EFFECTS OF INCREASED CONDUCTIVITY OF THE NUTRIENT SOLUTIONS
AND OF THE ADDITION OF POTASSIUM SILICATE AGAINST ALTERNARIA JAPONICA
ON ROCKET (ERUCA VESICARIA) IN SOILLESS CULTIVATION

E.E. Cogliati, G. Gilardi, A. Garibaldi and M.L. Gullino

Centre for Agro-Environmental Innovation (AGROINNOVA), University of Torino,
Via Leonardo da Vinci 44, 10095 Grugliasco (TO), Italy

SUMMARY

The objective of this study was to evaluate the effects of potassium silicate and of the electrical conductivity of nutrient solutions in three experiments against Alternaria japonica attacks to rocket (Eruca vesicaria) grown in a closed soilless system. Potassium silicate was added at 100 mg l⁻¹ of nutrient solution at three different levels of electrical conductivity (EC): 1.5-1.6 mS cm⁻¹ (EC-1), 3-3.2 mS cm⁻¹ (EC-2, 0.70 g l⁻¹ NaCl) and 4-4.2 mS cm⁻¹ (EC-3, 0.95 g l⁻¹ NaCl). Rocket plants were inoculated with A. japonica conidia 18-38 days after sowing or transplant. Electrical conductivity values were negatively correlated with the incidence and severity of the disease, the highest conductivity solution giving the best results. The addition of potassium silicate to the different nutrient solutions resulted in a significant reduction of disease incidence and severity compared with a solution without silicate. The best results were given by the addition of silicate with the highest electrical conductivity (EC-3) in all the trials carried out. The suitability and benefits of applying silicon amendments in practice are discussed.

Key words: disease management, closed soilless system, leaf spots, cultivated rocket.

INTRODUCTION

In recent years, the soilless cultivation of vegetables, which is mainly developed in southern Europe, has shifted to the use of closed systems (Savvas and Gizas, 2002; Gullino et al., 2003; Garibaldi et al., 2004; Yaoku, 2007). Management of soilless crop diseases is important for preventing economic losses. Since few chemicals are registered for use in soilless crops, other methods of disease control need to be developed (Garibaldi and Gullino, 2010).

Silicon (Si) is an important nutritional element for and a relevant constituent of plants as it represents 0.1-10% of the plant’s dry weight, according to the species (Epstein, 1994, 1999; Ma and Takahashi, 2002). Silicon accumulation in plant tissues is important for increasing plant resistance to harmful environmental factors such as drought, heavy metals, and salinity (Fauteux et al., 2005; Tuna et al., 2008; Doncheva et al., 2009; Savvas et al., 2009). Silicon amendments proved effective in suppressing soil-borne, foliar and post-harvest pathogens in turfgrass (Zhang et al., 2006; Nanayakkara et al., 2008). The inhibitory effects of silicate potassium on five pathogenic fungi (Shen et al., 2010) and the silicon-mediated resistance to plant pathogens in several pathosystems, i.e zucchini-Podosphaera xanthii (Savvas et al., 2009), wheat-Erysiphe graminis f. sp. tritici (Provance-Bowley et al., 2010), sorghum-Colletotrichum sublineolum (Resende et al., 2009), Lolium perenne-Magnaporthe oryzae (Nanayakkara et al., 2008), and bell pepper-Phytophthora capsici (Lee et al., 2004), have been recently demonstrated. Moreover, experiments in different soilless cultivation systems have shown the reductive and suppressive effects of potassium silicate on powdery and downy mildews of strawberry (Sphaerotheca fuliginea), tomato (Oidium neolycopersici) and lettuce (Bremia lactucae) (Kanto et al., 2004; Garibaldi et al., 2011a, 2011b).

Although the mechanisms involved in Si-mediated reduction of plant diseases remain unclear, various researchers have suggested that Si provides disease control because of the creation of a mechanical barrier against the pathogen penetration (Kim et al., 2002). Indeed, when Si administered to cucumber plants was interrupted, the prophylactic effects against powdery mildew were lost (Samuels et al., 1991). Several studies have suggested that Si activates plant defence mechanisms through the production and accumulation of antifungal low-molecular weight metabolites during pathogenesis (Cherif et al., 1994; Fawe et al., 1998). For instance, in the wheat-Blumeria graminis f. sp. tritici pathosystem, epidermal cells of Si-treated plants were...
shown to react to infection with specific defence reactions such as papilla formation and callose production (Belanger et al., 2003). Si-mediated resistance of rice to Magnaporthe grisea was shown to be associated with the accumulation of antimicrobial compounds, such as diterpenoid phytoalexins, at infection sites (Rodrigues et al., 2004). However, the mechanism by which Si modulates plant signalling remains unclear, although it could act as a potentiator of defence responses or as an activator of signalling proteins (Fauteux et al., 2005, 2006).

In arid and semiarid regions, agricultural crops, including soilless systems, are frequently irrigated with saline water, which may affect plant growth, production, metabolism and resistance to pathogens (Kylin and Quatrano, 1975; Poljakoff-Mayber, 1975; Hasegawa et al., 2000). A few pathogens, including Aspergillus, Penicillium, Fusarium spp. and Phytophthora spp. (Tresner and Hayes, 1971; MacDonald, 1982; Blaker and MacDonald, 1985) are highly tolerant to salt in culture. However, suppression of disease under saline conditions has been reported with Fusarium wilt of date palm (Brac de la Perriere et al., 1995), Rhizoctonia crown and root rot of table beet (Elmer, 1997), Fusarium crown and root rot of asparagus (Elmer, 2003) and Fusarium wilt of cyclamen (Elmer, 2002). Recently, it was demonstrated that an increase in the electrical conductivity of nutrient solution in soilless systems has positive effects in reducing pathogen attacks in tomato-Oidium neolycopersici and lettuce-Bremia lactucae pathosystems (Garibaldi et al., 2011a, 2011b).

Rocket is an important minor vegetable crop in Italy (Bianco, 2009) and its protection from pathogens is needed (Poschenrieder et al., 2000; Garibaldi et al., 2011c), including the foliar ones such as Alternaria japonica which has recently been observed on both wild (Diplotaxis tenuifolia) and cultivated (Eruca vesicaria) rocket in Italy (Garibaldi et al., 2011c).

The objective of this work was to evaluate the effect of potassium silicate amendments on nutrient solutions for their effect against A. japonica incidence and severity in soilless-grown rocket. The efficacy of silicon was tested under varying levels of electrical conductivity of nutrient solutions.

MATERIALS AND METHODS

Inoculum preparation and artificial inoculation. A. japonica conidia were recovered from lesions on rocket plants by shaking naturally infected leaves in 200 ml of sterile water containing 5 μl of Tween 20. The resulting suspensions were adjusted with the aid of a haemocytometer to 1.2-3×10⁵ conidia ml⁻¹. Inoculation was done by spraying the conidial suspension with a laboratory spray glass (20 ml capacity) onto rocket leaves 18-38 days after sowing or transplant. Conidial suspensions (5 ml) were sprayed to all plants used in each treatment. After inoculation, plants were covered with plastic to maintain a high level of relative humidity. Inoculations were carried out once in all trials.

Plant cultivation. Rocket seeds were sown in pots (12-15 seeds/pot) containing 3 litres of peat-perlite substrate (1:3 v/v). The pots were maintained on benches in the greenhouse at temperatures between 20 and 26°C and, after germination, were put into the soilless system for growth. In the case of trial 1, rocket seeds were sown directly in pots already placed in the soilless system (Table 1).

Experimental conditions. Three experimental trials were carried out at Grugliasco (Torino) in a glasshouse. In each trial, three nutrient solutions with different electrical conductivities (EC) (EC-1, EC-2 and EC-3) or with no EC (controls), and with the addition of potassium silicate (EC-1+Si, EC-2+Si and EC-3+Si) were applied.

---

**Table 1. Summary of the layout and operations of the different trials carried out at Grugliasco (Italy) on rocket plants (Eruca vesicaria cv. Rucola cultivata).**

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of sowing</td>
<td>February 2, 2011</td>
<td>May 6, 2011</td>
<td>June 13, 2011</td>
</tr>
<tr>
<td>Date of transplant</td>
<td>-</td>
<td>May 13, 2011</td>
<td>June 16, 2011</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>20-24</td>
<td>26-28</td>
<td>26-28</td>
</tr>
<tr>
<td>Nutrient solutions tested</td>
<td>EC-1, EC-2, EC-3, EC-1+Si, EC-2+Si, EC-3+Si*</td>
<td>EC-1, EC-2, EC-3, EC-1+Si, EC-2+Si, EC-3+Si</td>
<td>EC-1, EC-2, EC-3, EC-1+Si, EC-2+Si, EC-3+Si</td>
</tr>
<tr>
<td>Nutrient solution (and conidial concentration)</td>
<td>March 15, 2011 (1.2x10⁵ conidia ml⁻¹)</td>
<td>May 31, 2011 (3x10⁵ conidia ml⁻¹)</td>
<td>July 4, 2011 (2x10⁵ conidia ml⁻¹)</td>
</tr>
</tbody>
</table>

* EC-1: control nutrient solution; EC-1+Si: control nutrient solution plus potassium silicate at 100 mg l⁻¹; EC-2: control nutrient solution plus NaCl at 0.70 g l⁻¹; EC-2+Si: control nutrient solution plus NaCl at 0.70 g l⁻¹ and potassium silicate at 100 mg l⁻¹; EC-3: control nutrient solution plus NaCl at 0.90 g l⁻¹; EC-3+Si: control nutrient solution plus NaCl at 0.90 g l⁻¹ and potassium silicate at 100 mg l⁻¹.
plied immediately after sowing (trial 1) or immediately after germination (trials 2 and 3). Thus, each trial consisted of six treatments. The pots were placed over six channels measuring 6 m in length by 25 cm in width. Each hydroponic unit consisted of one channel connected with a storage tank (300 litres), filled with the nutrient solutions, which was automatically delivered to the plants with the aid of an electronic control unit programme (Idromat 2, Calpeda, Italy). Nutrient solutions were delivered by drip irrigation, by means of emitters (one per pot) at a flow rate of 6 l h⁻¹, at 4-7-9-11 a.m. (2 min), 1-3-5 p.m. (3 min) and 8-12 p.m. (2 min). The irrigation plan was revised according to the environmental conditions.

In a closed fully automated soilless system, the nutrient solution was pumped from the water storage tank, fed to the plants and left to drain back to the storage tank by gravity. The excess of nutrient solution was filtered with the slow sand method that was used for fertilization.

The composition of the base nutrient solution (EC-1) was 11.24 mM NO₃⁻, 4.8 mM NH₄⁺, 0.75 mM KH₂PO₄, 0.75 mM K₂SO₄, 0.012 mM Iron chelate EDTA, 2 mM MgO, 2 mM SO₃, 0.2 mM B, 0.012 mM Mo, 0.15 mM Zn, 3.1 mM CaO, 0.05 mM Cu⁺², 0.25 mM Mn, 12.2 mM K, 3.1 mM CaO, 0.05 mM Cu⁺², 0.25 mM Mn, 12.2 mM K.

The electrical conductivity in the low salinity nutrient solution (EC-1) was 1.5-1.6 mS cm⁻¹. The concentration of nutrient solutions EC-2 and EC-3 was identical to EC-1, except that NaCl was added at a rate of 0.70 and 0.95 g l⁻¹ to achieve an electrical conductivity of 3.0-3.2 and 4.0-4.2 mS cm⁻¹, respectively. Nutrient solutions EC-1+Si, EC-2+Si and EC-3+Si were prepared by adding 100 mg l⁻¹ of potassium silicate salt (K₂SiO₃, 33.7-34.7%). Since the potassium silicate salt has a strong alkaline reaction, it was delivered to the nutrient solutions from a separate stock solution tank.

The pH and the EC values were regularly registered by means of a portable pH meter and a conductivimeter SevenGo DUO TM SG23 (Tettler, Spain). The pH of all nutrient solutions was adjusted to 6.0 with citric acid (Greengeo, Italy) or sodium hydroxide (Sigma-Aldrich, Switzerland) as required.

Ninety pots of rocket belonging to cv. Rucola cultivata were used for each trial. On each trial six treatments were tested and divided in four replicates and a non-inoculated control. All replicates of the same treatment were managed similarly in terms of delivery, storage and disinfection of drained nutrient solutions. Fifteen pots were used per treatment and three pots per replicate (36-40 plants/replicate).

Data collection and analysis. Plants were checked weekly for disease development. The percentage of rocket leaves affected by A. japonica (disease incidence) was evaluated scoring 50 rocket leaves per replicate.

Disease severity was evaluated by using a disease index ranging from 0 to 5 (EPPO, 2004), based on the percentage of leaf area covered with lesions, in which 0 = healthy plant; 1 = 1-5% of leaf area affected; 2 = 6-10% leaf area affected; 3 = 11-25% leaf area affected; 4 = 26-50% leaf area affected; 5 = >50% leaf area affected. The final disease rating took place 13 (trial 2) and 14 (trials 1 and 3) days post inoculation (dpi). Data were expressed as percentage of diseased leaves (disease incidence) and percentage of leaf area with lesions of A. japonica (disease severity) by using the EPPO rating method (EPPO, 2004). Data were analysed by univariate ANOVA with Tukey’s multiple range test (P=0.05) using SPSS software 18.0. The general linear model was used to investigate the effect of each factor (EC and potassium silicate) and their interactions in each trial.

RESULTS

Signs of A. japonica infection were first observed 3-5 days post inoculation in all trials. Control rocket plants, grown with EC-1 nutrient solution without Si, showed a final mean disease severity of 9.6% in trial 1, 8.2% in trial 2 and 3.8% in trial 3, while the final mean disease incidence was 46.3% in trial 1, 56% in trial 2 and 30% in trial 3 (Tables 2, 3, 4).

Effect of electrical conductivity of nutrient solution on A. japonica development. The general linear model analysis confirmed that NaCl, added to the control nutrient solution EC to increase it to EC-2 and EC-3 levels was a significant factor (P<0.0001), influencing both disease incidence and severity in all the three trials.

In particular, in trial 1, with respect to 46.3% disease incidence observed in control plants grown with the base nutrient solution, the highest salinity nutrient solution reduced disease incidence to 22% and disease severity from 9.6 to 1.7% (Table 2). Similarly, in trial 2 the highest salinity nutrient solution reduced disease incidence from 56 to 29.5% and disease severity from 8.2 to 2.6% (Table 3). In trial 3, disease incidence was significantly reduced from 30 to 11% by the highest salinity nutrient solution and disease severity from 3.8 to 0.8% (Table 4).

Effect of potassium silicate on A. japonica development. According to the general linear model analysis the presence of potassium silicate, added to the nutrient solutions EC-1, EC-2 and EC-3, was a significant factor influencing disease index and severity in trials 1 and 2 (P<0.005) but not in trial 3 (P=0.049 and P=0.077). Under a moderate to a high level of disease pressure (30-56% of infected leaves), when neither NaCl nor K₂SiO₃ were added to the base nutrient solution, addition of sodium chloride and potassium silicate resulted in lower
Table 2. Effect of electrical conductivity (EC) and of potassium silicate on incidence and severity of leaf spots caused by *A. japonica* on rocket plants (cv. Rucola cultivata) expressed respectively as percentage of infected leaves and percentage of affected leaf area (Trial 1).

<table>
<thead>
<tr>
<th>Electrical conductivity (EC)</th>
<th>Infected leaves (%)</th>
<th>Affected leaf area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 dpi</td>
<td>14 dpi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 dpi</td>
</tr>
<tr>
<td>EC-1b</td>
<td>57 c</td>
<td>46.3 c</td>
</tr>
<tr>
<td>EC-1+Si</td>
<td>32.5 b</td>
<td>31.8 b</td>
</tr>
<tr>
<td>EC-2</td>
<td>33.3 b</td>
<td>31.8 b</td>
</tr>
<tr>
<td>EC-2+Si</td>
<td>23 ab</td>
<td>25 ab</td>
</tr>
<tr>
<td>EC-3</td>
<td>23.5 ab</td>
<td>22 ab</td>
</tr>
<tr>
<td>EC-3+Si</td>
<td>18.3 a</td>
<td>16.8 a</td>
</tr>
</tbody>
</table>

a Potassium silicate at 100 mg l⁻¹.
b EC-1 Nutrient control solution.
c The values of the same column, followed by the same letter do not differ significantly according to Tukey’s test (P=0.05).

According to the general lineal model at the last assessment, considering the disease incidence, the EC and potassium silicate were a significant factor (P<0.0001 and P=0.003) while their interaction was not significant (P=0.323). Considering the disease severity, the EC, potassium silicate and their interaction were significant factor (P<0.0001).

Table 3. Effect of electrical conductivity (EC) and of potassium silicate on incidence and severity of leaf spots caused by *A. japonica* on rocket plants (cv. Rucola cultivata) expressed respectively as percentage of infected leaves and percentage of affected leaf area (Trial 2).

<table>
<thead>
<tr>
<th>Electrical conductivity (EC)</th>
<th>Infected leaves (%)</th>
<th>Affected leaf area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 dpi</td>
<td>14 dpi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC-1b</td>
<td>35.3 d</td>
<td>56 d</td>
</tr>
<tr>
<td>EC-1+Si</td>
<td>28.3 cd</td>
<td>44.8 c</td>
</tr>
<tr>
<td>EC-2</td>
<td>34.5 d</td>
<td>45.5 c</td>
</tr>
<tr>
<td>EC-2+Si</td>
<td>21.5 bc</td>
<td>34.5 b</td>
</tr>
<tr>
<td>EC-3</td>
<td>13.8 ab</td>
<td>29.5 b</td>
</tr>
<tr>
<td>EC-3+Si</td>
<td>9.5 a</td>
<td>15.7 a</td>
</tr>
</tbody>
</table>

a Potassium silicate at 100 mg l⁻¹.
b EC-1 Nutrient control solution.
c The values of the same column, followed by the same letter do not differ significantly according to Tukey’s test (P=0.05).

According to the general lineal model at the last assessment, considering the disease incidence, the EC and potassium silicate were a significant factor (P<0.0001) while their interaction was not significant (P=0.613). Considering the disease severity, the EC and potassium silicate were a significant factor (P<0.0001) while their interaction was not significant (P=0.760).

Table 4. Effect of electrical conductivity (EC) and of potassium silicate on incidence and severity of leaf spots caused by *A. japonica* on rocket plants (cv. Rucola cultivata) expressed respectively as percentage of infected leaves and percentage of affected leaf area (Trial 3).

<table>
<thead>
<tr>
<th>Electrical conductivity (EC)</th>
<th>Infected leaves (%)</th>
<th>Affected leaf area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 dpi</td>
<td>14 dpi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC-1b</td>
<td>31.8 d</td>
<td>30 c</td>
</tr>
<tr>
<td>EC-1+Si</td>
<td>26.3 cd</td>
<td>26.8 bc</td>
</tr>
<tr>
<td>EC-2</td>
<td>18.3 bc</td>
<td>25.8 bc</td>
</tr>
<tr>
<td>EC-2+Si</td>
<td>12.8 ab</td>
<td>20.8 b</td>
</tr>
<tr>
<td>EC-3</td>
<td>6.5 a</td>
<td>11.3 a</td>
</tr>
<tr>
<td>EC-3+Si</td>
<td>7.3 a</td>
<td>10.3 a</td>
</tr>
</tbody>
</table>

a Potassium silicate at 100 mg l⁻¹.
b EC-1 Nutrient control solution.
c The values of the same column, followed by the same letter do not differ significantly according to Tukey’s test (P=0.05).

According to the general lineal model at the last assessment, considering the disease incidence, the EC was a significant factor (P<0.0001) while the potassium silicate and their interaction were not significant factor (P=0.049 and P=0.544). Considering the disease severity, the EC was a significant factor (P<0.0001) while the potassium silicate and their interaction were not significant factor (P=0.077 and P=0.428).
disease incidence and severity in all three trials. The best results were achieved in combination with the higher electrical conductivity nutrient solution. In trial 1, disease incidence was reduced from 46.3% of the control plants to 16.8% with the higher electrical conductivity nutrient solution and disease severity from 9.6 to 1.4% (Table 2). Similarly, in trial 2, disease incidence was decreased from 56 to 15.7% and disease severity from 8.2 to 0.9% (Table 3). Also in trial 3 the higher electrical conductivity nutrient solution reduced the disease incidence from 30 to 10.3% and the disease severity from 3.8 to 0.8% (Table 4).

However, comparing nutrient solutions with the same electrical conductivity with or without potassium silicate does not always discloses differences. In trial 1, in the last assessment, statistical difference was seen only by comparing EC-1/EC-1+Si for both disease incidence and severity, but not comparing EC-2/EC-2+Si and EC-3/EC3+Si (Table 2). In trial 2, statistical differences were found between all treatments with the same electrical conductivity for disease incidence EC-1/EC-1+Si, EC-2/EC-2+Si and EC-3/EC-3+Si, but for the disease severity there was only a difference between the nutrient solutions EC-2/EC-2+Si (Table 3). In trial 3, there were no statistical differences between nutrient solutions with or without potassium silicate for both disease incidence and disease severity (Table 4).

DISCUSSION

The beneficial effects of saline water to induce resistance against pathogens is well documented. For instance, its efficacy was demonstrated for Rhizoctonia crown and root rot of table beet (Elmer, 1997), Fusarium wilt of cyclamen (Elmer, 2002), Fusarium crown and root rot of asparagus (Elmer, 2003) and on tomato-Oidium neolycopersici and lettuce-Bremia lactucae soilless pathosystems (Garibaldi et al., 2011a, 2011b).

In our trials, according to the general lineal model, the electrical conductivity was a significant factor influencing both disease incidence and severity in all the trials. The addition of NaCl (70 g l$^{-1}$ and 95 g l$^{-1}$) reduced significantly the number of infected leaves and the percentage of affected leaf area compared with the control solution EC-1. This was evident particularly in the presence of EC-3, which had the highest NaCl content. The potassium silicon salt, added at 100 mg l$^{-1}$ to the nutrient solutions EC-1, EC-2 and EC-3, was a significant factor influencing the reduction of disease incidence and severity in trials 1 and 2 but not in trial 3. No interaction was found between EC and potassium silicon.

Nevertheless, the addition of potassium silicate to the nutrient solutions EC-2 and EC-3 showed a high and significant reduction of disease incidence and severity if compared with the control nutrient solution EC-1. The higher reduction on disease incidence and severity was obtained by adding 100 mg l$^{-1}$ of potassium silicon salt to the nutrient solution having the highest electrical conductivity.

The effect of silicate salt in reducing the incidence and severity of several diseases in a number of crops has been confirmed by extensive research (Fauteux et al., 2005; Walters and Bingham, 2007). In this study the efficiency of potassium silicate, supplied via nutrient solution in a soilless system, has been demonstrated for the first time in the rocket-A. japonica pathosystem.

Although Si is not usually classified as an essential element of higher plants, many species accumulate Si in their tissues and its beneficial role in the nutrition is well established (Epstein, 1995, 2009). In fact, it is well documented that Si provides disease control in rice plants due to the creation of a mechanical barrier to the penetration of pathogens (Kim et al., 2002). Similarly, the incidence of diseases in wheat caused by Erysiphe graminis and Septoria nodorum was reduced by sodium trisilicate amendments to the potting mix (Leusch and Buchenauer, 1989).

Moreover, silicon is involved in cellular processes aimed at protecting the plant from fungal diseases. Many types of organic compounds and complexes show affinity to silicon. Silicon can be involved in the polymerization of silicic acid, leading to the formation of hydrated silica and of organic defence compounds, such as lignin-carbohydrate complexes in the cell walls of epidermal cells, thus increasing their resistance to degradation by enzymes released under stress. The reinforcement of the cell wall by deposition of solid silica is one of the ways in which silicon-induced protection operates (Epstein, 2009). Si and lignin content were also significantly increased in Si-treated rice seedlings inoculated with Magnaporthe grisea (Cai et al., 2008). Fauteux et al. (2006) examined the role of silicon in Arabidopsis thaliana plants affected by powder mildew, and found that silicon promoted a response in which numerous genes were differentially expressed in these plants. These studies provide a possible explanation about the mechanisms involved in the significant reduction of both incidence and severity disease in the rocket-A. japonica pathosystem obtained in our trials. Finally, the application of silicon salts to the roots allows the plants to absorb and accumulate silicon in their tissues better than direct spraying onto leaves (Dallagnol et al., 2012), and it was suggested that both disease resistance and Si content in the leaves are directly related to the amount of Si available to the roots (Dann and Muir, 2002). Therefore, soilless systems seem especially suitable to deliver silicon salts for plant protection purposes.

Negative effects of silicon on human health have not been found. On the contrary, silicon has a protective role in some human disease; for example, it positively affects bone mass and skeletal development and pre-
vents osteoporosis (Eisinger and Clairet, 1993; Pérez-Granados and Vagueno, 2002; Sripanyakorn et al., 2005). Therefore, if the silicon content of leaves is increased, this may prove beneficial from the human health point of view.

In conclusion, the application of potassium silicate via nutrient solution protected the hydroponically-grown *E. vesicaria* from an important pathogen. The implications of this finding are of consequence, as soilless systems are increasingly being used and few registered fungicides are available. Furthermore, as silicon salts are the waste product of some industrial processes (Jenck et al., 2004), a recycling process can be promoted and ecological sustainability can be implemented. Supplied via nutrient solution, silicon is a cost-effective way to reduce the number of foliar fungicide sprays, and is compatible with an integrated disease management approach.

ACKNOWLEDGEMENTS

Work carried out within the project BYFRIEND, Polo della Chimica Sostenibile, funded by the Regione Piemonte and European Union (European fund for development POR FESR 2007/2013, Asse I - I.1.3 Innovazione e PMI). The authors thanks Dr. Deanna Palmer for language revision.

REFERENCES


Blaker N.S., MacDonald J.D., 1985. Effect of soil salinity on the forming of sporangia and zoospores by three isolates of *Phytophthora*. *Phytopathology* **75**: 270-274.


Dann E.K., Muir S., 2002. Peas grown in media with elevated plant-available silicon levels have higher activities of chitinase and beta-1,3-glucanase, are less susceptible to a fungal leaf spot pathogen and accumulate more foliar silicon. *Australasian Plant Pathology* **31**: 9-13.


First report of leaf spot of wild (Diplotaxis tenuifolia) and cultivated (Eruca vesicaria) rocket caused by Alternaria japonica in Italy. Plant Disease 10: 1316-1316.


