

# Induced systemic resistance to *Meloidogyne* spp by $\beta$ ,amino butyric acid in tomato

Shamaael S. Mutar, Farkad A. Fattah\*

Department of Plant Protection, College of Agriculture, University of Baghdad, Baghdad, Iraq;

\*Corresponding Author: [farkad.fattah@gmail.com](mailto:farkad.fattah@gmail.com)

Received 17 September 2013; revised 16 October 2013; accepted 27 October 2013

Copyright © 2013 Shamaael S. Mutar, Farkad A. Fattah. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## ABSTRACT

$\beta$ ,amino butyric acid (BABA) induced resistance against *Meloidogyne* spp in tomato. Significantly ( $p = 0.05$ ) less, 41.11 second stage juveniles (J2) enter the roots of treated than, 116.66 J2 in untreated control plants. Root fresh and dry weight (Rfw, Rdw) were 2.87 and 0.12 g in treated compared with 4.78 and 0.30 g in nematode infected control plants respectively, 30 d after nematode inoculation. Sfw and Sdw were 8.62 and 0.60 g compared with 3.94 and 0.22 g in control plants. Foliage spray at 40 and 20 mM of BABA was more effective than 10 and 5 mM treatments. The former two concentrations recorded the lowest, average gall index, 2.11 compared with 3.33, 4.11, and 5 for the latter two concentrations and nematode infected control respectively. Results also indicated that treatments with BABA prior to nematode inoculation were superior in inducing resistance to *Meloidogyne* spp over treatment at the time or after nematode inoculation.

**Keywords:** Induced Resistance;  $\beta$ ,Amino Butyric Acid; *Meloidogyne* spp; Tomato

## 1. INTRODUCTION

Tomato, *Solanum lycopersicum* L., formerly known as *Lycopersicon esculentum* Mill., is the second most important vegetable crop after potato with annual world production of about 152.9 million ton in 2009 [1]. Annual tomato production in Iraq was estimated at 830,000 tons in 2008 [2]. Tomato plants are subjected to infection by many important plant pathogens including the root knot nematodes, *Meloidogyne* spp which are considered as the most important nematode species worldwide and in Iraq. Many effective control measures were used to

manage these pathogens such as soil solarization chemical and biological control. Induced systemic resistance to plant pathogen provides an ideal control measures against plant pathogens [3]. Chemical, physical and biological inducers to control the root knot nematodes were used [4]. In recent years, various chemical, physical and biological agents were used to induce resistance to many plant pathogens.  $\beta$ -1,3 amino butyric acid (BABA), Benzol [1-3] thiazolidiazole-7-carbothionic acid S-methyl ester and salicylic acid are among the most widely studied chemical inducers [5-7]. These chemicals activate resistance against different plant pathogens like fungi, bacteria, viruses and nematodes [8]. BABA was reported to induce resistance against members of solanaceae, cucurbitaceae, legumenaceae, cruciferae, and rosaceae [9]. Jakob *et al.* [10], reported that BABA induced resistance to different plant pathogens such as fungi, bacteria, viruses, and plant parasitic nematodes. Only few studies on induced resistance by BABA against plant nematodes are reported. BABA was reported to reduce damage due to root knot nematode on tomato [11] and *M. javanica* and *Rotylenchulus reniformis* on pineapple [12] and induce resistance against *M. javanica* in cucumber [4].

This study was undertaken to assess the ability of  $\beta$ , aminobutyric acid to induce acquired systemic resistance against the root knot nematodes, *Meloidogyne* spp in tomato plants.

## 2. MATERIALS AND METHODS

Experiments were performed in a greenhouse ( $27 \pm 5$  C) and tomato, *Solanum lycopersicum* L. cv. "Supper Regina" highly susceptible to *Meloidogyne* spp was used. Plants were grown and maintained in 1kg plastic pots throughout the experiments.

### 2.1. Nematode Inoculation

Soil from cucumber grown plastic house heavily in-

infested with *Meloidogyne* spp (predominantly *M.javanica*) were collected and stored at 4 C in polyethylene pages until use to inoculate tomato seedlings. The nematode infested soil was mixed with peat moss in 1:1 ratio and used as nematode inoculums.

## 2.2. Preparation $\beta$ ,Amino Butyric Acid (BABA)

Stalk solution of BABA, Mwt = 103 (Sigma Aldrich, St Louis, Missouri, USA) was prepared by dissolving 412 mg in 100 ml of distilled water.

## 2.3. Foliage Treatments with BABA

Four concentrations of BABA, 5, 10, 20, and 40 mM were used as foliage application. The experiment was consisted of 13 treatments (one nematode inoculated control sprayed with distilled water and 12 combination of the 4 concentrations of BABA 3-d before, during and 7-d after nematode inoculation). Plants were carefully sprayed till complete wetness using 1L hand sprayer. Each treatment was replicated 4 times and arranged in randomized complete blocks in the greenhouse. Thirty days after inoculation, plants were assessed for growth and nematode infection.

## 2.4. Root Treatments with BABA

In this experiment, 2 mL of 1, 2.5 and 5 mM of BABA were used as soil drenching added around the stem of single tomato plants growing in nematode infested soil in 1 kg plastic pots. Ten treatments (one nematode inoculated control watered with 2 ml of distilled water and 9 combinations of the 3 concentration of BABA applied 3-days before, during and 7-days after nematode inoculation). Thirty days after inoculation, plants were assessed for growth and nematode infection. Each treatment was replicated 4 times and arranged in a randomized complete block in the greenhouse. Thirty days after inoculation, plants were assessed for growth and nematode infection.

## 2.5. Effect of BABA on *Meloidogyne* spp Rate of Gall Index

The rate of infestation of the root knot nematodes is determined using a 5 level scales [13]: 1 = no galls on roots, 2 = galls on 1% - 25% of the root, 3 = galls on 26% - 50% of the root, 4 = galls on 51% - 75% of the root, and 5, galls on 76% - 100% of the root.

## 2.6. Effect of BABA on Fresh and Dry Weight of Shoot and Root Systems

Plants were carefully uprooted and roots were washed under tap water to remove adhering soil. To determine

shoot and root dry and wet weight, shoots and roots were separately weights and dried at 70 C for 48 h or until weight fixed.

## 2.7. Effect of BABA on Nematode Penetration

To determine the effect BABA treatments on nematode penetration of tomato roots, roots were stained with acid fuchsin [14], washed with water to remove excess stain and 1 g of each root was individual examined under a compound microscope to count nematodes inside the roots.

## 3. STATISTICAL ANALYSIS

The data were subjected to analysis of variance and means were separated by the least significant method at ( $p = 0.05$ ) using SAS, 2004 [15].

## 4. RESULTS

### 4.1. Foliage Application

#### 4.1.1. Effect of Foliage Treatment of BABA on *Meloidogyne* spp Rate of Gall Index

BABA treatment induced resistant to *Meloidogyne* spp in tomato plants (Table 1). The treatments significantly ( $p = 0.05$ ) reduced the rates of gall index of treated plants compared with nematode infected control plants. While 40, 20, 10, and 5 mM of BABA treated plants recorded low average gall indices, 2.11, 2.11, 3.33, 4.11 respectively. BABA untreated plants recorded the highest average gall index, 5, 30 days after nematode inoculation. The former two concentrations render tomato plant sig-

**Table 1.** Effect of spraying BABA on tomato, *Solanum lycopersicum* L. shoot on rate of root galls index of *Meloidogyne* spp infected plants 30 days after nematode inoculation.

BABA Conc. (mM)	Rate of root gall index			Mean
	Nematode inoculation			
	7 days before	During	3 days after	
40	2.33	2.33	1.66	2.11
20	2.66	2	1.66	2.11
10	4	3	3	3.33
5	4	4	4.33	4.11
Control	5	5	5	5
Mean	3.60	3.26	3.13	

LSD ( $P = 0.05$ ) = Conc. =  $0.35^*$ , Trea. =  $0.27^*$ , Inter =  $0.60^*$ . Each number is a mean of three replicates and two plant each. \*Indicate significant deferens. Nematode inoculums (nematode infested soil + peat moss, 1:1) were added when plants were 4 - 5 true leaves. Gall index was according to 1 - 5 level scale: 1 = no galls on the roots, 2 = galls on 1% - 25% of the root, 3 = galls on 26% - 50% of the root, 4 = galls on 51% - 75% of the root, and 5 = galls on 76% - 100% of roots. BABA =  $\beta$ ,amino butyric acid.

nificantly more resistant to the nematode than the two latter concentrations (Table 1). The 40 and 20 mM scored significantly ( $p = 0.05$ ) the lowest nematode gall index, 1.66, when BABA treatments exceeded nematode inoculation by 3 days compared with other test treatments.

#### 4.1.2. Effect of BABA on Fresh and Dry Weight of Root Systems

Results in Table 2 showed that spraying tomato plants with BABA significantly ( $p = 0.05$ ) affected root fresh weight (Rfw) and root dry weight (Rdw) of *Meloidogyne* spp infected tomato plants. The 40 mM recorded the lowest average root weights, 5.74 and 0.34 g compared with other test treatments 30 days after nematode inoculation. Treatment with BABA 3 days before nematode inoculation produced the lowest Rfw and Rdw, 3.96 and 0.29 g respectively 30 days after nematode inoculation. The 40 mM concentration also recorded the lowest root weights, 2.35 and 0.21 g compared with the highest root weight, 12.98 and 0.80 g when the treatment was performed 7 days after nematode inoculation.

#### 4.1.3. Effect of BABA on Fresh and Dry Weight of Shoot Systems

Spraying of BABA on foliage of tomato plants significantly ( $p = 0.05$ ) increased root fresh and dry weight (Sfw and Sdw) of nematode infected tomato plants 30 days after inoculation (Table 3). The average weights for plants treated with 40 and 20 mM of BABA recorded the highest, 21.40 and 2.10 g Sfw and Sdw compared with the lowest average weights of 15.05 and 0.97 g in nematode infected controls. Treatment with BABA 3 days before nematode inoculation caused significantly the highest weight, 20.99 and 2.24 g compared with 14.24, 0.75, 19.31 and 1.35 g when nematode was inoculated during and 7 days after BABA treatment respectively. Treatment with 40 and 20 mM of BABA 3 days prior to nematode inoculation caused higher Sfw and Sdw, 25.32, 3.25 and 22.22, 3.90 g compared with, 12.86 and 0.51 g for nematode infected control plants respectively.

## 4.2. Soil Application

#### 4.2.1. Effect of Soil Drenching with BABA on *Meloidogyne* spp Rate of Gall Index

Soil drenching with BABA significantly ( $p = 0.05$ ) reduced the root gall index of tomato plants infected with *Meloidogyne* spp (Table 4). Gall index was decreased as the test BABA concentration was increased. The 5 mM concentration produced significantly the lowest average gall index, 2.33 compared with, 2.77, 3.55 and 5 for 2.5, 1 mM and control 30 days after nematode inoculation respectively. The lowest average gall index, 2.91 was recorded when BABA was applied 3 days before nematode

**Table 2.** Effect of spraying BABA on tomato, *Solanum lycopersicum* L. shoot on root weights of *Meloidogyne* spp infected plants 30 days after nematode inoculation.

BABA Conc. (mM)	Root weight of infected plants (g)						Mean Dry	Mean Fresh
	Nematode inoculation							
	7 days after		During		3 days before			
	Dry	Fresh	Dry	Fresh	Dry	Fresh		
40	0.21	2.35	0.37	5.97	0.45	8.90	0.34	5.74
20	0.24	2.72	0.40	5.98	0.47	10.09	0.37	6.26
10	0.28	3.91	0.50	6.74	0.51	10.16	0.43	6.94
5	0.30	5.89	0.72	8.92	0.50	11.44	0.51	8.75
Control	0.40	4.94	0.52	8.79	0.80	12.98	0.58	8.90
Mean	0.29	3.96	0.50	7.28	0.54	10.71		

LSD ( $P = 0.05$ ) Dry weight: Conc. = 0.065<sup>\*</sup>, Treat. = 0.050<sup>\*</sup>, Inter. = 0.11<sup>\*</sup>. LSD ( $P = 0.05$ ) Fresh weight: Conc. = 1.78<sup>\*</sup>, Treat. = 1.37<sup>\*</sup>, Inter. = 3.08<sup>\*</sup>. Each number is a mean of three replicates and two plant each. \*Indicate significant deferens. Nematode inoculums (nematode infested soil + peat moss, 1:1) were added when plants were 4 - 5 true leaves. BABA =  $\beta$ , amino butyric acid.

**Table 3.** Effect of spraying BABA on tomato, *Solanum lycopersicum* L. shoot on shoot weights of *Meloidogyne* spp infected plants 30 days after nematode inoculation.

BABA Conc. (mM)	Shoot weight of infected plants (g)						Mean Dry	Mean Fresh
	Nematode inoculation							
	3 days before		During		7 dayd after			
	Dry	Fresh	Dry	Fresh	Dry	Fresh		
40	3.25	25.32	1.15	13.69	1.92	25.13	2.10	21.38
20	2.90	22.22	1.00	17.92	1.26	24.06	1.72	21.40
10	1.39	21.23	0.57	12.88	1.31	14.31	1.09	16.14
5	2.27	18.34	0.53	13.88	1.24	18.58	1.35	16.93
Control	1.40	17.83	0.51	12.86	1.00	14.48	0.97	15.05
Mean	2.24	20.99	0.75	14.24	1.35	19.31		

LSD ( $P = 0.05$ ) Dry weight: Conc. = 0.2669<sup>\*</sup>, Treat. = 0.2067<sup>\*</sup>, Inter. = 0.4623<sup>\*</sup>. LSD ( $P = 0.05$ ) Fresh weight: Conc. = 3.20<sup>\*</sup>, Treat. = 2.4<sup>\*</sup>, Inter. = 5.54<sup>\*</sup>. Each number is a mean of three replicates and two plant each. \*Indicate significant deferens. Nematode inoculums (nematode infested soil + peat moss, 1:1) were added when plants were 4 - 5 true leaves . BABA=  $\beta$  amino butyric acid.

inoculation compared to 3.25 and 4.08 when BABA was applied during or 7 days after the nematode respectively. The lowest gall index, 1.66 was caused by application of 5 mM of BABA 3 days before nematode inoculation compared with the highest gall index, 5 in nematode infected control.

#### 4.2.2. Effect of Soil Drenching with BABA on Weight of Roots

Results in Table 5 showed that soil drenching with 5

**Table 4.** Effect of soil drenching of BABA on rate of root gall index caused by *Meloidogyne* spp on tomato, *Solanum lycopersicum* L. 30 days after nematode inoculation.

BABA Conc. (mM)	Rate of root gall index			Mean
	Nematode inoculation			
	3 days before	During	7 days after	
5	1.66	2.33	3	2.33
2.5	2	2.66	3.66	2.77
1	3	3	4.66	3.55
Control	5	5	5	5
Mean	2.91	3.25	4.08	

LSD ( $P = 0.05$ ) Conc. = 0.36\*, Treat. = 0.31\*, Inter. = 0.62\* Each number is a mean of three replicates and two plant each. \*indicate significant deferens. Nematode inoculums (nematode infested soil + peat moss, 1:1) were added when plants were 4 - 5 true leaves. Gall index was according to 1 - 5 level scale: 1 = no galls on the roots, 2 = galls on 1% - 25% of the root, 3 = galls on 26% - 50% of the root, 4 = galls on 51% - 75% of the root, and 5 = galls on 76% - 100% of roots. BABA =  $\beta$ ,amino butyric acid.

**Table 5.** Effect of soil drenching of BABA on root weights of tomato, *Solanum lycopersicum* L. infected with *Meloidogyne* spp 30 days after nematode inoculation.

BABA Conc. (mM)	Root weight (g)						Mean Dry	Mean Fresh
	Nematode inoculation							
	3 days before		During		7 days after			
	Dry	Fresh	Dry	Fresh	Dry	Fresh		
5	0.27	3.25	0.34	3.72	0.39	9.86	0.35	5.61
2.5	0.16	2.50	0.39	8.98	0.51	9.44	0.35	6.97
1	0.32	3.37	0.49	11.39	0.52	9.43	0.43	8.06
Control	0.35	3.75	0.36	10.23	0.61	9.77	0.44	7.91
Mean	0.28	3.21	0.39	8.58	0.51	9.62		

LSD ( $P = 0.05$ ) Fresh weight: Conc. = 1.41\*, Traet. = 1.22\*, Inter. = 2.44\*. LSD ( $P = 0.05$ ) Dry weight: Conc. = 0.0724\*, Inter. = 0.1447\*. Each number is a mean of three replicates and two plant each. \*Indicate significant deferens. Nematode inoculums (nematode infested soil + peat moss, 1:1) were added when plants were 4 - 5 true leaves. BABA =  $\beta$ ,amino butyric acid.

mM BABA significantly ( $p = 0.05$ ) affected Rfw and Rdw of *Meloidogyne* spp infected tomato plants. At this concentration average Rfw and Rdw were 5.61 and 0.35 g compared with 7.91 and 0.44 g in control plants respectively. However, 2.5 and 1 mM did not significantly affect root weights. The 40 mM recorded the lowest average root weights, 5.74 and 0.34 g compared with other test treatments 30 days after nematode inoculation. Treatment with BABA 3 days before nematode inoculation produced the lowest average Rfw and Rdw, 3.21 and 0.28 g compared with 8.58, 0.39, 9.62 and 0.51 g at the time and 7 days after nematode inoculation respectively.

While the lowest root weights were recorded for the 5 and 2.5 mM, 3 days before nematode inoculation, 3.25, 0.27, 2.50, 0.16, the 1 mM concentration and control recorded the highest root weights, 11.39, 0.49, 10.23, 0.36 g respectively when the treatment was performed at the time of nematode inoculation.

#### 4.2.3. Effect of Soil Drenching with BABA on Weight of Shoots

Soil drenching with the test concentrations of BABA significantly ( $p = 0.05$ ) affected shoot weights of *Meloidogyne* infected tomato plants (Table 6). The average Sfw and Sdw was grater, 20.43 and 2.34 g in 5 mM treatment compared with 15.11 and 1.19 g in control. Grater shoot weights were observed when BABA treatments exceeded nematode inoculation by 3 days, 20.91, 2.65 compared with 13.11, 0.70 and 18.61, 1.52 g when BABA treatment was at or 7 days after nematode inoculation respectively. The greatest average Sfw and Sdw, 24.32 and 4.22 g were recorded for 5mM application 3 days before nematode inoculation while the lowest Sdw, 0.43 g and Sfw, 11.75 g for the 1mM at the time of nematode inoculation and the untreated control plants respectively.

## 5. DISCUSSION

Results of this work indicated that foliage as well as soil drench application of BABA induced systemic resistance against *Meloidogyne* spp in susceptible tomato plants. This was manifested by the reduction of galls on roots and numbers of J2 in roots of BABA treated plants compared with those in BABA untreated but nematode

**Table 6.** Effect of soil drenching of BABA on shoot weights of tomato, *Solanum lycopersicum* L. infected with *Meloidogyne* spp 30 days after nematode inoculation.

BABA Conc. (mM)	Shoot weight (g)						Mean Dry	Mean Fresh
	Nematode inoculation							
	3 days before		During		7 days after			
	Dry	Fresh	Dry	Fresh	Dry	Fresh		
5	4.22	24.32	1.09	16.47	1.71	20.50	2.34	20.43
2.5	2.76	22.92	0.75	11.96	1.64	20.90	1.71	18.59
1	1.90	20.51	0.43	12.25	1.45	15.39	1.26	16.05
Control	1.73	15.89	0.53	11.75	1.30	17.67	1.19	15.11
Mean	2.65	20.91	0.70	13.11	1.52	18.61		

LSD ( $P = 0.05$ ) Fresh weight: Conc. = 2.50\*, Traet. = 2.16\*, Inter. = 4.33\*. LSD ( $P = 0.05$ ) Dry weight: Conc. = 0.319\*, Treat. = 0.2763\*, Inter. = 0.5252\*. Each number is a mean of three replicates and two plant each. \*Indicate significant deferens. Nematode inoculums (nematode infested soil + peat moss, 1:1) were added when plants were 4 - 5 true leaves. BABA =  $\beta$ ,amino butyric acid.

infected plants. The growth of the nematode infected plants by decreasing root weight and increasing shoot weight of BABA treated tomato plants. These findings also support previous reports indicating that treatments with  $\beta$ -amino butyric acid reduced root knot disease through decreased penetration of J2, gall number on roots and nematode development [4,11,12]. Root weight increase in heavy *Meloidogyne* spp infection was previously reported and thought to be caused due to biomass accumulations in infected roots [16]. *Meloidogyne* spp infection is known to have negative effects on water and nutrient elements as well as photosynthesis [17]. It was reported that *M. incognita* infection caused biomass accumulation in roots and this is controlled by the efficiency of the pathogen in capturing the light energy and directing it in favor of the pathogen or the infected host [18]. Because of the relative large size of females of *Meloidogyne* spp and its ability to produce large number of eggs, it requires large amount of energy. Beside this energy requirement, these pathogens caused obvious distortion in xylem vessels, swellings of root cells and formation of giant feeding cells which alter root normal functions. Treatments of nematode infected plants with the high concentration of BABA produced more shoots compared with untreated nematode infected plant. This is mainly due to the fact that *Meloidogyne* infections embed photosynthesis and chlorophyll synthesis which negatively influences plant growth [17]. It was clear from the results of this study that treatments with BABA was more effective when applied before nematode inoculation, which is probably due to the mechanism of induce resistance of this chemical inducer. The mechanism of induce resistance to *Meloidogyne* in tomato by BABA is not fully understood. It was believed that treatments with this inducer render roots less attractive to J2 through altered plant nutrient assimilation or render plant cell walls harder to penetrate by J2 or that giant cells were smaller or not able to provide enough nutrients for the developing nematodes [11]. Treatments with BABA were reported to increase levels of salicylic acid (SA) and pathogenesis related proteins (PRP) [19], and enzymes like catalase (CAT), polyphenoloxidase (PPO) and guaiacol peroxidase (GPOX) [4,7] and phenol compounds [20]. BABA was also reported to induce the accumulations of PPO, GPOX, H<sub>2</sub>O<sub>2</sub>, CAT and phenols in *M.javanica* infected cucumber roots [21].

Results of this research work clearly indicate and endorse previous reports on the effectiveness of  $\beta$ -amino-butyric acid to the induced systemic resistance as environmentally sound alternative for the control of *Meloidogyne* spp on tomato.

## 6. ACKNOWLEDGEMENTS

The authors would like to thank Mr. Dhulfiqar Layth (Graduate stu-

dent, Dept., of Plant Protection, College of Agriculture, Univ. of Baghdad, Baghdad, Iraq) for his valuable assistance.

## REFERENCES

- [1] Anonymos (2009) www.Frehplaza.com/news.
- [2] FAOSTAT (2008) List of countries by tomato production. <https://www.google.com/search>
- [3] Kumagai, T. (1988) Photocontrol of fungal development. *Photochemistry and Photobiology*, **47**, 889-896. <http://dx.doi.org/10.1111/j.1751-1097.1988.tb01672.x>
- [4] Sahebani, N. and Hadavi, N.S. (2011) The effects of  $\beta$ -amino-butyric acid on resistance of cucumber against root-knot nematode, *Meloidogyne javanica*. *Journal of Plant Physiology*, **33**, 443-450.
- [5] Grolach, J., Volrath, S., Knauf-Beiter, G., Hengy, G., Beckhove, U., Kogel, Oostendorp, M., Staub, T., Ward, E., Kessmann, H. and Ryals, J. (1996) Benzothiadiazole, a novel class of inducers of systemic acquired resistance, activates gene expression and disease resistance in wheat. *Plant Cell*, **8**, 629-643.
- [6] He, C.Y. and Wolyn, D.J. (2005) Potential role for salicylic acid in induced resistance of asparagus roots to *Fusarium oxysporum* f. sp. *asparagi*. *Plant Pathol.* **54**, 227-232. <http://dx.doi.org/10.1111/j.1365-3059.2005.01163.x>
- [7] Sahebani, N. and Hadavi, N.S. (2009) Induction of H<sub>2</sub>O<sub>2</sub> and related enzymes in tomato roots infected with root knot nematode (*M. javanica*) by several chemical and microbial elicitors. *Biocontrol Science and Technology*, **19**, 301-313.
- [8] Kessmann, H., Staub, T., Hofmann, C., Maetzke, T., Herzog, J., Ward, E., Uknes, S. and Ryals, J. (1994) Induction of systemic acquired resistance in plants by chemicals. *Annual Review of Phytopathology*, **32**, 439-459.
- [9] Cohen, Y. (2002)  $\beta$ -aminobutyric acid-induced resistance against plant pathogens. *Plant Disease*, **86**, 448-457. <http://dx.doi.org/10.1094/PDIS.2002.86.5.448>
- [10] Jacob, G., Cottier, V., Toquin, V., Rigoli, G., Zimmerli, L., Mettraux, J.P. and Mauch-Mani, B. (2001)  $\beta$ -aminobutyric acid-induced resistance in plants. *European Journal of Plant Pathology*, **107**, 29-37. <http://dx.doi.org/10.1023/A:1008730721037>
- [11] Oka, Y., Cohen, Y. and Spiegel, Y. (1999) Local and systemic induced resistance to the root-knot nematode in tomato by DL-b-aminon-butyric acid. *Phytopathology*, **89**, 1138-1143. <http://dx.doi.org/10.1094/PHYTO.1999.89.12.1138>
- [12] Chinnasri, B., Sipes, B.S. and Schmitt, D. P. (2006) Effect of inducer of systemic acquired resistance on reproduction of *Meloidogyne javanica*. *Journal of Nematology*, **38**, 319-325.
- [13] Dube, B. and Smart, G.C.J. (1987) Biological control of *Meloidogyne incognita* by *paecilomyces lilacinus* and *pasturia penetrans*. *Journal of Nematology*, **9**, 222-227.
- [14] Byrd, D.W., Kirkpatrick, T., Barker, K.R. (1983) An improved technique for clearing and staining plant tissue for detection of nematodes. *Journal of Nematology*, **15**, 142-

- 143.
- [15] SAS (2004) SAS user's guide for personal, computers. SAS Institute Inc., Cary.
- [16] Fortnum, B.A., Decoteau, D.R., Kasperbauer, M.J. and Bridges, W. (1995) Effect of colored mulch on rootknot of tomato. *Phytopathology*, **85**, 312-318. <http://dx.doi.org/10.1094/Phyto-85-312>
- [17] Melakeberhan, H. (2004) Physiological interactions between Nematodes and Their Host Plants. In: Chen, Z.X., Chen, S.Y. and Dickson, D.W., Eds., *Nematode Management and Utilization II*, CABI Publishing, p. 786.
- [18] Melakebrhan, H. and Ferris, H. (1988) Growth and energy demand of *Meloidogyne incognita* on susceptible and resistance *Vitis vinifera* cultivars. *Journal of Nematology*, **20**, 545-554.
- [19] Hwang, B.K., Sunwoo, J.Y., Kim, Y.J. and Kim, B.S. (1997) Accumulation of beta-1,3-glucanase and chitinase isoforms, and salicylic acid in the DL-beta-amino-n-butyric acid-induced resistance response of pepper stems to *Phytophthora capsici*. *Physiological and Molecular Plant Pathology*, **51**, 305-322. <http://dx.doi.org/10.1006/pmpp.1997.0119>
- [20] M'Piga, P., Belanger, R.R., Paulitz, T. and Benhamou, N. (1997) Increased resistance to *Fusarium oxysporum* f. sp. *radicis-lycopersici* in tomato plants treated with the endophytic bacterium *Pseudomonas fluorescens* strain 63-28. *Physiological and Molecular Plant Pathology*, **50**, 301-320. <http://dx.doi.org/10.1006/pmpp.1997.0088>
- [21] Siegrist, J., Orober M. and Buchenauer, H. (2000)  $\beta$ -amino butyric acid mediated enhancement of resistance in tobacco to tobacomosaic virus depends on the accumulation of salicylic acid. *Physiological and Molecular Plant Pathology*, **56**, 95-106.