meters above sea level.

The effects of Acibenzolar-S-Methyl (Actigard® 50 GS), Potassium Phosphite (Hortikem Phos K®), Potassium Silicate (Silisec-K®), and without inducer were studied on leaf mineral concentration of peach. The three inducers were applied at commercially recommended dose of 75 $mg \cdot L^{-1}$, 3.5 $ml \cdot L^{-1}$, and 3 $ml \cdot L^{-1}$, respectively. Three applications of the inducers were carried out, at 40, 80, and 120 days after full flowering. The applications of the treatments were made with a previously calibrated Jacto® 20 L hand-held sprayer. All mixtures had Inex-A® adherent. The experimental design was in randomized blocks with four replicates. The experimental unit consisted of six trees; two rows were left between blocks and one row between treatments.

For all treatments, one fertilization per tree was carried out as follows: in spring 22 g of nitrogen (N), 10 g of phosphorus (P_2O_5), 64 g of potassium (K_2O), 48 g of calcium (Ca), and 8 g of magnesium (Mg) were applied and in autumn another 44 g of N were applied. The other crop management practices were carried out according to conventional management. The temperature and relative humidity were recorded in a HOBO H21-USB micro meteorological station (Onset Computer Corporation, Bourne, USA). The mean annual temperature and relative humidity were 14 °C and 73.3% in 2017 and 14.6 °C and 74.1% in 2018.

For the evaluation of the foliar nutritional status, samplings were done in the two years of evaluation and 50 healthy and fully developed leaves were collected from the middle part of the mixed branches at the four cardinal points of each experimental unit. The leaf nutrient concentration of N was determined by micro-Kjeldahl (HORNECK & MILLER, 1998), and of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and copper (Cu), by wet digestion with acid mixture (HNO_3-$HClO_4$-H_2SO_4). For the case of S and silicon (Si), digestion with HNO_3 and $HClO_4$ was used (ALCÁNTAR & SANDOVAL, 1999). The quantification was done with an inductively coupled plasma optical emission spectrometer (Model Liberty Series II Sequential, Varian® Brand, Germany). The analysis of the elements was carried out in quadruplicate samples.

For the statistical analysis, inducers and year of evaluation were considered. An analysis of variance was performed with a significance of $P \leq 0.05$ and when the interaction of the factors was significant, the LSD test was performed for the comparison of means ($\mu = 0.05$). The SAS (Statistical Analysis System) Software Version 9.0 was used in both cases.

According to the results obtained, the inducers did not affect the foliar concentration of N, K, Cu, and Si. However, the inducers and year interaction affected Ca, P, Mg, and S.

The Ca concentration increased 16% with the acibenzolar treatment with respect to the control (Figure 1). This result agreed with those reported by GORNI et al. (2016) who observed an increase in calcium concentration in *A. millefolium* plants treated with salicylic acid (SA). The acibenzolar inducer is an analog of SA, which would explain the increase in calcium concentration with this treatment. In addition to the structural role of calcium, the main function of calcium lies in its ability to serve as a secondary messenger in a wide variety of processes, among which is the response to biotic and abiotic stress (DANGL et al., 2013). Calcium is involved in the signaling of PAMP-triggered immunity (PTI) and effector-triggered immunity (ETI). These processes trigger a cascade of events involving the entry of Ca^{2+} into the cytosol, the production of reactive oxygen species (ROS), MAPK signaling, and the expression of defense genes (THOR, 2019).

The inducers increased the phosphorus concentration compared to the control, only in the first year of evaluation. The highest P concentration (0.24%) was presented in the interaction without inducer and year 2018 (Figure 2A), and P decreased

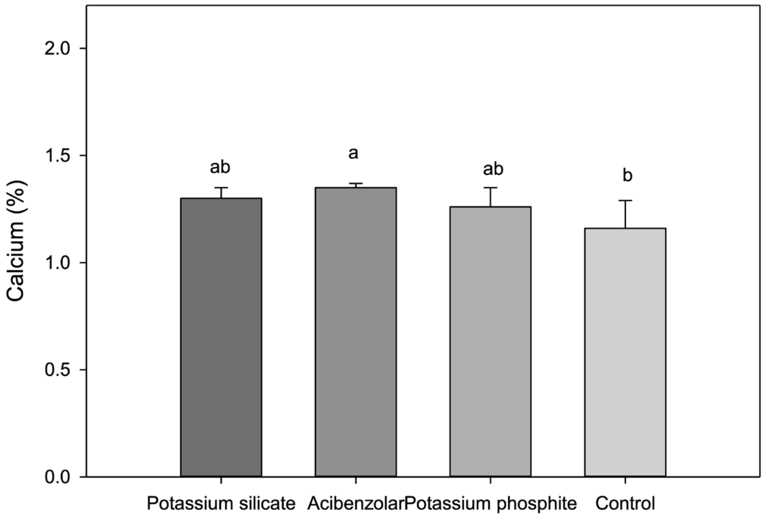

Figure 1 - Leaf calcium concentration in peach trees treated with resistance inducers during two years of evaluation. Each point represents the mean and the vertical bars indicate the standard deviation of the mean (n = 8). Different letters indicate significant differences (P < 0.05).

on average 17% with the use of inducers. The main theory suggested that the energy and resources that are diverted to the synthesis of defensive compounds cannot be used in the primary metabolism, causing growth reduction (KARASOV et al., 2017). However, the response of the phosphorus concentration after the application of the inducers was modified during the years of evaluation, so it is suggested to make more evaluations in field.

The potassium silicate and year 2017 interaction presented the highest leaf concentration of Mg and S, 0.53% and 1791.99 $mg \cdot kg^{-1}$, respectively; however, in 2018 their concentration decreased (Figure 2B, 2C). The increase in Mg and S with the use of potassium silicate, agrees with what was reported by MEHRABANJOUBANI et al. (2015), who observed that when applying silicon to canola, the concentration of Mg^{2+} was increased. In fruit trees such as orange, the use of potassium silicate was also tested and it was observed that the application of the inducer improved the nutritional status (EL-GIOUSHY, 2016).

The application of potassium silicate did not significantly modify the leaf concentration of Si in peach, compared to the control (data not shown), which is due to the fact that silicon is classified as a non-essential element according to the classical criteria postulated by Arnon and Stout (EPSTEIN, 1994). Nevertheless, it is considered a biostimulant in dicots (ZHU & GONG, 2014).

Results obtained indicate that the application of resistance inducers modified the leaf mineral concentration of peach trees in the production cycles of 2017 or 2018. This may be due to the fact that resistance induction is a complex response of plants. It is likely that its expression under field conditions is influenced by multiple factors, including the environment, genotype, crop nutrition, and the degree to which plants are already induced (WALTERS et al., 2013).

In the present research, the use of inducers increased the leaf concentrations of Ca. The interaction of inducers and the years of application modified magnesium, phosphorus, and sulfur foliar concentrations. Therefore, inducers by themselves do not modify the concentrations of these elements, the year in which the inductors were applied also influenced. More studies are needed in order to understand the effect of inducers applied in the field on the leaf concentration of nutrients in peach.

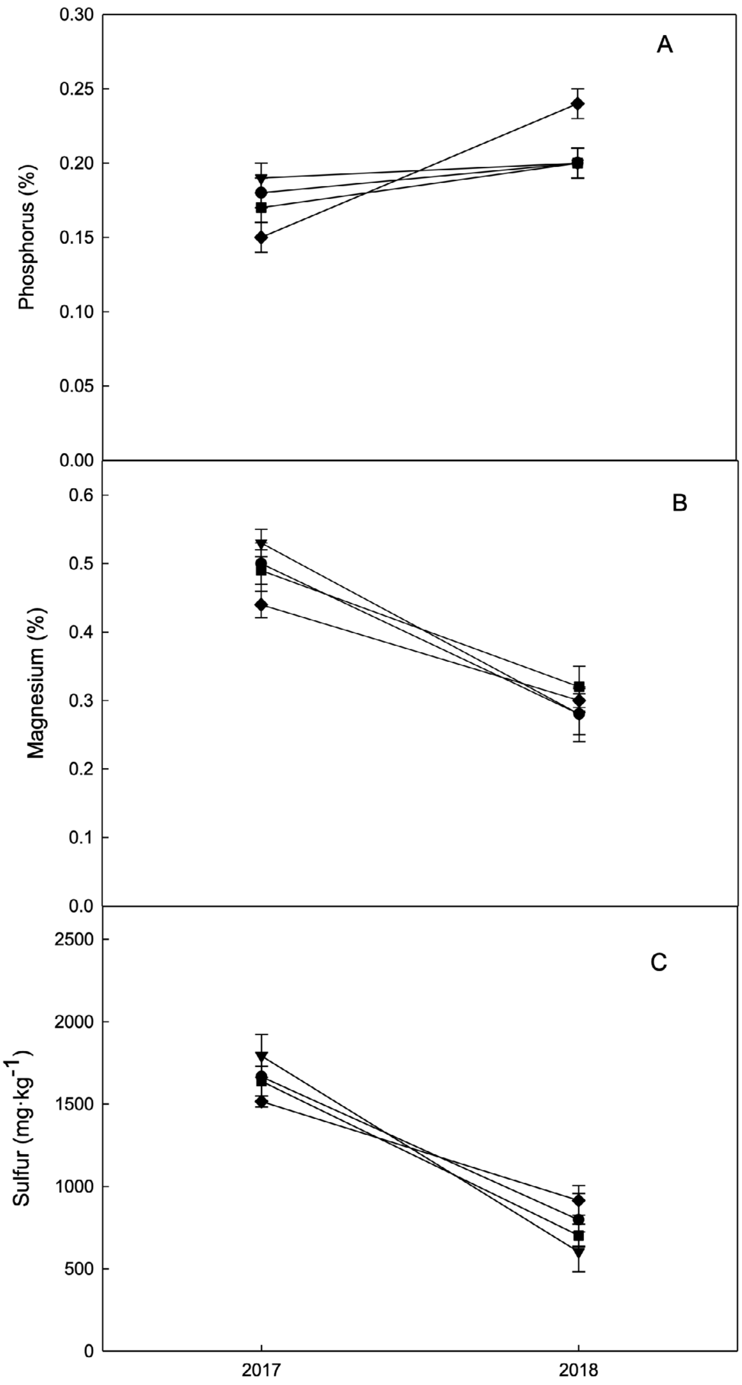

Figure 2 - Leaf concentration of phosphorus (A), magnesium (B), and sulfur (C) in peach trees treated with acibenzolar-S-Methyl (●), potassium silicate (▼), potassium phosphite (■), and without inducer (♦) for two years of evaluation. Each point represents the mean and the vertical bars indicate the standard deviation of the mean (n = 8).

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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