Control of Root Rot Diseases of Tomato Plants Caused by *Fusarium solani*, *Rhizoctonia solani* and *Sclerotium rolfsii* Using Different Chemical Plant Resistance Inducers

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ABSRACT

El-Mohamedy, R.S.R., Jabnoun-Khiareddine, H., and Daami-Remadi, M. 2014. Control of root rot diseases of tomato plants caused by *Fusarium solani, Rhizoctonia solani* and *Sclerotium rolfsii* using different chemical plant resistance inducers. Tunisian Journal of Plant Protection 9: 45-55.

Root rots of tomato plants caused by *Rhizoctonia solani, Fusarium solani* and *Sclerotium rolfsii* are serious diseases leading to delayed growth and subsequent death of severely infected plants. Effect of some chemical inducers such as potassium salts, salicylic acid and sorbic acid on control of root rot pathogens and their impact on growth, quantity and quality parameters of tomato cv. Super Strain B were investigated. All the tested chemical inducers significantly reduced severity of root rots under greenhouse and field conditions. Potassium salts based-treatments, followed by salicylic acid, were the most effective in decreasing incidence of root rots induced by all tested pathogens. However, sorbic acid was found to be the least effective treatment. In field trials, the highest reductions of root rot incidence and disease severity were recorded on tomato plants treated with potassium sorbate used at 7.5% and dipotassium hydrogen phosphate (K_2HPO_4) 400 mM followed by salicylic acid 100 mM treatment. Disease incidence and severity were reduced by 65.4 and 62.5% in 2012, and by 63.2 and 53.8% in 2013 cropping seasons, respectively. Application of potassium salts followed by salicylic acid was the most efficient for the increase of growth parameters, yield and quality of tomato fruits while compared to control. Therefore, it could be suggested that application of plant chemical resistance inducers could be commercially used for controlling tomato root rot diseases and increasing both quality and quantity of tomato since they are safe, less expensive and effective against these diseases even under field conditions.

Keywords: Chemical resistance inducers, disease control, root rot, tomato, yield quality

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Tomato is an important vegetable crop not only for its economic importance but also for its nutritional value (19). It is essentially present in all countries either as open field or protected crops. As other countries, it is one of the most important vegetable crops in Egypt and used for food and industrial purpose (16).

Tomato plants are infected by several soilborne fungal pathogens such as *Fusarium* spp., *Rhizoctonia solani,* and *Sclerotium rolfsii* which cause serious diseases as root rots and wilt and finally reduced crop yield and quality (6, 28).

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Accepted for publication 9 April 2014

Control of such diseases mainly depends on fungicide treatments and grafting (17). However, intensive application of fungicides causes hazards to human health and environmental degradation and is not always satisfactory. Therefore, alternative approaches for the control of plant diseases should be emphasized (24).

Induction of resistance in plants to overcome pathogen infection is a promising approach for controlling plant diseases. Exogenous or endogenous factors could substantially affect host physiology, lead to rapid and coordinated activation of defense-gene in plants normally expressing susceptibility to pathogen infection (24, 25). This induced resistance to pathogens can be achieved by the application of various abiotic agents (chemical inducers) such as salicylic acid, potassium salts and sorbic acid (6, 8, 13, 15). Conversely, application of these chemical inducers under field conditions have increased growth parameters, yield components and quality of fruits in many vegetable plants (16, 17, 22, 31).

The present study was conducted to investigate the effects of some chemicals as resistance inducers in tomato plants against root rot pathogens under greenhouse and field conditions and to more elucidate their impacts on growth parameters, yield and fruit quality.

MATERIALS AND METHODS

Root rot pathogens.

Rhizoctonia solani RsG1, *Fusarium solani* FsG1, and *Sclerotium rolfsii* Sr Mn2 isolates obtained from Plant Pathology Department, National Research Center, Egypt, were used in this study. These isolates were proved to be aggressive for inducing root rot of tomato plants in previous studies (15, 16).

Preparation of fungal inocula.

Inoculum of *F. solani* was prepared by culturing pathogen on Potato Dextrose Broth (PDB) medium in 250 ml Erlenmeyer flasks for 10 days at 25 ± 2°C. The culture was filtered to remove mycelia and the resulting conidial suspension was adjusted to 10^6 conidia/ml by using a haemocytometer. Soil infestation was carried out by adding 50 ml of the conidial suspension (10^6 conidia/ml) to 1 kg of soil (12).

Inoculum of *R. solani* and *S. rolfsii* was the upper solid mycelium layers grown on Potato Dextrose Agar (PDA) medium which was washed and air-dried with sterilized filter paper layers. The air-dried mycelium was blended in distilled water to obtain inoculum pieces of 1-2 mm. Soil inoculation was carried out at the rate of 2.0 g of dry mycelium/kg of soil (9).

Greenhouse experiment.

The efficacy of four chemical resistance inducers i.e. salicylic acid, dipotassium hydrogen phosphate (K_2HPO_4), potassium sorbate and sorbic acid, used at different concentrations, was tested against tomato root rot pathogens. These chemicals were applied as seedling root dipping for 2 h before transplanting, followed by foliar spray application after transplanting, applied as follows:

(a) Seedlings root dipping

1 - Salicylic acid 25, 50 and 100 mM,

2 - Dipotassium hydrogen phosphate (K_2HPO_4) 100, 200 and 400 mM,

3 - Potassium sorbate 2.5, 5.0 and 7.5%,

4 - Sorbic acid 2.5, 5.0 and 7.5%,

5 - Control untreated seedlings.

(b) Foliar spray

1 - Salicylic acid 25 mM,

2 - Dipotassium hydrogen phosphate (K_2HPO_4) 100 mM,

3 - Potassium sorbate 2.5%,

4 - Sorbic acid 2.5%,

5 - Control untreated plants.

Plastic pots (25 cm diameter, 5.0 kg of soil) were filled with soil artificially inoculated with each of the tested pathogens. Healthy tomato seedlings (40 day-old, cv. Super Strain B) were sown in plastic pots at the rate of 4 seedlings/pot, following five replicates for each treatment along with check treatment (non-inoculated soil).

Root rot disease incidence and severity were evaluated 45 days post-planting. Disease incidence was recorded as the number of root rot diseased plants relative to the number of planted seedlings in each treatment.

Disease severity was scored based on a modified Rowe (27) scale where: 0 = no internal or external browning, 1 = no internal browning, discrete superficial lesions on tap root or stem base and root lesions at the points of emergence of lateral roots, 2 = brown tap root with slight internal browning at the tip of the tap root, 3 = moderate internal browning of the entire tap root, 4 = severe internal browning extending from tap root into lower stem above soil surface, abundant lesions on distal roots and 5 = dead plants.

The percentages of reduction of disease incidence and severity were also calculated.

Open field experiment.

The most promising treatments found to be effective against tomato root rot diseases based on pot experiments were applied under field conditions. Four different chemical resistance inducers i.e., salicylic acid 100 mM, dipotassium hydrogen phosphate (K_2HPO_4) 400 mM, potassium sorbate 7.5%, and sorbic acid 7.5% were applied as seedling root dipping for 2 h + foliar application treatments (as mentioned above for the greenhouse experiment). This experiment was conducted in two successive growing seasons 2012 and 2013 in a field naturally infected with the causal organisms of root rot disease of tomato located at the private farm of El-Minia Governorate, Egypt.

Tomato seedlings (cv. Super Strain B, 40 days-old) were soaked for 2 h at the rate of 100 seedlings per 250 ml of the tested chemical resistance inducers. Two seedlings/hill were sown with 50 cm apart between hills. Untreated seedlings were used as control. Disease incidence and severity were recorded at 25, 50 and 75 days post-planting (DPP) and the percentages of their reductions as compared to the control were also calculated. Plant height, number of branches, number of fruits per plant, fruit weight per plant (kg), mean fruit weight (g) and fruit yield (T/ha) were noted at the end of the growing season. Total soluble solids of tomato fruits from each treatment were measured using a refractometer.

Statistical analyses.

All experiments were set up according to a complete randomized block design. One-way ANOVA was used to analyze differences between treatments. A general linear model option of the analysis system SAS (SAS Institute Inc.) (29) was used to perform the ANOVA. Duncan's multiple range test at $P < 0.05$ was used for mean separation (30).

RESULTS

Management of the disease under greenhouse.

Data shown in Tables 1 and 2 clearly indicate that all chemical inducers tested have significantly ($P \leq 0.05$) reduced tomato root rot incidence (Table 1) and severity (Table 2) caused by *F. solani*, *R. solani* and *S. rolfsii* compared with the untreated control plants. Root rot incidence and severity on tomato plants were decreased by all tested concentrations and reached their minimum records at the highest concentration of potassium sorbate 7.5%, dipotassium hydrogen phosphate (K_2HPO_4) 400 mM, salicylic acid 100 mM and sorbic acid 7.5%. The most effective treatments were potassium sorbate 7.5% followed by dipotassium hydrogen phosphate (K_2HPO_4) 400 mM. In fact, they decreased *F. solani* and *R. solani* root rot incidence by 80.0 and 76.3% and by 74.1 and 63.1%; while *S. rolfsii* incidence was reduced by 71.0 and 61.7%, respectively (Table 1). For root rot severity, these treatments decreased *F. solani* by 67.6 and 61.7%, *R. solani* by 61.9 and 52.3% and *S. rolfsii* by 58.3 and 50.0%, respectively (Table 2). Meanwhile, plants treated with salicylic acid and sorbic acid showed reduced root rot incidence (72 and 60.2%, respectively) and severity (55.8 and 50.0%, respectively).

Tomato plants treated with salicylic acid 25 mM, dipotassium hydrogen phosphate (K_2HPO_4) 100 mM, potassium sorbate 2.5%, sorbic acid 2.5% combined with foliar spray with the same concentrations of the same chemicals gave rise to the lowest protection against all tested pathogens as compared with the other tested concentrations (Table 1).

Table 1. Effect of chemical resistance inducers tested at different concentrations on the incidence of tomato root rots caused by *Fusarium solani*, *Rhizoctonia solani* and *Sclerotium rolfsii* (greenhouse conditions)

Chemical resistance inducer	Treatment / Concentration		Incidence of root rot pathogens					
			F. solani		*R. solani*		*S. rolfsii*	
	SRD	FA	Incidence (%)	Reduction (%)	Incidence (%)	Reduction (%)	Incidence (%)	Reduction (%)
K_2HPO_4	100 mM	100 mM	26.1 b	55.0	21.9 b	48.0	23.6 b	42.2
	200 mM		17.3 c	70.1	18.9 c	55.2	19.0 c	53.4
	400 mM		13.7 d	76.3	15.5 c	63.1	15.6 c	61.7
SA	25 mM	25 mM	27.8 b	52.1	23.5 b	44.1	24.4 b	40.1
	50 mM		19.8 c	65.8	17.7 c	58.0	18.0 c	55.8
	100 mM		16.2 cd	72.0	15.5 c	63.1	16.2 c	60.2
PSO	2.5%	2.5%	22.5 c	61.1	17.6 c	58.3	18.0 c	55.8
	5.0%		15.1 cd	73.9	13.5 d	67.9	14.4 c	64.7
	7.5%		11.6 d	80.0	10.9 d	74.1	11.8 d	71.0
SOA	2.5%	2.5%	29.0 b	50.0	24.8 b	41.2	26.2 b	35.7
	5.0%		23.0 c	60.2	21.1 b	50.0	21.2 bc	48.0
	7.5%		25.0 b	56.8	18.2 c	56.8	8.8 d	54.0
Control			58.0 a	-	42.2 a	-	40.8 a	-

For each column, means followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). SA: Salicylic acid, PSO: Potassium sorbate, SOA: Sorbic acid, SRD: Seedling root dipping, FA: foliar application.

Table 2. Effect of chemical resistance inducers tested at different concentrations on root rot severity on tomato plants inoculated with *Fusarium solani*, *Rhizoctonia solani* and *Sclerotium rolfsii* (greenhouse conditions)

Chemical resistance inducer	Treatment / Concentration		Root rot severity					
			F. solani		*Rhizoctonia R. solani*		*S. rolfsii*	
	SRD	FA	Severity	Reduction (%)	Severity	Reduction (%)	Severity	Reduction (%)
K_2HPO_4	100 mM	100 mM	1.9 b	44.1	1.3 b	38.0	1.6 b	33.3
	200 mM		1.5 c	55.8	1.2 b	42.8	1.3 c	45.8
	400 mM		1.3 c	61.7	1.0 c	52.3	1.2 c	50.0
SA	25 mM	25 mM	2.0 b	41.1	1.4 b	33.3	1.7 b	29.1
	50 mM		1.9 b	50.0	1.2 b	42.8	1.5 bc	37.5
	100 mM		1.5 c	55.8	1.1 cd	47.6	1.3 c	45.8
PSO	2.5%	2.5%	1.6 c	52.9	1.1 cd	47.6	1.4 c	41.6
	5.0%		1.4 cd	58.8	0.9 de	59.1	1.1 cd	54.2
	7.5%		1.1 d	67.6	0.8 de	61.9	1.0 d	58.3
SOA	2.5%	2.5%	2.1 b	38.2	1.5 b	28.0	1.7 b	29.1
	5.0%		1.9 b	44.1	1.3 b	38.0	1.6 b	33.3
	7.5%		1.7 b	50.0	1.2 b	42.8	1.4 c	41.6
Control			3.4 a	-	2.1 a	-	2.4 a	-

For each column, means followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). SA: Salicylic acid, PSO: Potassium sorbate, SOA: Sorbic acid, SRD: Seedling root dipping, FA: foliar application.

Management of the disease in open field.

Effect of chemical resistance inducers on root rot incidence and severity. Data presented in Tables 3 and 4 indicate that all chemical inducers had significantly protected tomato plants against root rot pathogens as compared to the untreated control in both growing seasons (2012 and 2013). In fact, all tested chemicals had significantly reduced the percentages of root rot incidence on tomato plants noted 25, 50 and 75 DPP. The highest reductions of root rot incidence (Table 3) and severity (Table 4) were obtained with potassium sorbate 7.5% and dipotassium hydrogen phosphate (K_2HPO_4) 400 mM based-treatments followed by salicylic acid 100 mM. Indeed, these both parameters were decreased by 65.4 and 62.5% in 2012 cropping season, as compared to 63.2 and 53.8% recorded in 2013. Treatment of tomato seedlings by root dipping with potassium sorbate 7.5% and potassium hydrogen phosphate (K_2HPO_4) 400 mM combined with foliar spray with 2.5% and 100 mM of the same inducers led to high decrease in tomato root rot disease incidence and severity after 25, 50 and 75 DPP in the two cropping seasons. At 75 DPP, the same treatments reduced, respectively, disease incidence records by 65.4 and 60.0% in 2012 and by 63.2% and 57.4% in 2013, respectively (Table 3). Disease severity, noted 75 DPP, was also decreased by 62.5 and 54.1% in 2012 and by 53.8 and 50.0% in 2013 cropping season (Table 4). Salicylic acid 100 mM based-treatment caused considerable reduction in tomato root rot during the two seasons where incidence and severity decreased up to 51.7 and 50.0%, respectively. Meanwhile, sorbic acid 7.5% treatment exhibited the least inhibitory effect with 50.0% reduction recorded at 75 DPP during both cropping seasons. The most effective chemical inducers in decreasing root rot incidence and severity at 25 and 50 DPP were potassium sorbate 7.5% and dipotassium hydrogen phosphate (K_2HPO_4) 400 mM, whereas salicylic acid 100 mM and sorbic acid 7.5% based-treatments showed the lowest efficacy.

Table 3. Effect of chemical resistance inducers tested at different concentrations on incidence of root rot diseases on tomato plants grown in a naturally infested soil (open field conditions)

Chemical resistance inducer	Treatment / Concentration		Incidence					
			25 DPP		50 DPP		75 DPP	
	SRD	FA	Incidence (%)	Reduction (%)	Incidence (%)	Reduction (%)	Incidence (%)	Reduction (%)
Season 2012								
K_2HPO_4	400 mM	100 mM	17.8 cd	52.2	19.2 c	58.6	16.4 d	60.0
SA	100 mM	25 mM	20.0 b	46.2	22.0 b	52.6	19.8 c	51.7
PSO	7.5%	2.5%	15.6 d	58.1	16.6 c	64.2	14.2 d	65.4
SOA	7.5%	2.5%	21.4 b	42.4	23.8 b	48.7	22.2 b	45.8
Control			37.2 a	-	46.4 a	-	41.0 a	-
Season 2013								
K_2HPO_4	400 mM	100 mM	19.6 c	51.0	21.1 c	53.1	18.8 de	57.4
SA	100 mM	25 mM	22.0 b	46.0	22.4 c	50.2	21.4 c	51.6
PSO	7.5%	2.5%	18.0 c	55.0	17.4 d	61.3	16.2 e	63.2
SOA	7.5%	2.5%	24.0 b	40.0	25.2 b	44.0	25.2 b	43.0
Control			40.0 a	-	45.0 a	-	44.2 a	-

For each column, means followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). SA: Salicylic acid, PSO: Potassium sorbate, SOA: Sorbic acid, SRD: Seedling root dipping, FA: foliar application, DPP: days post-planting.

Table 4. Effect of chemical resistance inducers tested at different concentrations on root rot severity on tomato plants grown in a naturally infested soil (open field conditions)

Chemical resistance inducer	Treatment / Concentration		Severity					
			25 DPP		50 DPP		75 DPP	
	SRD	FA	Severity	Reduction (%)	Severity	Reduction (%)	Severity	Reduction (%)
Season 2012								
K_2HPO_4	400 mM	100 mM	0.8 c	50.0	1.0 c	54.5	1.1 c	54.1
SA	100 mM	25 mM	1.0 b	44.4	1.2 b	43.4	1.2 bc	50.0
PSO	7.5%	2.5%	0.8 c	55.5	0.9 c	59.1	0.9 c	62.5
SOA	7.5%	2.5%	1.1 b	38.8	1.3 b	40.4	1.4 b	41.6
Control			1.8 a	-	2.2 a	-	2.4 a	-
Season 2013								
K_2HPO_4	400 mM	100 mM	1.1 c	45.0	1.2 c	50.0	1.3 c	50.0
SA	100 mM	25 mM	1.2 bc	40.0	1.4 b	41.6	1.4 b	46.2
PSO	7.5%	2.5%	1.0 c	50.0	1.1 c	54.2	1.2 c	53.8
SOA	7.5%	2.5%	1.4 b	30.0	1.4 b	41.6	1.5 b	42.2
Control			2.0 a	-	2.4 a	-	2.6 a	-

For each column and each cropping season, means followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). SA: Salicylic acid, PSO: Potassium sorbate, SOA: Sorbic acid SRD: Seedling root dipping, FA: foliar application, DPP: days post-planting.

Effect of chemical resistance inducers on tomato growth parameters. All of the tested chemical inducers significantly increased growth parameters in treated tomato plants i.e. plant height and number of branches per plant compared with the untreated control in both growing seasons (Table 5). The most effective chemical inducers in enhancing plant height (68.4 and 60.4 cm), was potassium sorbate 7.5% followed by dipotassium hydrogen phosphate (K_2HPO_4) 400 mM (66.4 and 65.2 cm) in

2012 and 2013 growing seasons, respectively.

The same trend was also observed in the case of the number of branches per plant. In fact, tomato seedlings treated with potassium sorbate 7.5% exhibited the highest branch number per plant (6.2 and 5.8 during 2012 and 2013 cropping seasons, respectively) followed by dipotassium hydrogen phosphate (K_2HPO_4) 400 mM (5.8 and 5.4, respectively). Salicylic acid 100 mM based-treatment led to significant increase in plant height during the two seasons. Meanwhile, sorbic acid 7.5% treatment showed the least effect, as there are no significant difference in plant height between treated and untreated (control) plants during the 2013 season.

Table 5. Effect of different chemical resistance inducers on growth parameters of tomato plants grown in naturally infested soil (open field conditions)

Chemical resistance inducer	Treatment /Concentration		Plant height (cm)		No. of branches/plant	
	SRD	FA	2012	2013	2012	2013
K_2HPO_4	400 mM	100 mM	66.4 a	65.2 a	5.8 b	5.4 b
SA	100 mM	25 mM	58.0 b	55.8 b	5.0 c	4.8 c
PSO	7.5%	2.5%	68.4 a	60.4 b	6.2 a	5.8 a
SOA	7.5%	2.5%	50.4 c	52.0 c	4.6 d	4.4 d
Control			42.8 d	48.2 c	3.8 e	4.0 c

For each column, means followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). SA: Salicylic acid, PSO: Potassium sorbate, SOA: Sorbic acid, SRD: Seedling root dipping, FA: foliar application.

Effect of chemical inducers on tomato yield and fruit quality. Reduction in disease incidence during two seasons, 2012 and 2013, means increasing in plant stand and growth parameters, which reflect on the obtained tomato fruit yield. There was a significant effect of the chemical inducers on the tested quantitative parameters i. e., number of fruits/plant, fruit weight per plant, mean fruit weight, total soluble solids and total fruit yield. The obtained data in Table 6 show that all tested chemicals significantly improve the quality parameters of tomato compared with the untreated control. The most efficient inducers were potassium sorbate (PSO) 7.5% and potassium hydrogen phosphate (K2HPO4) 400 mM where the highest numbers of fruits per plant recorded were 75 and 68, and 71 and 65 during 2012 and 2013 cropping seasons, respectively. Fruit weight per plant noted on tomato plants treated with potassium hydrogen phosphate (K_2HPO_4) 400 mM and potassium sorbate (PSO) 7.5% was 4.62 and 5.28 kg, and 4.35 and 5.12 kg for each treatment in 2012 and 2013, respectively. Mean fruit weight (70 and 62, 6.2 and 5.5 g) and total yield increase, compared to the untreated control (63.2 and 56.4%, 53.6 and 50.3%), were higher in tomato plants treated with potassium sorbate (PSO) 7.5% and potassium hydrogen phosphate (K_2HPO_4) 400 mM in 2012 and 2013 cropping seasons, respectively. Salicylic acid 100 mM and sorbic acid 7.5% based-treatments also increased all yield parameters as compared to the control.

Table 6. Effect of different chemical resistance inducers on yield and fruit quality of tomato plant grown in a naturally infested soil (open field conditions)

Chemical resistance inducer	Treatment /Concentration		Quality parameters				Total yield	
	SRD	FA	NF	FWP (kg)	FW (g)	TSS	Yield (T/ha)	Increase (%)
Season 2012								
K_2HPO_4	400 mM	100 mM	68 a	5.28 a	62 b	5.2 b	62.38 b	56.4
SA	100 mM	25 mM	55 b	4.4 a	57 a	4.8 b	49.52 c	45.1
PSO	7.5%	2.5%	75 a	4.62 a	70 a	6.2 a	73.80 a	63.2
SOA	7.5%	2.5%	46 b	3.15 b	60 b	4.2 b	44.76 c	39.3
Control			32 c	1.52 c	58 a	4.0 b	27.14 d	0.0
Season 2013								
K_2HPO_4	400 mM	100 mM	65 a	5.12 a	61 b	5.5 a	67.14 a	50.3
SA	100 mM	25 mM	52 b	4.25 a	50 c	5.0 ab	55.71 b	40.1
PSO	7.5%	2.5%	71 a	4.25 a	72 a	6.2 a	71.90 a	53.6
SOA	7.5%	2.5%	42 b	2.88 b	44 d	4.4 ab	48.09 c	30.6
Control			30 c	1.25 c	50 c	4.1 b	33.33 d	0.0

For each column and each cropping season, means followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$). SA: Salicylic acid, PSO: Potassium sorbate, SOA: Sorbic acid, SRD: Seedling root dipping, FA: foliar application, NF: Number of fruits per plant, FWP: fruit weight per plant, FW: fruit weight, TSS: Total soluble solids.

DISCUSSION

Soilborne diseases including root rots are involved in considerable losses of the most important vegetable crops including tomato. Chemical resistance inducers are largely used as bioactive substances in controlling soilborne as well as foliar plant pathogens (2, 3, 4, 6, 7, 11, 14, 15, 17, 26). In the present study, different concentrations of salicylic acid, dipotassium hydrogen phosphate (K_2HPO_4), potassium sorbate, sorbic acid were used as seedlings root dipping combined with foliar application of the same chemical inducers in order to evaluate their efficacy in controlling tomato root rot caused by *F. solani*, *R. solani* and *S. rolfsii* in artificially infested soil under greenhouse conditions as well as in naturally infested soil under open field conditions.

Our data in pot experiment clearly show that root rot incidence and severity on tomato plants were reduced at all tested chemicals concentrations. The lowest records of these two parameters were noted at the highest concentration of potassium sorbate 7.5%, dipotassium hydrogen phosphate (K_2HPO_4) 400 mM, salicylic acid 100 mM and sorbic acid 7.5%. The most effective treatments were potassium sorbate 7.5% followed by dipotassium hydrogen phosphate (K_2HPO_4) 400 mM. They reduced both incidence and severity of root rot. These results are in agreement with previous findings (1, 2, 14, 17, 26) where many chemical resistance inducers were successfully used against root rot pathogens infecting many crops. Chemically induced resistance in plants against pathogens is a widespread phenomenon that has been investigated with respect to the underling signaling pathways as well as to its potential use in plant protection. Elicited by a local infection, plants respond with a salicylic acid dependent signaling cascade that leads to the systemic expression of a broad spectrum and long-lasting disease resistance that is efficient against fungi, bacteria and viruses (21). The tested chemical inducers might stimulate some defense mechanisms such as phenolic compounds, oxidative enzymes and other metabolites (7, 10, 13).

Under open field conditions, our results indicate that the highest reduction of root rot incidence and severity was obtained with potassium sorbate 7.5% and dipotassium hydrogen phosphate (K_2HPO_4) 400 mM treatments followed by salicylic acid 100 mM combined with foliar application with 2.50%, 100 mM, 25 mM of the same chemical inducers, respectively. Many research studies have been conducted on chemical resistance inducers used for controlling root rot and wilt diseases under greenhouse and field conditions (2, 5, 10). It should be mentioned that some chemical inducers may also have a direct antimicrobial effect and are, thus, involved in cross-linking in cell walls, induction of gene expression, phytoalexin production and induction of systemic resistance (6).

On the other hand, an important finding from this study revealed that all tested chemical inducers had positive effects on plant growth, yield and fruit quality of tomato plants grown under field conditions during two cropping seasons. These increases in growth, yield quantity and quality may be attributed to elicitors effect on physiological processes in plant such as ion uptake, cell elongation, cell division, enzymatic activation and protein synthesis (11, 18). Gunes *et al*. (20) also reported that salicylic acid acts as endogenous signal molecule involved in induction of tolerance to abiotic stresses in plants. They emphasized that exogenous application of salicylic acid increased plant growth significantly both under saline and non saline conditions. Some chemical inducers are also endogenous growth regulators of phenolic nature, which influence a range of diverse processes in plants, including seed germination (6, 18), ion uptake and transport, membrane permeability, photosynthetic and growth rate (23).

ACKNOWLEDGEMENT

This work was carried out during a Collaborative Project Tunisia-Egypt Funded by the Ministry of Scientific Research, in Egypt (Grand no.4/10/4) and the Ministry of Higher Education and Scientific Research of Tunisia.

RESUME

El-Mohamedy R.S.R., Jabnoun-Khiareddine H. et Daami-Remadi, M. 2014. Contrôle des pourritures racinaires des plants de tomate causées par *Fusarium solani*, *Rhizoctonia solani* et *Sclerotium rolfsii* en utilisant différents inducteurs chimiques de résistance. Tunisian Journal of Plant Protection 9: 45-55.

Les pourritures racinaires des plants de tomate causées par *Rhizoctonia solani*, *Fusarium solani* et *Sclerotium rolfsii* sont des maladies graves conduisant à un retard de croissance et à la mort des plants sévèrement infectés. L'effet de certains inducteurs chimiques, à savoir, les sels de potassium, l'acide salicylique et l'acide sorbique, dans la lutte contre les pathogènes causant les pourritures racinaires et leur impact sur les paramètres de croissance, de la quantité et de la qualité de tomate cv. Super Strain B a été étudié. Tous les inducteurs chimiques testés ont réduit significativement la sévérité des pourritures racinaires sous serre et en plein champ. Les traitements à base de sels de potassium, suivi par l'acide salicylique, ont été les plus efficaces dans la réduction de l'incidence des pourritures des racines induites par tous les agents pathogènes testés. Cependant, le traitement par l'acide sorbique s'est montré le moins efficace. Pour les essais au champ, les réductions les plus importantes de l'incidence et de la sévérité des pourritures racinaires ont été enregistrées sur les plants de tomate traités avec du sorbate de potassium utilisé à 7,5% et le phosphate d'hydrogène dipotassique (K_2HPO_4) 400 mM, suivi par le traitement par l'acide salicylique 100 mM. L'incidence et la sévérité des maladies ont été réduites de 65,4 et 62,5% en 2012, et de 63,2 et 53,8% en 2013, respectivement. L'application des sels de potassium, suivie par de l'acide salicylique a été la plus efficace pour l'augmentation des paramètres de croissance, de rendement et de la qualité de la tomate par rapport au témoin. Par conséquent, il pourrait être suggéré que l'application des inducteurs chimiques de résistance à la plante peut être utilisée dans le commerce pour le contrôle des pourritures des racines de la tomate et pour l'augmentation de la qualité et de la quantité de tomate à la fois, car ils sont sains, moins coûteux et efficaces contre ces maladies, même dans les conditions du champ.

Mots clés: Contrôle de la maladie, inducteurs chimiques de résistance, pourriture racinaire, tomate, qualité, rendement.

ملخص

المحمدى، رياض صدقي رياض وهيفاء جبنون-خيار الدين وماجدة الدعمي-الرمادي. 2014. مقاومة أمراض تعفنات جذور نباتات الطماطم المتسببة عن الفطريات *Fusarium solani* و *Rhizoctonia solani* و *Sclerotium rolfsii* باستخدام مختلف مستحثات كيمائية للمقاومة. Tunisian Journal of Plant Protection 9: 45-55.

تعتبر أمراض تعفنات الجذور من أخطر الأمراض التي تصيب نباتات الطماطم متسببة في تأخر في النمو وموت للكثير من النباتات شديدة الإصابة. في هذه الدراسة تم اختبار تأثير بعض المستحثات الكيمائية للمقاومة في النبات مثل سوربات البوتاسيوم وفوسفات البوتاسيوم ثنائية القاعدة وحمض الساليسليك وحمض السوربيك في مقاومة المسببات المرضية تحت ظروف العدوى الصناعية في البيت الحامي وكذلك تحت ظروف الحقل. كما تمت أيضا دراسة تأثير تلك المعاملات على النمو والمحصول لنباتات الطماطم خلال موسمين متتاليين 2012 و 2013. تبين أن كل المستحثات الكيمائية المختبرة لها تأثير معنوي في خفض نسبة وشدة الإصابة بأمراض تعفنات الجذور وكذلك في زيادة النمو والمحصول لنباتات الطماطم المعاملة بمقارنتها بالشاهد. تحت ظروف العدوى الصناعية بالمسببات المرضية *Fusarium solani* و *Rhizoctonia* *Sclerotium rolfsi solani*، لوحظ أن أحسن المعاملات في خفض نسبة وشدة الإصابة بأمراض تعفنات الجذور هي معاملة شتلات الطماطم بأملاح البوتاسيوم {سوربات البوتاسيوم (% 7.5) وفوسفات البوتاسيوم ثنائية القاعدة } (400Mm)، يليها حمض الساليسيلك (100 mM) وأخيرا حمض السوربيك. أما تحت ظروف الحقل وخلال موسمين متتالين 2012 و 2013، فتبين أن معاملة شتلات الطماطم بسوربات البوتاسيوم 7.5% وفسوفات البوتاسيوم ثنائية القاعدة يليها معاملة حمض السالسيلك هي أحسن المعاملات في خفض نسبة الإصابة بأمراض تعفنات الجذور كما سببت تلك المعاملات زيادة في النمو الخضري والمحصول للنباتات المعاملة وكذلك في زيادة في صفات الجودة لمحصول الطماطم مقارنة بالشاهد. تشير نتائج هذه الدراسة إلى إمكانية استخدام المستحثات الكيمائية للمقاومة بطريقة تطبيقية في مقاومة مسببات أمراض تعفنات الجذور وكذلك في زيادة النمو والمحصول لنباتات الطماطم خاصة وأن تلك المعاملات آمنة بيئيا وغير مكلفة وفعالة في مقاومة المسببات المرضية حتى تحت ظروف الحقل.

كلمات مفتاحية: تعفنات الجذور، جودة، مكافحة المرض ، مردود، مستحثات المقاومة الكيمائية، طماطم

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