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Performance of Three Silicon Sources in Suppressing *Rhizoctonia solani* Diseases on Sage (*Salvia officinalis* L.) and in Improving Yield of Plant Herb and Essential Oil

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ABSTRACT

Isolation trials from infected sage seedlings and plants, growing in Ismailia, North Sinai and Qalubyia governorates, showing symptoms of damping –off and root rot diseases yielded *Fusarium oxysporum, F. solani, Macrophomina phaseolina, Pythium ultimum* and *Rhizoctonia solani.* However, *R. solani* recorded the highest frequency in isolation (52.6%), followed by *Fusarium solani* (24.6%), while *M. phaseolina* was the least (3.5%). These fungi were found to be pathogenic to sage seedlings. *Rhizoctonia solani* followed by *F. solani* were the most virulent fungi, causing the highest damping – off incidence. Three silicon (si) sources, *i.e.* calcium silicate, potassium silicate and sodium silicate with four concentrations (25, 50, 100 and 200 ppm) significantly inhibited the *in vitro* growths of *R. solani* in different degrees. Potassium silicate was more effective than the other silicon sources tested, and completely inhibited mycelial growth at 200 ppm. Soaking seeds (30 min.) and /or dipping treatment for seedlings (30 min.) in each of these silicon sources (400 ppm) or the fungicide Vitavax /Thiram (3 g/l water) gave sufficient control to *R. solani* diseases, *i.e.* damping –off in greenhouse and nursery as well as root rot in the field .Also, they recorded significant increases in growth parameters of seedlings (height & root length) and mature plants (height & no. of branches /plant). Potassium silicate, however, was significantly the most effective treatment among other silicon sources. Using calcium silicate and potassium silicate as dipping treatment for seedlings, gave significant increases in yields of fresh herb and essential oil content. Vitavax /Thiram treatment in the nursery and field experiments was more effective than silicon treatments, except with potassium silicate in the field, which increased fresh herb weight per plant and essential oil content than the fungicide.

Keywords: Sage (*Salvia officinalis*), Rhizoctonia diseases, calcium silicate, potassium silicate, sodium silicate, plant growth and plant yield (herb and oil).

INTRODUCTION

Sage, garden sage or common sage (*Salvia officinalis* L.) is one of the most important medicinal and aromatic plants relating to family lamiaceae grown in Egypt and all over the world. A good phytosanitary state of plants during their cultivation is a condition for a high quality yield and raw material of sage leaf (folia salviae and herba salviae) (Zimowska, 2008). It is native to the Mediterranean region with a herb of ancient repute, valued as a culinary and medicinal plant as well as its usage in some pharmaceutical preparations .It is also serves as a source of natural anti-oxidants. The principal constituents of essential oil are thujone (about 42%), cineole, borneol caryophyllene and other terpenes (Lawless, 1992).

Rhizoctonia solani diseases (damping –off, root rot and /or aerial blight) caused severe losses in vegetative growth and stand of seedlings and plants as well as considerable reduction in sage plant yield (Subbiah *et al*., 1996, Voltolina, 2001 and Zaki and Waleed, 2008). Also, Rhizoctonia diseases infection yielded the same negative impact on other medicinal and aromatic plants (Hilal *et al.*, 1998, Hilal and Baioumy, 2000, Conway *et al*., 1992 and Conway *et al*., 1997, Bano *et al*., 2012 and Nada, 2014 and 2015).

Silicon (Si) is one of the most plentiful elements on the earth's surface and is known to play an important role in plant growth and development (Epstein, 1994 and Datnoff *et al.,* 2001). Silicon amended to soil or nutrient solution low in soluble silicon, exhibited the improvement of plant growth and yield, increased disease and insect resistance and reduced mineral toxicities (Belanger *et al*., 1995, Savant *et al*., 1999 and Saigusa *et al*., 2000). Soluble silicon has shown potentiality for the increasing resistance to fungal diseases such as powdery mildew and root rot (Epstein, 1994 and Belanger *et al.,* 1995), which infecting cherry fruit, cucumber, muskmelon, Squash and peach (Menzies *et al*., 1992, Biggs *et al*., 1997 and Qin and Tian, 2005). Also,it was found to be effective in controlling Fusarium wilt on many economic important crops (Datnoff *et al*., 2007) . For soilborne pathogens, amendment of Si to soil or to nutrient solution led to decrements in the intensities of diseases caused by *Pythium ultimum* and *Pythium aphanidermatum* on cucumbers, *Phytophthora capsici* on bell peppers, *Fusarium oxysporum* f. sp. *radicis–lycopersici* on tomatoes and *F. oxysporum* f.sp. *cubense* on banana (Belanger *et al*., 1995, Cherif *et al*., 1992a, b: Dannon and Wydra, 2004, French - Monar *et al*., 2010, Huang *et al*., 2011, Fortunato *et al*., 2012 and Nada *et al*., 2014).

The present study was mainly designed to evaluate performance of applying silicon (Si) for controlling *R.solani* diseases on sage by soaking seeds and /or dipping seedlings in soluble silicon in comparison with the fungicide Vitavax/Thiram under greenhouse, nursery and field conditions .Also, improvement of plant growth parameters as well as increase in herb yield per plant and essential oil content were considered.

MATERIALS AND METHODS

Isolation and identification of the associated fungi to damping-off and root rot diseases and their frequency (%):

Sage seedlings and plants showing damping –off and/or root rot symptoms were collected from different locations at Ismailia, North Sinai and Qalubyia governorates during 2011/12 and 2012/13 growing seasons. Infected roots and stems were washed several times under tap and sterile water , cut into small pieces , surface sterilized by immersing in 3% sodium hypochlorite for 2 min, washed in several changes of sterile water then aseptically transferred into PDA plates and incubated at 25$\pm$ 2^{0}C for 7 days . The growing fungi were purified and identified according to their morphological and cultural characteristics as described by Domsch *et al*., (1980), Nelson *et al*., (1983). Percentage of frequency per each fungus was also determined.

Pathogenicity tests:

Pathogenicity tests were carried out using *F. oxysporum*, *F. solani, M. phaseolina* , *P. ultimum* and *R. solani*. Inocula of the tested fungi were prepared by growing their pure cultures on maize meal –sand medium in glass bottles and incubated at 25 $\pm$ 2 ^{0}C for two weeks. Formalin- disinfested plastic pots (20- cm-diam.) packed with formalin – disinfested clay and washed sand (1:1, v/v) were infested with the tested fungi at the rate of 2% (w/w), 7 days before planting, four replicates (pots) were used for each tested fungus, ten apparently healthy seeds of sage were planted in each pot .Disease incidence (%) as pre –and post-emergence damping –off as well as survived plants were determined 30, 45 and 60 days after planting, respectively.

Effect of three sources of silicon on mycelial growth of *R. solani* isolated from diseased sage plants:

Stock solutions were prepared from Calcium silicate (Ca_2SiO_4), Potassium silicate (K_2SiO_3) and Sodium silicate (Na_2SiO_3) produced by (Central Drug House (P) LTD post Bon No. 7138, New Delhi-110002). Appropriate amount of each Si solution was transferred into conical flasks containing sterilized PDA medium (100 ml) before solidification in order to obtain 10, 25, 50, 100 and 200 ppm. Media amended with Si sources were individually poured in Petri dishes then inoculated after solidification at the centre with 5mm of *R.solani* growth disc, taken from 7-day- old culture. PDA medium free from Si sources was served as control. Six plates were used as replicates for each particular treatment. All plates were incubated at 25$\pm$ 2^{o}C until the fungal growth of any Petri dish reached the edges. The growth diameters were then recorded and the growth inhibition percentages were calculated according to the following formula:

$$\text{Inhibition (\%)} = \frac{C - T}{C} \times 100$$

Whereas: C = Growth diam. of control and T = Growth diam. of the treatment.

Effect of three sources of silicon and the fungicide Vitavax/Thiram on incidence of *R.solani* damping–off and some seedling growth parameters, under greenhouse conditions:

For evaluating the efficiency of Si sources in controlling damping – off, greenhouse experiment was carried out in pots (20 cm diam.)filled with soil infested with *R.solani* as mentioned before. One hundred milliliters. of calcium silicate (Cs), potassium silicate (Ps) or sodium silicate (Ss) solutions (each at 400 ppm) as well as the fungicide Vitavax/Thiram at the rate of 3g/l water were used to soak the plant seeds for 30 min. before sowing. Four replicates (pots) were used per each particular treatment; ten soaked or not soaked seeds (control) of sage were planted in each pot. Percentages of pre- and post-emergence damping – off as well as survived seedlings were determined 30, 45 and 60 days after planting, respectively.

Nursery experiments:

Nursery experiments were carried out during two successive seasons (2012/13 and 2013/14) in a private farm at Hala village, Mitghamr, Dakahlia governorate. The soil of this farm was continuously planted with sage for three years. Healthy – sage seeds were soaked for 30 min. in any tested solution (400 ppm) of Cs, Ps and Ss as well as the fungicide Vitavax /Thiram at the rate of 3g /l water .Treated seeds were sown in plots (3x4m), each with 4 rows and 10 hills/row ,Five seeds /hill were sown with total of 200 seeds/plot . Untreated seeds were sown as check and three replicated plots were used for each treatment. Percentages of pre- and post emergence damping –off as well as survived plants were recorded 30, 45 and 60 days after sowing. Also, root length and seedlings height were recorded.

Field experiments

Field experiments were performed at the same site of nursery experiments as mentioned before. Healthy- looking seedlings of sage (60 – day –old) were chosen from those produced in nursery experiments in order to transplanting in field experiments (2012& 13 &2013/14 seasons). They were dipped in each soluble Si source (400 ppm) or Vitavax /Thiram (3 g /l. water) for 30 min. just before transplanting in field plots (3x4 m), each with 4 rows, at the rate of 10 seedlings /row (40 ones /treatment).Untreated seedlings were served as control. Three replicates (plots), however, were used per each treatment. After 60 days from transplanting, percentages of *R.solani* root rot were recorded as well as plant growth parameters, *i.e.* plant height (cm), number of branches, fresh weight of foliage of herb plant (g). Whereas, essential oil of sage leaves produced from each treatment was extracted with steam distillation and determined according to Guenther(1961).

Determination of leaves essential oil:

Samples of sage leaves were collected separately from each treatment of the field experiments during the harvesting of the 1 st. cut of herb yield, 60 days after transplanting. They were left to dry under shade for 15 days. Leaves oil were extracted according to the (British pharmacopoeia method, 1963) by using Clevenger's apparatus for determination of essential oils lighter than water. The air dried leaves were mixed together and 50g were taken for the determination. Leaves were placed in a flask of 500cc capacity and sufficient wetter; *i.e*. 200-300 ml was added. The apparatus consisting of a proper essential oil – trap and condenser was attached to the flask, which was heated by using Bunsen –flame. The distillation process was continued for 2.5-3 hours until no further increase in the oil was observed. After cooling of the apparatus, essential –oil quantity and percentage were estimated as follows:

$$\text{Essential oil (\%)} = \frac{\text{Essential oil quantity (read of apparatus)}}{\text{Weight of sample in g}} \times 100$$

Statistical analysis:

Data were statistically analyzed using analysis of variance and means were compared using L.S.D. test at 5% probability as described by Gomez and Gomez (1984).

RESULTS

1. Isolation and identification of the associated fungi to damping–off and/or root rot diseases and their frequency percentages:

Isolation trails from infected stem and root tissues of sage seedlings and plants on PDA medium yielded five fungi (Table 1). They were identified as: *F. oxysporum, F. solani*, *P. ultimum*, *M. phaseolina* and *R. solani*. *Rhizoctonia solani*, however, recorded the highest frequency (52.6 %), followed by *F. solani* (24.6%), *F. oxysporum* (12.3%) *P. ultimum* (7%) and *M. phaseolina* (3.5%). *Fusarium solani* was isolated from only rotted roots and *F. oxysporum* was obtained from rotted roots and stem tissues of wilted seedlings and plants. Whereas, *M. phaseolina, P. ultimum* and *R. solani* were isolated from rotted roots and stems.

Table 1. Mean frequency (%) of fungi isolated from sage diseased seedlings and mature plants.

Fungi	No. of isolates	(%) frequency	Disease symptoms
F. oxysporum	7	12.3	Root & stem rots
F. solani	14	24.6	Root rot
M. phaseolina	2	3.5	Root&stem rots
P. ultimum	4	7.0	Root&stem rots
R. solani	30	52.6	Root&stem rots
Total	57	100.0	--------------

$$\text{\% Frequency} = \frac{\text{No. of isolates per each fungus}}{\text{Total no. of isolates per all fungi}} \times 100$$

2. Pathogenicity tests:

All fungi (Table 2) were found to be pathogenic, at different degrees, to sage seedlings, since they significantly increased percentages of pre- and post-emergence damping –off. than the controls. The highest damping-off (pre- + post- emergence) percentages were achieved by *R. solani* (80%) followed by *F.oxysporum* (52.5 %) and *F.solani* (50.0%), 45 days after planting .In contrast, *P. ultimum* (37.5%) appeared to be the least pathogenic one. On the other hand, percentages of survival plants ranged between 20.0% (*R. solani)* to 62.5% (*P. ultimum*) were recorded, 60 days after planting .

3. The *in vitro* effect of three Si sources on mycelial growths of the pathogenic *R. solani* to sage:

Data in Table (3) show that the mycelial growth of *R.solani* varied in their sensitivity against the tested soluble Si sources*, i.e.* Cs, Ps and Ss. In general. Inhibition was increased when the concentration of the Si sources was increased. The inhibitory effect was observed at 10ppm for the three Si tested. However, Ps at 100 ppm caused 91.1% growth inhibition, while Cs and Ss caused 81.1% &73.3%, respectively. On the other hand, all the Si sources at 200ppm caused complete growth inhibition for the tested fungus. Ps recorded significantly the best result in this concern, followed by Cs, while Ss was the least effective one.

Table 2. Pathogenicity of the isolated fungi to sage seedlings, grown in infested soil, under greenhouse conditions.

Fungi	Damping-off			Survivals %
	Pre-emergence %	Post -emergence %	Total	
F. oxysporum	20.0	32.5	52.5	47.5
F. solani	35.0	15.0	50.0	50.0
M. phaseolina	17.5	30.0	47.5	52.5
P. ultimum	25.0	12.5	37.5	62.5
R. solani	52.5	27.5	80.0	20.0
Control(untreated)	00.0	00.0	00.0	100.0
L.S.D. at 5%	1.61	1.02	------	3.36

Table 3. Effect of three Si sources at five concentrations on linear growths of the pathogenic *Rhizoctonia solani* to sage .

Concentration (ppm)	Soluble silicon of : Calcium silicate		Potassium silicate		Sodium silicate	
	Colony diam. (cm)	Inhibition (%)	Colony diam. (cm)	Inhibition (%)	Colony diam. (cm)	Inhibition (%)
0.0	9.0	00.0	9.0	00.0	9.0	00.0
10	8.2	8.9	8.0	11.1	8.9	1.1
25	6.2	31.1	5.9	34.4	7.5	16.7
50	3.5	61.1	2.5	72.2	4.7	47.8
100	1.7	81.1	0.8	91.1	2.4	73.3
200	0.0	100.0	0.0	100.0	0.00	100.0

L.S.D. at 5 % for: Treatments (T) = 0.04
Concentration (C) = 0.06 T x C = 0.11

4.Effect of three Si sources at three concentrations and the fungicide Vitavax /Thiram on damping – off incidence, under greenhouse conditions:

The effects of three Si sources and the fungicide Vitavax /Thiram applied as seed soaking on percentages of damping-off (pre-and post-emergence) as well as percentages of survival seedlings , grown in soil artificially infested with *R. solani*, were investigated (Table 4). All three soluble Si sources as well as the fungicide Vitavax/Thiram significantly decreased percentages of pre- and post – emergence damping – off and increased percentages of survival plants than the controls. Percentages of survived seedlings ranged between 40.0-67.5% in case of Cs, 57.5-85.0 in case of Ps and 37.5-55.0 % for Ss as well as 87.5% for Vitavax /Thiram. Efficacy of each soluble Si was found to be variable according to its concentration. The tested Ps, however, was found to be the most effective treatment in controlling damping –off in comparison with the other treatments, while the Cs occupied the second position in this respect and Ss was the least effective treatment Generally, the fungicide

(Vitavax/Thiram) was found to be the superior treatment in increasing percentages of survival seedlings, followed by Ps.

Table 4. Effect of three Si sources at three concentrations on percentages of damping-off on sage seedlings, grown in soil infested with *Rhizoctonia solani*, under greenhouse conditions.

Treatment	Concentrations (ppm)	Damping-off: Pre-emergence	Post-emergence	Total	Survivals
Calcium silicate	0.0	57.5	42.5	100.0	00.0
	200	42.5	17.5	60.0	40.0
	300	32.5	12.5	45.0	55.0
	400	25.0	07.5	32.5	67.5
Potassium silicate	0.0	57.5	42.5	100.0	00.0
	200	30.0	12.5	42.5	57.5
	300	12.5	05.0	17.5	82.5
	400	12.5	02.5	15.0	85.0
Sodium silicate	0.0	57.5	42.5	100.0	00.0
	200	45.0	17.5	62.5	37.5
	300	32.2	15.0	47.2	52.8
	400	30.0	15.0	45.0	55.0
Vitavax /Thiram	2250	10.0	02.5	12.5	87.5
Control (untreated)	------	0.00	00.0	-------	100

L.S.D. at 5% for:	Pre -	Post -	Survivals
Treatment (T): =	0.5	0.3	0.8
Concentration (C) =	0.7	0.5	1.0
T x C =	1.2	0.8	1.8

5. Nursery experiments:

Effect of three Si sources and Vitavax /Thiram as seed soaking on Damping-off incidence under nursery conditions, 2012/13and2013/ 14 seasons:

Data (Table 5) show that soaking sage seeds in either of each Si sources tested and the fungicide Vitavax /Thiram before sowing significantly decreased percentages of damping –off incidence as well as increased percentages of healthy survived seedlings in the two experimental seasons (2012/2013 and 2013/2014) than the controls (untreated). Seed soaking in Ps followed by Cs were the most effective Si treatments as they recorded the least percentages of disease incidences during the two growing seasons. While, Ss was the least efficient treatment, since it recorded survivals by 65.0% in the two seasons. The fungicide Vitavax/Thiram was, however, superior than the other treatments in all cases.

Effect of three Si sources and Vitavax/Thiram as seed soaking on seedling height (cm) and root length (cm), under nursery conditions, 2012/2013 and 2013/2014 seasons :

The treatments tested (Table 6) yielded significant increases in seedling height and root length in both trial seasons. Soaking seeds in Ps was found to be the superior treatment in improving seedling height and root length in both seasons. In this regards, this treatment increased these two parameters by (122.0% &100%) in the first season and (75.8% & 77.4%) in the second season. In the contrary, Ss was significantly the least effective treatment since it recorded the lowest increase in this respect. The fungicide Vitavax /Thiram was, however, the most effective treatment, since it recorded the highest seedling height and root length compared with the other treatments.

Table 5. Effect of three Si sources and Vitavax / Thiram as seed soaking on damping – off incidence under nursery conditions, 2012 /2013 and 2013/2014 seasons.

Treatment	2012/2013 season Damping -off: Pre-emergence (%)	Post-emergence (%)	Survivals (%)	Increase* (%)	2013/2014 season Damping -off: Pre-emergence	Post--emergence	Survivals ((%)	Increase* (%)
Calcium silicate	17.5	10.0	72.5	31.8	17.5	15.0	67.5	50.0
Potassium silicate	10.0	10.0	80.0	45.5	15.0	10.0	75.0	66.7
Sodium silicate	20.0	15.0	65.0	18.2	25.0	20.0	65.0	44.4
Vitavax /Thiram	12.5	02.5	85.0	54.6	10.0	10.0	80.0	77.8
Control(untreated)	30.0	15.0	55.0	-	35.0	20.0	45.0	-

* Increase relative to the control.

L. S.D. at 5 % for:	Pre-	Post-	Survivals
Seasons (S) =	0.32	0.43	1.62
Treatments (T) =	0.50	0.69	2.56
S x T =	0.70	0.97	3.61

Table 6. Effect of three Si sources and Vitavax / Thiram as seed soaking on seedling height (cm)and root length (cm) under nursery conditions, 2012/2013 and2013 / 2014 seasons.

Treatments	2012/2013 season: Seedling height (cm)	Increase* (%)	Root length (cm)	Increase* (%)	2013/2014 season: Seedling height (cm)	Increase* (%)	Root length (cm)	Increase* (%)
Calcium silicate	30.60	104.0	34.50	085.5	32.50	64.1	35.9	69.3
Potassium silicate	33.30	122.0	37.20	100.0	34.80	75.8	37.6	77.4
Sodium silicate	22.40	049.3	28.40	052.7	26.40	33.3	30.7	44.8
Vitavax /Thiram	36.90	146.0	39.90	114.5	38.80	96.0	40.3	90.1
Control(untreated)	15.00	------	18.60	------	19.80	----	21.2	-----

*Increase relative to the control.

L.S.D. at 5% for:	Plant height	Root length
Seasons (S) =	0.36	0.18
Treatments (T) =	0.24	0.11
S x T =	0.51	0.26

6. Field experiments:

Effect of three Si sources and Vitavax /thiram as dipping treatment for seedlings on incidence of root rot caused by *R .solani*:

All treatments (Table 7) reduced the disease incidence of root rot in comparison with the control in both seasons. In this concern, Ps was more effective than other Si sources, recording 43.1% and 50.1% reduction, in disease incidence in both seasons, respectively while Ss was the least effective treatment (15.5% and 20.6%); The fungicide Vitavax /Thiram was significantly the best treatment, since it reduced the disease incidence percentages by 53.4%and 55.9% in the two seasons under field conditions, respectively.

Table 7. Effect of three Si sources and Vitavax/ Thiram as dipping treatment for seedlings on incidence percentages of root rot caused by *Rhizoctonia solani* under field conditions, 2012 / 2013 and 2013 / 2014 seasons.

Treatments	2012/2013 season		2013/2014 seasons	
	Disease incidence (%)	Reduction* (%)	Disease incidence (%)	Reduction * (%)
Calcium silicate	35.0	27.5	37.5	33.9
Potassium silicate	27.5	43.1	28.3	50.1
Sodium silicate	40.8	15.5	45.0	20.6
Vitavax /Thiram	22.5	53.4	25.0	55.9
Control (untreated)	48.3	-----------	56.7	-----------

***Reduction relative to the control.**
L.S.D. at 5 % for: Disease incidence
Seasons (S) = 1.4
Treatment (T) = 2.2
SXT = 3.2

Effect of three silicon sources and Vitavax /Thiram as dipping treatment for seedlings on plant height and number of branches under field conditions, 2012/2013- 2013/2014 seasons:

Dipping sage seedlings in any of the Si sources gave significant increases in number of branches and height per plant in the two experimental seasons compared to the control treatments (Table 8) .In this respect, increases occurred in numbers of branches ranged between (20.0—60.0%) and (28.7-90.1%) in both seasons , respectively, while, increases in plant height reached (22.4-31.4%) and (31.4-45.0%) . Ps followed by Cs were the superior treatments, since they yielded the highest increases (%) in these two plant parameters. Whereas, Ss was the least effective treatment in this regard, during the two tested seasons. On the other hand, the superiority in improving these plant growth criteria was always recorded with Vitavax /Thiram, except in case of Ps with no. of branches in 2 *nd*. season.

Effect of three Si sources and Vitavax /Thiram as dipping treatment for seedlings on fresh herb weight per plant at 1st. cut and essential oil ml/100g dry leaves, 2012/2013 and 2013/2014 seasons:

All tested treatments increased fresh herb weight per plant and oil yield (ml) /100g of dry leaves at different degrees , than the control treatments in the two experimental seasons (Table 9) .The increases in fresh herb yield /plant and oil yield than the controls were always significant in both trial seasons, except in case of Ss. The highest values of increases were realized with Ps followed by Vitavax/Thiram in all cases. Percentages of these increases in plant height in case of Ps were (36.4 -46.3%) and (19.5- 28.6%) in both seasons, respectively. Whereas, those values of Ss were only (4.3-7.8%) and (2.3-7.1%).

Table 8. Effect of three silicon sources and Vitavax/ Thiram as dipping treatment on height and number of branches per plant, under field conditions, 2012/2013 and 2013/ 2014 seasons.

Treatments	2012/2013 season				2013/2014 season			
	Plant height (cm)	Increase* (%)	No. of Branches	Increase* (%)	Plant Height (cm)	Increase * (%)	No. of Branches	Increase * (%)
Calcium silicate	40.7	26.4	13.5	35.0	42.7	38.2	14.0	38.6
Potassium silicate	42.3	31.4	16.0	60.0	44.8	45.0	19.2	90.1
Sodium silicate	39.4	22.4	12.0	20.0	40.6	31.4	13.0	28.7
Vitavax /Thiram	45.5	41.3	18.3	83.0	44.3	43.4	18.3	81.2
Control (untreated)	32.2	-----	10.0	----	30.9	----	10.1	----

***Increase relative to the control.**

L.S.D. at 5 % for:	Plant height	No. of branches
Seasons (S) =	0.27	0.97
Treatment (T) =	0.41	1.53
SXT =	0.58	2.21

Table 9. Effect of three Si sources and Vitavax/ Thiram as dipping treatment for seedlings on fresh weight of herb/plant(g) at the 1st cut and essential oil ml/100g dry leaves under field conditions, 2012 / 2013 and 2013 / 2014 seasons.

Treatments	2012/2013 season				2013/2014 season			
	Fresh herb weight (g)	Increase* (%)	Essential oil (ml)	Increase* (%)	Fresh herb weight (g)	Increase * (%)	Essential oil (ml)	Increase* (%)
Calcium silicate	176.7	20.3	0.93	06.9	184.3	22.5	0.91	08.3
Potassium silicat	200.4	36.4	1.04	19.5	220.1	46.3	1.08	28.6
Sodium silicate	153.2	04.3	0.89	02.3	162.3	07.8	0.90	07.1
Vitavax /Thiram	181.5	23.6	1.03	18.4	187.3	24.5	1.05	25.0
Control (untreated)	146.9	-----	0.87	----	150.5	----	0.84	----

*** Increase relative to the control.**

L.S.D. at 5% for:	Fresh weight	Essential oil
Seasons (S) =	12.15	0.02
Treatments (T) =	19.23	0.04
S x T =	27.19	0.05

DISCUSSION

Sage is important medicinal and aromatic plant in Egypt and all over the world. Infections by soilborne fungal diseases including those of *R. solani* were increased year after year in Egypt causing severe losses in yield *Rhizoctonia solani* which was continuously isolated from sage seedlings, showing damping – off symptoms and from rotted roots of plants, was found to be virulent fungus in pathogenicity tests. However, it caused the highest percentage of damping –off among the other fungi tested. These results are similar to those reported by Subbiah *et al*., (1996), Voltiolina, (2001) and Zaki and Waleed (2008). In this respect, *R. solani* is considered as important and dangerous soilborne fungal pathogen affecting different medicinal and aromatic plants (Minuto *et al*., 1997, Hilal *et al*., 1990, Hilal *et al*., 1994, Hilal *et al*.,1998, Hilal *et al*., 2009, Conway *et al*., 1992 and Conway *et al*. , 1997, Machowicz-Stefaniak *et al*., 2002, Kalra *et al*., 2004, Yadav and Anamika, 2005 and Nada, 2014 and Nada, 2015).

The *in vitro* growth of *R. solani* was suppressed, in different degrees, on PDA medium amended with Cs, Ps or Ss at the rates of 10, 25, 50, 100 & 200 ppm. Moreover, the efficiency of these Si sources was always increased by increasing their concentrations and they completely suppressed the fungal growth at 200 ppm. The positive effect of these Si sources was found also by several researchers on several pathogenic fungi, including *R. solani* (Cherif *et al*.,1994, Rachniyom and Jaenaksorn 2008, Bekker *et al.,*2009, Li *et al*., 2009, Shen *et al*., 2010 and Nada, 2014) Potassium silicate at 10, 25 and 100 ppm, was more effective than the others silicon compounds in suppressing the fungal growth. This finding was supported by the aforementioned investigators, who reported that Ps was an effective silicon source in suppressing pathogenic fungi. In order to evaluate the effects of Si compounds against *R. solani* diseases, sage seeds were soaked in each of their solutions (400 ppm) for 30 min. before sowing in greenhouse (artificially infested soil) and nursery (naturally infested soil). While, seedlings (60-day–old) were dipped in the Si solution for 30 min. just before transplanting in naturally infested soil in the field. The fungicide Vitavax / Thiram (3g/L, water) was used in all experiments as control. The positive efficiency of the three silicon sources tested in suppressing *R.solani* diseases in greenhouse (damping–off), nursery (damping–off) and field (root–rot) was confirmed. However, using these treatments in all experiments gave significant reductions in the diseases incidence than the controls (untreated seeds or seedlings) and the superiority was always to Ps treatment. In this respect, there is accumulating evidence that increased Si absorption by the plants offers protection against the fungal diseases(Carver *et al*.,1987 and Ghareeb *et al*., 2011) including Fusarium wilt of several crops of great economic importance (Datnoff *et al*., 2007). Also, Si amended in the soil or in the nutrient solution decreased the intensities of the diseases caused by *P. ultimum* and *P.aphanidermatum* on cucumber, *Phyt. capsici* on bell pepers, *F. oxysporum* f.sp. *cubense* on banana (Cherif *et al*., 1992b*,* Belanger *et al*., 1995 , Dannon and Wydra , 2004, French –Monar *et al* ., 2010, Huang *et al* ., 2011 and Fortunato *et al*., 2012). Soaking coriander seeds or drenching soil, just before planting, with each of Cs,Ps and Ss greatly reducing incidence of damping –off caused by seven soilborne fungi including *R. solani* (Nada *et al*., 2014). They also found that Ps was the most effective Si source against the disease. Reduction in disease incidence on seedlings and plants treated with the Si sources might be due to: (1) A direct effect of Si on the pathogen (Guevel *et al*., 2007), since phenolic laden cell of Si amended plants were found to seriously damaged fungal hyphae and antifungal phenolics conclusively shown to be fungitoxic (Cherif and Belanger, 1992 and Cherif *et al* ., 1994), (2) The higher deposit of Si in plant tissues to form physical barrier to impede pathogen penetration; mechanical barrier hypothesis (Buck *et al*.,2008 and Hayasaka *et al.,* 2008) and (3)Inducing defense responses in plant tissues (Shen *et al*., 2010) similar to acquired resistance by elevating the activities of protective enzymes ; PO, PPO& PAL(Cherif and Belanger, 1992 , Datnoff *et al* ., 2007, Nanayakkara *et al*., 2008 and Rezende *et al*., 2009) and chitinase and glucanase(Dann and Muir ,2002). According to the previous investigators, these enzymes had important role in regulation the accumulation of the antifungal compounds such as phenolics, lignin, phytoalexins and flavonoid phytoalexins as PR proteins. On the other hand the fungicide Vitavax/Thiram was always the best treatment in reducing *R .solani* diseases incidence than those of Si under greenhouse, nursery and field conditions. Soaking or dipping treatments in the fungicidal water suspension gave effective protection to seed or seedling tissues against the fungal attacks and prolonged the presence of the fungicide or its breakdown product (s) in these tissues, thus having a beneficial effect in the limitation of the disease incidence and development. This action might be due to: (1) The direct toxic effect of this fungicide on the fungal growth, (2) Reducing or preventing the fungal penetration, (3) Its capability to curing or healing plant tissues by exterminating or inhibiting pathogen after infection has occurred (Gruznyev *et al*., 1983), and (4) Changing the soil microflora profile leading to the dominance of some antagonistic microflora .

All Si sources and Vitavax/Thiram as seed soaking (nursery) and dipping treatment for seedlings (field) significantly increased criteria of seedlings and plant growth than the controls. The highest values of increases were always recorded with the fungicide followed by Ps. Fresh herb yield/plant of the 1st cut and oil yield of dry leaves were also increased significantly, except in case of Ss. Ps, however, gave the highest increases, followed by the fungicide. Since Si appears to alleviate both biotic and a biotic stress (Epstein, 1994) it may be that the effects of Si on plant performance are evident only when some form of stress is imposed similar to *R. solani* disease infection on sage Moreover, Si enhanced growth and quality, photosynthesis stimulation, transpiration reduction and increased plant resistance to a biotic and biotic stresses (Ma and Takahashi, 2002). There is a relationship between Si and the improving in plant growth and yield as found on gerbera Savvas *et al*. (2002) and ornamental sunflowers (Kamenidon *et al*., 2008). Also, applying three Si sources to soil infested with seven soilborne fungi including *R. solani* improved height and fresh weight of coriander plant (Nada *et al* ., 2014). They also found that seeds soaking plus soil drenching by Cs (800 ppm), Ps (400 ppm) or Ss (800 ppm) significantly increased plant height, number of branches and blossoms, and improved seed yield/plant and essential oil seed contents. In this regard, the superiority of Ps than the other treatments was found and this action is similar to our result.

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فعالية مركبات السليكون فى مقاومة أمراض الريزوكتونيا سولانى وتحسين إنتاجية محصول العشب والزيت الطيار لنبات المريميه

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تهدف هذه الدراسة إلى عزل المسببات الفطرية التى تسبب مرض موت البادرات وأعفان الجذور لنبات المريمية وإختبار قدرتها على إصابة البادرات .وكذلك تقييم فعالية ثلاثة من مركبات السليكون (سليكات الكالسيوم ،سليكات البوتاسيوم وسليكات الصوديوم) على نمو الفطر ريزوكتونيا سولانى فى المعمل وكذلك الحد من حدوث الإصابة بأمراض الريزوكتونيا سولانى عند استخدامهم فى تجارب نقع البذور و تجارب غمر الشتلات قبل الزراعه فى الصوبه ، وفى تجارب المشتل والحقل تحت ظروف العدوى الصناعية بالفطر فى الصوبة والطبيعية فى المشتل والحقل ، وكذلك تقييم تأ ثيرهم على بعض مقاييس نمو الشتلات والنباتات وانتاجية محصول النبات من العشب والزيت الطيار .تم عزل خمسة فطريات من بادرات ونباتات المريمية المصابة بأ مراض موت البادرات وعفن الجذور والتى تم جمعها من تلك النامية فى محافظات: الإسماعيلية ، شمال سيناء والقليوبية وهى: فيوزاريوم أوكسيسبورم ، فيوزاريوم سولانى ، ماكروفومينا فاصولينا , بيثيم التيمم وريزوكتونيا سولانى . ولقد سجل الأخير أعلى تكرارا فى العزل (٥٢.٦ %) تلاه فيوزاريوم سولانى (٢٤.٦%) فى حين كان الفطر ماكروفومينا فا صولينا (٣.٥%) الاقل فى هذا المجال. أدت إضافه أى من مركبات السليكون بتركيزات(٥٠،٢٥، ١٠٠ و٢٠٠ جزء فى المليون) فى بيئة النمو الفطرى إلى تثبيط نمو الفطر ريزوكتونيا سولانى بدرجات مختلفه وتفوق مركب سليكات البوتاسيوم على مركبات السليكون الأخرى فى هذا المجال حيث ثبط النمو كلية عند تركيز ٢٠٠ جزء فى المليون . كما أدى نقع البذور (٣٠دقيقة) أو غمر الشتلات (٣٠ دقيقة) فى أى من هذه المركبات بتركيزات ٤٠٠ جزء فى المليون أو فى المبيد الفطرى فيتافاكس /ثيرام (٣ جم /لترماء) إلى الحد من حدوث الاصابه بدرجة كافية لمرض موت البادرات فى الصوبه والمشتل وعفن الجذور فى الحقل .كماأدى استخدام هذه المعاملات ايضا إلى حدوث زيادة معنوية فى بعض مقاييس نمو البادرات (أرتفاع البادرة وطول الجذر)والنبات (أرتفاع النبات وعدد الافرع) عن معاملات المقارنة ، وكان تأثير مركب سليكات البوتاسيوم الأفضل فى هذا المجال بالمقارنة بمركبات السليكون الأخرى ، كما أدى إستخدام مركبى سليكات البوتاسيوم وسليكات الكالسيوم كمعامله لغمر الشتلات إلى زيادة فى محصول العشب الطازج والزيت الطيار لنبات المريمية. ولقد تفوق تأثير مبيد الفيتافاكس/ثيرام على مركبات السليكون فى كل التجارب التى تم تنفيذها الا مع استخدام مركب سليكات البوتاسيوم فى غمر الشتلات الذى تفوق عن المبيد فى زيادة محصول النبات من العشب الطازج والزيت الطيار فى تجارب الحقل.