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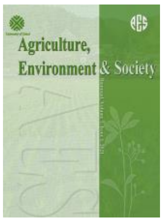

Potassium silicate and salicylic acid effects on onion thrips population density and some growth indices of onion cultivars

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ABSTRACT

Thrips tabacci Lind. (Thysanoptera: Thripidae), the onion thrips, is one of the most damaging pests to onion fields. By using biotic or abiotic stimuli or growth regulators, it is possible to induce resistance, which activates the plant's natural defense. The effect of foliar application of two growth regulators, salicylic acid and potassium silicate, separately and in combination, on onion thrips population density, fresh weight, dry weight, chlorophyll concentration, and height of onion cultivars was investigated in the Jiroft region between 2016 and 2017. The experiment was conducted as a factorial design with 12 replications. Two onion cultivars (Gardesco and Milky Way F1), salicylic acid (0, 0.25, 0.5 mM), and potassium silicate (0, 1, 2 cc. lit^{-1}) were used in three different concentrations. The analysis of variance revealed that the effect of biological fertilizer on thrips population density, fresh and dry weight, chlorophyll concentration, and the effect of onion cultivar on plant height and thrips population density were all statistically significant ($P_{value \leq}0.01$). Additionally, the interaction between fertilizer and cultivar was significant only for the pest population density parameter at the 1% level. The treatment with potassium silicate (2 cc. lit^{-1}) resulted in the highest fresh and dry weight values, 363.29 and 120.25, respectively. Milky Way F1 plants were taller (41.16 cm) than Gardesco plants (37.10 cm). These findings indicate that salicylic acid and potassium silicate have the potential to significantly reduce the *T. tabaci* population and should be considered in integrated pest management programs for this pest.

Highlights

- Resistance in plants can be induced by using biotic or abiotic stimuli or growth regulators.
- The effect of foliar application of two growth regulators on onion thrips population density and plant characteristics was studied in Jiroft.
- An onion cultivar's effect on plant height and thrips population density was statistically significant.
- Salicylic acid and potassium silicate may be used in *T. tabaci* integrated pest management programs.

1. Introduction

The onion is a biennial plant, *Allium cepa* L. (Alliaceae). Onion thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae), is one of the most important pests that damage onion fields (Rovenska and Zemek, 2006). Onion thrips indirectly reduce bulb yield by feeding on aerial parts of the plant (Trdan et al. 2005). Decreased bulb yield can be due to reduced leaf photosynthesis, degradation of transfer processes, and food consumption (Trdan et al. 2007). This pest is a vector of important viral diseases, such as tomato spot wilt disease and Iris yellow spot, and thus reduces the yield of onion fields by up to 50% (Trdan et al. 2007).

Considering the importance of the pest and its rapid resistance to various insecticides, it is necessary to develop a sustainable method for its integrated management. The use of resistance cultivars is also one of the environmentally friendly solutions and is one of the simplest and most important agronomic methods to manage onion thrips (Rovenska and Zemek, 2006). Insect-resistant cultivars can also increase the efficiency of natural enemies by reducing the ability of the pest to reproduce (Nouri-Ghanbalani, 1977). Many synthetic and hormonal compounds, including salicylic acid, have been used to control pests without considering their anti-vital effects (Vanpoecke and Dicke, 2004; Conrath, 2009). Induction resistance, which activates

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the plant's natural defense mechanism, can be used as a safe alternative and thus contribute to the development of sustainable agriculture (Edreva, 2004). In general, inducing resistance in plants using biotic or abiotic stimuli is one of the solutions approved by researchers in pest management (Cao et al. 2014).

Compared to most modification methods, which are generally long-term and costly, increasing plant resistance in various ways, including the use of growth regulators, is possible. Bartels and Sunkar (2005). Salicylic acid belongs to a group of phenolic compounds that are widely present in plants and play a key role in the development of immune responses and systemic acquired resistance (SAR) (Carr et al. 2010). This is a growth regulator that participates in the regulation of several physiological processes in crop plants, such as stomata closure, ion uptake, inhibition of ethylene biosynthesis, and transpiration (Chrzanowski et al. 2004; El-Mergawi and Abdel-Wahed, 2004). In addition, salicylic acid plays a key role in the plant's response to abiotic environmental stresses such as ozone, heat stress, chilling stress, and drought stress (Khandaker et al. 2011; Hak et al. 2012; Pradhan et al. 2016). Various reports have also shown that low concentrations of salicylic acid in plants cause defensive reactions against insects by affecting some volatile plant compounds (Engelberth et al., 2011; Lotfi et al., 2014; Dinary et al. 2015; Nayebzadeh et al., 2016). This combination attracts more natural enemies of pests to the plant and thus reduces the population of pests (James and Price, 2004).

The effect of salicylic acid (600 and 800 μM) on wheat showed induced resistance in wheat against the Russian wheat aphid, *Diuraphis noxia* (kurdjumov) (Dinary et al. 2015). Salicylic acid treatment of the Okapi rapeseed cultivar made it resistant to cabbage aphid (Lotfi et al. 2014). Using changes in salicylic acid concentration, the researchers conducted studies on two winter wheat cultivars and concluded that increasing the concentration of this compound in resistant cultivars reduces the nutrition of the aphid, *Sitobion avenae* F. (Chrzanowski et al. 2004). It has been reported that β-aminobutyric acid (BABA) and salicylic acid (SA) can induce resistance against the peach green aphid, *Myzus persicae* (Sulzer) in broad beans (*Vicia faba*) (Nayebzadeh et al., 2016). Potassium silicate is the potassium salt of silicic acid that is easily absorbed by plants and plays an important role in enhancing growth as well as increasing the quality and quantity of agricultural crops (Reilly et al. 2007). Potassium silicate, when used as a spray, limits the population of mites, whiteflies, and other insects; the effect of this compound on crops, pome, and stone fruit trees has been proven (Reilly et al. 2007). In fact, the presence of a very thin film of silicon on the leaf surface, by creating a physical and biochemical barrier, protects the plant against the attack of sucking and chewing insects (Reilly et al. 2007). Silica consumption also reduces fungal infections such as *Pseudocercospora griseola* (Sacc.) Crous & U. Braun in bean, *Phakopsora pachyrhizi* Syd. P. Syd. in soybean and *Podosphaera xanthii* Haustorium in cucumber (Liang et al. 2005; Rodrigues et al. 2009; Rodrigues et al. 2010; Cruz et al. 2013). Due to the high level of onion cultivation in the southern regions of Iran and the importance of onion thrips as one of the important pests (Rovenska and Zemek, 2006), applied research in the field can solve many problems in the production, sale, and export of this crop. Since there is no comprehensive study on the use of biological fertilizers on pests in Iran, the purpose of this study was to investigate the effects of salicylic acid and potassium silicate separately and in combination on *T. tabaci's* population density and growth indices of onion cultivars to manage this pest in onion fields.

2. Materials and Methods

2.1. Experimental design and induction treatments

The field experiments were conducted during the growing seasons (2016 and 2017) in a field (lat. 28.38 N, long. 57.47 E) located in Jiroft city, Kerman, Iran. The experiment was performed as a factorial experiment with a completely randomized design with 12 replications. Seeds of two onion cultivars, Milky Way F1 and Gardesco, were used. Onion seedlings were grown in loamy-clay soil containing poultry manure and drip irrigation. About three months after planting, after the establishment and growth of onion seedlings at the beginning of bulb growth, foliar application of treatments was performed. Experimental treatments include control (distilled water), salicylic acid (0.25 mM), salicylic acid (0.5 mM), potassium silicate (1 cc.lit^{-1}), salicylic acid (0.5 mM) + potassium silicate (1 cc.lit^{-1}), Salicylic acid (0.5 mM) + potassium silicate (1 cc.lit^{-1}), potassium silicate (2 cc.lit^{-1}), salicylic acid (0.25 mM) + potassium silicate (2 cc.lit^{-1}), salicylic acid (0.5 mM) + Potassium silicate (2 cc.lit^{-1}). The field conditions are such that each treatment has two stacks. (each plot contains two stacks). The width of each stack was 50 cm and its length was 200 cm (the width and length of the empty space between treatments were 50 and 200 cm, respectively). In other words, the total width of the ridge for each treatment, taking into account the empty space between them, was one and a half meters. Twenty-five days after treatment spraying, for each treatment from each plot, four plants were randomly cut from the plant base and transferred to the laboratory in a plastic bag.

2.2. Determination of thrips population density and plant growth parameters

We measured the population density of *T. tabaci* per plant, wet weight, dry weight, chlorophyll concentration, and height of onion cultivars. The wet weight (g per plant) and dry weight (g after drying at 70 °C for 48 hours) of the whole plant were measured with a digital scale to the nearest thousandth of a gram. In order to calculate the height (cm), the length of each plant was measured from the beginning of stem growth, about five cm above the bulbs, to the sharp end of the largest leaf. Chlorophyll concentration (SPAD number) was measured using the SPAD-502 chlorophyll meter. The SPAD number does not indicate the amount of chlorophyll but is an estimate of the chlorophyll concentration that has a high correlation with the amount of leaf chlorophyll. A

Chlorophyll meter shows the relative concentration of leaf chlorophyll based on the amount of light passing through the leaf at two wavelengths at which chlorophyll absorption is different (Hasibi, 2007). Analysis of variance was performed after transforming the data by the equation log (x +2) using SAS software (SAS 9.4) and multiple comparisons were made using the Tukey test (SPSS 2015).

3. Results and Discussion

3.1. Determination of thrips population density and plant growth parameters

The results showed that different treatments significantly affected the dry weight, fresh weight, chlorophyll concentration, and population density of onion thrips, but did not have significant effects on plant height. The effect of onion cultivars on plant height ($P \leq 0.01$) and thrips population density ($P \leq 0.05$) was also significant (Table 1). The interaction effect of fertilizer and cultivar only on thrips population density showed a significant difference ($P \leq 0.01$; Table 1).

In this study, the analysis of chlorophyll data in potassium silicate treatment (2 $cc.lit^{-1}$) (58.58%) was significantly higher than in salicylic acid treatments (0.25 mM). The highest amount and the lowest amount of dry weight and wet weight were observed in the potassium silicate treatment (2 $cc.lit^{-1}$) (120.250 and 363.29 g, respectively) and in salicylic acid treatments (0.5 mM) (47.67 and 272.96 g) and control (55.11 and 271.92 g), respectively (Table 2). In addition, the comparison of the mean data showed that the plant height in the Milky Way F1 cultivar (41.16 cm) is higher than in Gardesco (37.10 cm) (Table 2).

Table 1. Analysis of variance effect of different treatments of salicylic acid and potassium silicate, on onion growth parameters and population density of onion thrips

		Mean Squares				
Sources of Change	**DF**	**Fresh weight (g/ plant)**	**Dry weight (g/ plant)**	**chlorophyll content index (SPAD number) (%)**	**Plant height (cm)**	**Density (insect / plant)**
Growth regulator	8	0.07^{**}	0.35^{**}	0.00^{*}	0.01^{ns}	0.35^{**}
Cultivar	1	0.01^{ns}	0.00^{ns}	0.00^{ns}	0.15^{**}	0.50^{*}
Growth regulator* Cultivar	8	0.03^{ns}	0.00^{ns}	0.00^{ns}	0.01^{ns}	0.30^{**}
Error	187	0.03	0.05	0.00	0.02	0.10
Coefficient of variation (%)	-	3.87	5.94	0.91	3.73	11.24

ns, * and ** non-significant and significant level on 5% and 1% respectively

Table 2. Population density (mean ± SE) of *Thrips tabaci* Lind. and agronomic traits of onion varieties by application of salicylic acid and potassium silicate

	Characters			
Treatments	**Plant height (cm)**	**chlorophyll content index (SPAD number) (%)**	**Dry weight (g / plant)**	**Fresh weight (g / plant)**
Growth regulators				
Control (distilled water)	40.71a	55.38 ab	55.11 bc	271.92 b
Salicylic acid 0.25 mM	40.13 a	54.65 b	75.93 bc	285.54 ab
Salicylic acid 0.5 mM	38.86 a	55.34 ab	47.65 c	272.96 b
Potassium silicate 1 $cc.lit^{-1}$	38.45 a	55.76 ab	73.07 bc	340.33 ab
Salicylic acid 0.25 mM* Potassium silicate 1$cc.lit^{-1}$	37.56 a	56.28 ab	87.92 ab	294.79 ab
Salicylic acid 0.5 mM* Potassium silicate 1$cc.lit^{-1}$	38.58 a	56.59 ab	71.23 bc	304.08 ab
Potassium silicate 2 $cc.lit^{-1}$	39.98 a	58.58 a	120.25 a	363.29 a
Salicylic acid 0.25 mM* Potassium silicate 2 $cc.lit^{-1}$	38.21 a	56.66 ab	84.22 abc	301.96 ab
Salicylic acid 0.5 mM* Potassium silicate 2 $cc.lit^{-1}$	39.70 a	57.73 ab	79.83 bc	336.17 ab
Cultivars				
Milky way F1	41.16 a	56.13 a	77.04 a	302.78 a
Gardesco	37.10 b	56.52 a	77.45 a	313.01 a

Means with the same letters in each column do not show significant differences according to Tukey's test at 5% level

In the present study, the significant effects of salicylic acid and potassium silicate were evident on plant growth parameters, and the combination of the two compounds significantly reduced thrips population density. According to the results of this study, increasing the concentration of potassium silicate enhances the growth parameters of onions and reduces the population density of onion thrips. Several studies have shown the positive effect of salicylic acid and potassium silicate on reducing the population density of some pests (Ma et al. 2001; Rogerio et al. 2005; Nayebzadeh et al. 2016). Also, increased plant resistance to disease, improved growth, and increased yield using silica have been reported in plants such as squash, rice, and faba beans (Ghasemi et al. 2013; Jayawardana et al. 2014). Ranganathan et al. (2006) reported that increasing the concentration of silica in plant tissues can enhance the protective properties of the plant against biotic and abiotic stresses.

Amin et al. (2007) reported that low concentrations of salicylic acid (50 and 100 mg/ml) caused a significant increase in the height, fresh weight, and dry weight of onion plants. Research on soybeans and various wheat and maize cultivars has shown that low concentrations of salicylic acid increase the growth parameters of these plants (Iqbal et al., 2006); while other studies on tomatoes, wheat, maize and onions proved the inhibitory effect of high concentrations of this compound on plant growth (Abdel-Wahed et al. 2006; Amin et al. 2007). Growth regulators such as salicylic acid also affect plant physiological processes such as ion uptake, cell elongation, cell division, enzymatic activity, protein synthesis, and photosynthetic activity (Abdel-Wahed et al. 2006).

Analysis of onion growth parameters treated with salicylic acid (250 mg/ml) at six different time points (30, 45, 60, 75, 90, and 105 days after transplanting) showed that the plant height and chlorophyll content (SPAD number) of the plant grow significantly over time (Pradhan et al. 2016). The positive effect of this compound might be due to its effect on plant properties such as stomata closure, ion uptake, and inhibition of ethylene biosynthesis and transpiration (Pradhan et al. 2016). Salicylic acid increases the photosynthetic activity of the plant and thus increases the number of leaves per plant, the chlorophyll content and plant height (Hattori et al. 2005). This compound also has a significant effect on the morphology and physiology of the plant (Gharib, 2006; Pradhan et al. 2016). Similar reports have been recorded on the beneficial effects of salicylic acid on plant growth in terms of plant height, leaf number, and leaf chlorophyll content in several crops such as pepper, eggplant, red Amaranthus, garlic, and green peas (El-Tayeb, 2005; Bideshki and Arvin, 2010; Gawade and Sirohi, 2011; Khandaker et al. 2011). The effect of three concentrations of 25, 50, and 75 mg/l potassium silicate on chlorophyll content index (SPAD number) and the number of Asian lilium florets showed that the highest chlorophyll content index at harvest was related to foliar application of potassium silicate at the rate of 25 mg per liter and the number of florets per plant at this time was 5.27% (Mir Abbasi Najafabadi et al. 2014). The Concentration of 25 mg/l potassium silicate spray increased the chlorophyll content by 11.63% compared to potassium silicate solution. Increasing the concentration of silica in plant tissues can enhance the protective properties of the plant against biotic and abiotic stresses (Ranganathan et al. 2006).

Since silica is absorbed as mono silicic acid and converted to polysilicic acid in leaf epidermal cells, it accumulates in the cell wall and increases the plant's protective properties against pathogen penetration, insect attack ,and resistance of different plants against drought stress and high temperatures (Ma et al. 2001; Baker and Pilbeam, 2007). Reinforced cell walls of plants during drought stress or heat stress help to withstand stress by preventing compression of the xylems and reducing transpiration by reducing the diameter of the stomata (Ma et al. 2001).

Additionally, it has been shown that the use of silicon-containing compounds by foliar and soil application can significantly kill *Bemisia tabaci* (Gennadius, 1889) in squash (Rogerio et al. 2005).

Foliar use of silica as potassium silicate on citrus reduces the oviposition and longevity of *Planococcus citri* (Risso). In the present study, the effect of cultivars on thrips population density and plant height was significant, which could be due to morphological and biochemical differences between the studied cultivars. In some studies, the amount of wax, leaf color, and distance between leaves have been reported as the most important factors affecting the population density of the pest (Vanpoecke and Dicke, 2004). Further, seed priming with salicylic acid caused a significant increase in plant height and fresh weight compared to the control (Sharifi et al. 2015). From the results of the present study and the research of other researchers, it can be inferred that the type of cultivar has a significant effect on the studied parameters, such as thrips population density. It should also be noted that the method of application, growth regulator concentration, plant species, and growth stage are among the factors affecting the effectiveness of fertilizer compounds such as salicylic acid and potassium silicate. For example, when maize seeds were treated with 0.5 mM salicylic acid, it enhanced drought resistance, while using the same concentration as foliar application reduced drought resistance (Nemeth et al. 2002).

4. Conclusion

Since the management of fertilizer compounds is an important factor in the success of crop cultivation, identifying their compatible types with nature and suitable for the plant can have favorable effects on plant yield and, of course, plant pests. In this study, salicylic acid and potassium silicate had a significant effect on plant growth indices such as fresh weight, dry weight, and chlorophyll concentration. In addition, the combined use of salicylic acid and potassium silicate in comparison with the separate use of these compounds caused a significant reduction in the onion thrips population. It is also suggested that the extent of changes in the biochemical composition of onion cultivars when using different growth regulators can identify the factors involved in reducing the population of thrips. Therefore, fertilization, with better relative control and prevention of thrips damage, indirectly increases plant growth indices.

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