Research Article

Pathogenicity and Management of Root-Knot Nematode, *Meloidogyne javanica* Infecting Soybean Plants at Different Inoculum Levels

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Abstract | Susceptibility of four soybean cultivars (Giza 21, 35, 82, and 111) to root-knot nematode, *Meloidogyne javanica* categorized according to damage index (DI). Data revealed that all cultivars were susceptible to *M. javanica* infection. Results showed that increasing inoculum levels of *M. javanica* infecting soybeans significantly increased root galling severity and damage index. Nevertheless, root galling was most severe on soybean cv. Giza 111as highest index was nine (inoculum population= 3000 J_2s). Likewise, final nematode population in soil (J_2s), and egg- masses/root system was increased with the increasing of inoculum levels of *M. javanica* on soybean plants. The comparison between infected and uninfected plants revealed a significant decrease in all growth parameters among the infected and control plants. Plant growth parameters reduced to a small extent at lower initial inoculum levels, however, at greater inoculum levels; the plant growth parameters significantly reduced compared to control plants. The nematicidal activities of ammonium sulfate, chicken manure, and urea 46%, alone or in combination tested against *M. javanica*. The obtained data revealed that the combined treatments of tested agents were more efficacious than individual ones. The nematicide Fosthiazate 10G significantly reduced egg masses, galls numbers, and the final nematode population in soil. A combination of (chicken manure+ urea 46%) occupied the second rank. Meanwhile, the combined treatment of ammonium sulfate + urea 46% was recorded as the third effective treatment. All tested agents affected total protein content, free phenolic compounds, and proline content.

Received | November 24, 2024; **Accepted** | February 03, 2025; **Published** | March 26, 2025
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Citation | Abdel-Baset, S.H., M.E.A. Abo-Rehab and S.M.A. Mohamed. 2025. Pathogenicity and management of root-knot nematode, *Meloidogyne javanica* infecting soybean plants at different inoculum levels. *Pakistan Journal of Nematology*, 43(1): 23-31.
DOI | https://dx.doi.org/10.17582/journal.pjn/2025/43.1.23.31
Keywords | Soybean cultivars, *Meloidogyne javanica*, Inoculum levels, Ammonium sulfate, Chicken manure, Urea

Introduction

Soybean, *Glycine max* (L.) globally, no other crop surpasses the importance of soybeans in terms of oil and protein production. Among all leguminous crops, its seeds have the highest protein content. Because soybean protein has a high ratio of necessary amino acids, it is the best plant protein source currently available in terms of nutritional value. Its oil is utilized in numerous manufactured valuable goods or directly for human consumption. Soybean seeds do indeed have a variety of purposes, including animal feed and human nourishment (Abdel-Reheem *et al*., 2018). A significant biotic factor that has a detrimental impact on soybean production globally is plant-parasitic nematodes, which result in an approximate annual yield loss of 10% to 15%. There have been reports of over 100 nematode species from 50 genera associated with soybeans. The most significant nematode affecting soybean plants globally is Root-knot nematodes, *Meloidogyne* spp., which particularly, distorts soybean root systems when galls grow, which negatively influences the roots' ability to absorb nutrients and water (Abdel-Baset and Abdel-Monaim, 2020). RNNs, *M. javanica,* and *M. incognita* recognized as species responsible for the greatest yield reduction in susceptible soybean cultivars, causing a significant increase in yield loss from plant-resistant soybean cultivars by up to 90% (Fourie *et al*., 2001). A correlation between soybean cultivars (Carpentieri-Pípolo, 2005; Bridge and Starr, 2007). When the initial population of *M. incognita* (J_2) reaches 150 per 500cm^3 of soil, crop yields can decrease by 10%. Previous studies have shown that this nematode reduced the productivity of resistant and susceptible soybean cultivars by over 40% and 90%, respectively in the USA (Fourie *et al*., 2010). It is a well-established agricultural practice to use organic soil amendments to manage plant parasitic nematodes. In addition to potentially increasing the number of nematode-opposing microorganisms in the soil, amendments can produce harmful substances directly or indirectly as they break down in the soil. During the decomposition process, several organic acids are released, which are nematicidal in a soil environment (Oka *et al*., 2007). In alkaline soils, ammonia is extremely good at controlling nematodes and fungi. Ammonia-releasing materials, including both organic and inorganic chemicals, have been utilized as both nematicides and fungicides (Oka and Pivonia, 2002). The goals of this work were; (1) Screening different local Egyptian soybean cultivars against root-knot nematode, *M. javanica* (2) Assessing the impact of increasing initial population densities (Pi) of *M. javanica* on some susceptible soybean cv. Giza111growth criteria, and on nematode reproduction (3) Evaluating of ammonium sulfate, urea, and chicken manure to manage *M. javanica* infected soybean plants.

Materials and Methods

Greenhouse experiments

All experiments performed at Ismailia Agricultural Research Station, Egypt, to evaluate four soybean cultivars' growth response infected with RNN, *Meloidogyne javanica,* in season 2022.

Susceptibility of soybean cultivars infected with M. javanica

Reaction of four soybean cultivars (Giza 21, 35, 82, and 111) to *M. javanica* were assessed. Cultivars were obtained from Field Crop Research Institute, Agriculture Research Centre, Ministry of Agriculture, Giza, Egypt. The seeds received surface sterilization and then sowed into 25 cm-in diameter pots with sandy clay that has been steam-sterilized soil at a ratio of one to four. A week after planting, the plants were thinned such that each pot contained only one seedling. Each seedling (14-days old) inoculated with about 3000 newly hatched second stage juveniles (J_2s) of *M. javanica* obtained from pure cultures maintained and propagated on tomato cv. Elisa. Each inoculated cultivar duplicated 4 times. Treatments in those nematodes were not included, as a control. Experimental design followed a Randomized Complete Block Design. After 90 days post-inoculation, the experiment concluded, and data on plant growth and disease assessment were gathered.

Impact of an initial population (Pi) of M. javanica on soybean plant growth and reproduction of nematode

Fourteen days old, seedlings of Giza111 cultivar inoculated by pipetting the required inoculum density of nematodes on three holes around each base seedling. The range of Pi used for every cultivar was about 1000, 2000, and 3000 (0.3, 0.6, and 1 nematode/1gm soil) *M. javanica* newly hatched second stage juveniles (J_2s) per seedling. The untreated control treatment was not inoculated (Pi = 0).

Efficacy of ammonium sulfate, urea, and chicken manure in managing M. javanica infected soybean plants

Ammonium sulfate $(NH_4)_2SO_4$, urea $CO(NH_2)_2$ (46% nitrogen), and chicken manure (pH = 7.0, organic matter = 84.12%, C/N ratio = 20:1) were obtained from Soils, Water and Environ. Res. Inst. (SWERI), Agric. Res. Center, Giza, Egypt. The nematicide, Fosthiazate 10 G (Nemathorin®), used for comparison. Nematode only (control treatment).

Tested treatments

- Ammonium sulfate at 120 kg fed^{-1}
- Chicken manure at 2 ton fed^{-1}
- Urea 46% at 2 ton fed^{-1}
- Ammonium sulfate + chicken manure
- Ammonium sulfate + urea 46%
- Chicken manure+ urea 46%
- Fosthiazate 10 G at 12.5 kg fed^{-1}
- Control (left without any amendment or chemical).

Seven days before transplantation, all tested materials uniformly integrated into the top of the soil pot. Soybean cv. Giza 111 seeds sown, thinned, and inoculated with nematode as mentioned before. All data collected after 90 days from nematode inoculation.

Nematode assessment

After uprooting each cultivar's plants, the roots washed gently. Then, nematode gall index (GI), gall size (GS), gall area (GA), and damage index (DI), and based on DI, the host susceptibility for each plant cultivar is determined according to (Sharma *et al*., 1994). Egg-masses number /root system, addition to, number of second stage juveniles (j_2s) counted in every pot (Goodey, 1957).

Collection data

After uprooting plants, shoot and root systems were separated. The data of shoot and root systems: Fresh weights (g), lengths (cm), and dry weights (g). As well as the number of nodules/roots and pod weights (g) were documented. The percentage of reduction (R %) = Control plants − infected plants/ Control plants X100.

Effect of treatments on some of biochemical compounds

- Total protein (mg /g FW) evaluated according to (Bradford, 1976).
- Proline (mg /g FW) determined as described by Bates *et al*. (1973).
- Free phenolic compounds (mg /g FW) measured according to Horwitz *et al*. (1970). The percentage increase % in treatments was compared with the control treatment.

Statistical analysis

The experiments conducted using a completely randomized design with four replications per treatment. Data performed to analysis of variance (ANOVA) using MSTAT-C program version 2.10 (Anonymous, 1991). Duncan's multiple range test used to compare the means with a probability of $P \le 0.05$ (Duncan, 1955). Relationships between initial nematode densities (pi) and soybean yield depicted as regression lines for derivation linear and quadratic equations and determination correlation coefficient (r) between nematode infestation and soybean yield.

Results

Susceptibility of testing cultivars infected with M. javanica

Resistance, and susceptibility of four cultivars of soybean infecting with root-knot nematode, *M. javanica* were categorized using the damage index (DI), as demonstrated in Table 1. Results showed that, all cultivars were susceptible. Among the cultivars of soybean, there were notable differences ($p \le 0.05$) in final nematode population (j_2s) in soil, as well egg masses number, and egg mass indices (EI). Giza111 cultivar recorded the highest numbers of final nematode population (j_2s) /250 g of soil as 286, followed by Giza 35 as 186. While, egg-masses index (E.I =5.6) of Giza111 cultivars, while other cultivars (Giza 21, 35 and 82) recorded E.I. =4.3, 4.6 and 4.0, respectively.

Table 1: *Susceptibility comparison of four soybean cultivars to M. javanica infection.*

Cultivars	No. of root galls/ root system	G.I	Gall size (GS)	Gall area (GA)	Damage index (DI)	Host susceptibility/ Resistance	No. of j_2s/250 g of soil	No. of egg masses/root system	E.I
Giza 21	52.3^b	6.6^{ab}	5.6^a	5.6^a	6.0^b	S	173.0^b	20^b	4.3^b
Giza35	51.3^b	6.6^{ab}	5.6^a	5.6^a	6.0^b	S	186.0^b	21^b	4.6^b
Giza82	45.6^c	6.0^b	5.6^a	5.6^a	5.7^b	S	166.0^b	18^b	4.0^b
Giza111	68.3^a	7.3^a	7.0^a	7.0^a	7.0^a	S	286.0^a	31^a	5.6^a
LSD 0.05	5.01	0.94	1.88	1.88	1.07		34.3	4.2	0.94

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test (P ≤ 0.05). * Gall index (G.I), and egg-masses index (E.I) counted according to Sharma et al. (1994).*

Table 2: *Plant growth reactions of four soybean cultivars to M. javanica infection.*

Cultivars	Fresh weights (g)			Dry weight (g)			Length (cm)			Pods weight (g)		
	C.P	I.P	R%	C.P	I.P	R%	C.P	I.P	R%	C.P	I.P	R%
Shoot												
Giza 21	12.2^{c}	8.7^{bc}	28.0	4.9^{b}	3.1^{b}	37.0	46.0^{bc}	32.2^{bc}	30.0	14.5^{b}	9.0^{a}	38.0
Giza35	14.5^{b}	9.0^{ab}	38.0	5.9^{a}	3.3^{ab}	44.0	48.5^{b}	34.5^{b}	29.0	13.0^{b}	7.2^{b}	45.0
Giza82	17.0^{a}	10.2^{a}	40.0	6.2^{a}	3.4^{a}	45.0	44.5^{c}	30.7^{c}	31.0	14.5^{b}	8.0^{ab}	45.0
Giza111	13.7^{bc}	7.5^{c}	45.0	6.4^{a}	3.4^{a}.	47.0	59.0^{a}	37.2^{a}	37.0	17.2^{a}	9.0^{a}	48.0
LSD0.05	1.8	1.4		0.7	0.2		3.1	2.4		2	1.3	
Root												
Giza 21	6.1^{b}	3.3^{b}	46.0	2.6^{a}	1.5^{a}	42.0	43.0^{c}	31.5^{c}	27.0	76.5^{c}	38.2^{b}	50.0
Giza35	7.5^{a}	3.8^{a}	49.0	2.6^{a}	1.5^{a}	42.0	47.0^{b}	35.2^{b}	25.0	85.2^{b}	37.5^{b}	56.0
Giza82	6.3^{b}	3.1^{bc}	51.0	2.6^{a}	1.4^{a}	46.0	45.5^{b}	36.2^{b}	20.0	79.5^{c}	39.5^{ab}	50.0
Giza111	6.2^{b}	2.9^{c}	53.0	2.4^{a}	1.1^{a}	54.0	54.2^{a}	40.7^{a}	25.0	89.7^{a}	42.0^{a}	53.0
LSD0.05	0.95	0.35		0.3	0.5		2.2	2.3		4.3	3.1	

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test ($P \le 0.05$). C.P =control plants I.P = infected plants.*

Table 3: *Reproduction of M. javanica on soybean cv. Giza 111 at different initial population densities (Pi) under greenhouse conditions.*

No. of j_2s/250 gm soil	E.I	No. of egg masses/root system	Damage index (DI)	Gall size (GS)	Gall area (GA)	G.I	No. of root galls/ root system	*Pi (M. javanica)*
140^{c}	4^{b}	18^{c}	5c	5^{c}	5^{c}	6^{c}	52^{c}	1000
246^{b}	6^{a}	35^{b}	7^{b}	7^{b}	7^{b}	8^{b}	79^{b}	2000
413^{a}	6^{a}	45^{a}	9^{a}	9^{a}	9^{a}	9^{c}	127^{a}	3000
82	0.66	6	0.6	1.3	0.6	0.6	12.6	LSD 0.05

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test ($P \le 0.05$). * Gall index (G.I), and egg-masses index (E.I) counted according to Sharma et al. (1994).*

Root-knot nematode, *M. javanica* significantly reduced yield and growth parameters of cultivars soybean. Fresh weights of shoots and roots, in addition to pods weight, and nodules number per plant of all cultivars reduced significantly because of nematode infection. Significant variations observed in parameters of plant growth between infected and control soybean plants. In general, the data illustrated in Table 2 revealed that Giza 111 cultivar more affected by the nematode infection, followed by Giza82 cultivar.

Effect of initial population (Pi) of M. javanica on soybean plant growth and nematode reproduction

Results in Table 3 demonstrated that severity of root galling and damage index (DI) increased as increase of *M. javanica* inoculum level on soybean cv. 111. Nevertheless, root galling was most severe on soybean plants as highest index rate with at initial inoculum level (3000 j_2s) was (9). It was also observed that a maximum of (45) egg-masses/root system at Pi (3000 j_2s). Results also, revealed that final nematode population (j_2s) was about finding maximum (413) per 250 g of soil with initial inoculum level (3000 j_2s).

As shown in Table 4 all parameters of soybean growth significantly decreased in all nematode-inoculated plants in comparison to control plants. With inoculum levels (3000j_2s) parameters of plant growth decreased notably, compared with control plants. The greatest decrease in shoot fresh weight (50%) root fresh weight (54%) and nodules number/ plant (52%) were found with the higher initial inoculum level (3000J_2s) where, a progressive increase in inoculum level and a progressive decrease in plant growth was observed during growing seasons. Data in Figure 1 showed that relationship between initial population densities, and yield weight of (100 seeds) of soybean was negative with a correlation coefficient. According to the quadratic equation, the expected loss of soybean yield severely infected with nematodes (pi =3000) was more than the loss obtained from (pi=1000).

Table 4: *Effect of increasing initial population densities (Pi) of M. javanica on some soybean cv. Giza 111 growth parameters.*

Pi (*M. javanica*)	Shoot length (cm)	R%	Shoot fresh weights (g)	R%	Root fresh weights (g)	R%	Root length (cm)	R%	No. of nodules / plant	R%
1000	54^{b}	23	21^{b}	19	11^{b}	15	31^{b}	16	96^{b}	25
2000	48^{c}	31	18^{b}	31	9^{c}	31	28^{c}	24	73^{c}	43
3000	39^{d}	44	13^{c}	50	6^{d}	54	21^{d}	43	61^{d}	52
Non-inoculated	70^{a}	-	26^{a}	-	13^{a}	-	37^{a}	-	128^{a}	-
LSD 0.05	4.8	-	4.2	-	1.6	-	2.4	-	7.6	-

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test (0.05).*

Table 5: *Efficacy of ammonium sulfate, urea, and chicken manure on M. javanica reproduction infecting soybean plants.*

Treatment	No. Galls / root system	Red (%)	No. egg -mass/ root system	Red (%)	No. J_2s/250 g soil	Red (%)	Gall index	Egg-mass index
Ammonium sulfate (A)	43.0^{bc}	60.0	21.0^{b}	49.0	300^{b}	34.0	6.0	5.0
Chicken manure (B)	40.0^{c}	63.0	22.0^{b}	46.0	273^{bc}	40.0	6.0	5.0
Urea 46% (C)	46.0^{b}	58.0	22.0^{b}	46.0	253^{cd}	45.0	6.0	5.0
Ammonium sulfate +(B)	31.0^{d}	72.0	19.0^{c}	54.0	226de	50.0	6.0	4.0
Ammonium sulfate + (C)	30.0^{d}	72.4	17.0^{cd}	58.0	220^{e}	52.0	5.0	4.0
Chicken manure + (C)	27.0^{d}	75.0	16.0^{d}	61.0	213^{e}	53.0	5.0	4.0
Fosthiazate 10 G	15.0^{e}	86.0	9.0^{e}	78.0	73^{f}	84.0	4.0	3.0
Control (without any amendment)	109.0^{a}	-	41.0^{a}	-	456^{a}	-	9.0	6.0
LSD 0.05	5.3	-	2.03	-	31.7	-		-

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test (P ≤ 0.05). * Gall index, and egg-masses index counted according to Sharma et al. (1994).*

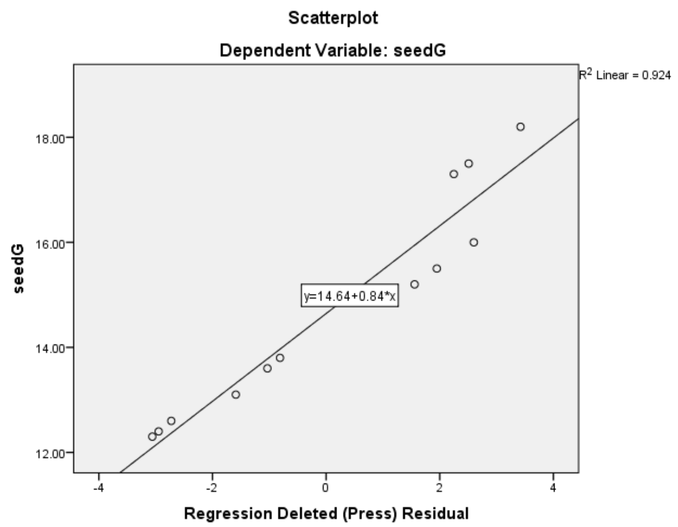

Figure 1: *Relationship between initial nematode densities (pi) and soybean yield.*

Efficacy of ammonium sulfate, urea, and chicken manure in managing of M. javanica infected soybean plants

Data displayed in Table 5 showed that all treatments alone or in combination notably decreased galls, egg-masses numbers / root, and final nematode population (J_2s) in soil compared with control. Additionally, the results showed that the combined treatments were more effectiveness in managing *M. javanica* than individual one. The nematicide Fosthiazate 10 G had highest decrees in galls (86%), egg-masses number (78%), and final nematode population (J_2s) with (84%). However, the combination of (chicken manure+ urea 46%) reduced galls number with (75%), egg-masses number (61%), and the final nematode population (J_2s) (53%). Meanwhile, a combined treatment (Ammonium sulfate + urea 46%) was the third most effective treatment that caused reduced in galls at (72.4%), egg-masses at (58%), and final nematode population (J_2s) at (52%).

Effects of ammonium sulfate, urea, and chicken manure on soybean growth

Data of plant growth parameters in Table 6 demonstrated that all of treatments significantly enhanced growth parameters compared to control treatment. Additionally, data showed that the combination treatments were more effective in enhancement of growth parameters. The greatest increase in shoot fresh weight was recorded at

Table 6: *Efficacy ammonium sulfate, urea, and chicken manure on some growth parameters of soybean plants infected with M. javanica.*

Treatment	Shoot fresh weights (g)	Inc %	Shoot length (cm)	Inc %	Weigh of 100 seed (g)	Inc %	Root fresh weights (g)	Inc %	No. of nod-ules/ plant	Inc %
Ammonium sulfate (A)	17.0[b]	31.0	60.0[b]	66.0	14.2[d]	29.0	8.0 [c]	51.0	128.0[d]	85.0
Chicken manure (B)	17.6[b]	35.0	57.0[bc]	58.0	14.8[d]	35.0	8 .0[c]	51.0	133.6[bcd]	93.0
Urea 46% (C)	17.6[b]	35.0	53.0[c]	47.0	15.7[c]	43.0	8.0[c]	51.0	130.6[cd]	89.0
Ammonium sulfate + (B)	20.0[a]	54.0	66.0[a]	83.0	17.3[b]	57.0	10.3 [b]	94.0	141.6[ab]	105.0
Ammonium sulfate + (C)	21.6[a]	66.0	67.0[a]	86.0	18.2[a]	65.0	11.0[ab]	107.0	140.3[abc]	103.0
Chicken manure + (C)	22.0[a]	69.0	68.0[a]	88.0	18.3[a]	66.0	11.6[a]	118.0	144.3[a]	109.0
Fosthiazate 10G	17.0[b]	31.0	55.0[c]	52.0	14.8[d]	35.0	10.3 [b]	94.0	98.0[e]	42.0
Control (without any amendment)	13.0[c]	-	36.0[d]	-	11.0[e]	-	5.3 [d]	-	69.0 [f]	-
LSD 0.05	2.1	-	4.5	-	0.74	-	1.2	-	10.3	-

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test (P ≤ 0.05). Inc %= treatment -control/controlX100*

Table 7: *Content of biochemical compounds in soybean cv. Giza 111 infected with M. javanica.*

Treatment	Total protein (mg/g FW)	Free phenolic compounds (mg/g FW)	Proline (mg /g FW)
Ammonium sulfate (A)	11.14[f]	2.91[cd]	2.96[c]
Chicken manure (B)	12.10 [d]	2.55[e]	3.58[b]
Urea 46% (C)	12.40 [d]	2.84[de]	1.91[e]
Ammonium sulfate +(B)	13.70 [c]	3.20[bc]	1.58[ef]
Ammonium sulfate + (C)	14.17[b]	3.14[bcd]	1.84[e]
Chicken manure + (C)	15.15[a]	3.73[a]	1.40[f]
Fosthiazate 10 G	11.63 [e]	3.24[b]	2.35[d]
Control (without any amendment)	7.78 [g]	2.10[f]	7.06[a]
LSD 0.05	0.42	0.315	0.34

*Means are the average of 4 replicates. *Different letter(s) indicate significant differences among treatments within the same column according to Duncan's multiple range test (P ≤ 0.05).*

combination chicken manure+ urea 46% with (69%), followed by a combination of ammonium sulfate + urea46% (66%). The same trend with weight of 100 seeds 66, and 65%, respectively.

Effect of ammonium sulfate, urea, and chicken manure on some of biochemical compounds

Results in Table 7 demonstrated that all treatments had higher total protein contents than the control treatment. The maximum protein content determined with combined chicken manure+ urea 46% (15.15mg/g FW) compared to control treatment (7.78 mg/g FW). Impact of treatments on non-enzymatic antioxidant such as free phenolic compounds (mg/ g FW), and proline (mg g/FW). Results in Table 7 cleared that greatest of phenolic compounds value were detected in treatments chicken manure+ urea 46%, Fosthiazate 10 G, ammonium sulfate + chicken manure, and ammonium sulfate + urea 46% respectively. It was during the control treatment that the proline content reached its maximum (7.06), whereas the least was detected with a combined of chicken manure+ urea 46% (1. 4).

Discussion

Root-knot nematodes (*Meloidogyne* spp.) attack soybean plants around the world, resulting in significant yield losses. Yield losses were often significant, exceeding 100% in extremely vulnerable soybean cultivars (Korayem and Mohamed, 2018). Based on the results, the four Egyptian soybean cultivars that were studied (Giza 21, 35, 82, and 111) to their susceptibility to root-knot nematode *M. javanica*, data demonstrated that all cultivars are nematode-susceptible. Obtained results were agreement with (Korayem *et al.*, 2023) they determined that cultivars; Giza 21, 22, 35, 82, 83, and

111 were susceptible to *M. incognita*. Among the best strategies for managing nematodes is using resistant plants, as they are environmentally safe, cost-effective, and compatible with other management techniques (Starr *et al*., 2002). Therefore, the best approach could be to look for genotypes of soybeans that are highly productive, resistant to nematodes, and appropriate for Egyptian circumstances to increase soybean domestic productivity and decrees current imports. According to data, damage index (DI) differed at various inoculum levels (1000, 2000, and 3000J_2s) of *M. javanica*. Damage index increased as inoculum levels increased of *M. javanica* on susceptible soybean cv. Giza 111. The current study found that all *M. javanica* inoculum densities significantly decreased growth and yield while increasing nematode infestations. Fourie *et al.* (2010, 2013) determined that the damage-threshold level of *M. incognita* among soybean that is resistant cultivars was ten times more than its susceptible counterpart. While, (Korayem and Mohamed, 2018) that the root-knot nematode, *M. arenaria* has infected soybean cv. Giza-21, causing a significant decline in yield at severe infection (Gall Index-5). It recommended that RNN damage threshold values for crops, namely soybeans, be regarded as circumspective and utilized as a maximum guideline for the execution of control measures. It suggests that effective control of soybean root-knot nematodes is not possible by using a single strategy such as host plant resistance. Furthermore, management of nematode strategies to be used on an integrated basis to ensure efficient long-range reduction of nematode populations (Fourie *et al*., 2015).

The obtained results from applying ammonium sulfate, chicken manure, and urea 46% alone or in combinations were significantly reduced galls, egg-mass/root system numbers, and final nematode population (J_2s) in soil on soybean plants. Additionally, the data showed that the combination treatments were more efficient at controlling *M. javanica* than individual treatment. The nematicide fosthiazate 10G had highest decreased in galls, egg masses number, and final nematode population (J_2s). While, combined of (chicken manure +urea 46%) was the second most effective treatment. Meanwhile, a combined treatment (Ammonium sulfate + urea 46%) was the third most effective treatment, this results are in agreement with (Karajeh and Al-Nasir, 2013) who proved that ammonium sulfate was more effective was more effective in suppressed *M. javanica* by decreasing root galling and nematode reproduction in tomato, *in vivo*. Walker (2004) revealed that the application of urea and poultry manure reduced in both carrot galling and *M. javanica* population density. Organic amendments, particularly those with low C: N ratios that release ammonia as they break down in the soil, have additionally been found efficacious in nematodes controlling (Oka *et al*., 1993). In this work, the potential of using ammonia-releasing amendments required for nematode management was tested by combining them with chicken manure, which is recognized as nematicides and nitrification inhibitors and can be applied in organic farming systems. The breakdown of organic matter results in the accumulation of certain substances in soil, which might possess a nematicidal influence on nematodes (Akhtar and Malik, 2000). Furthermore, long-range influence may encompass increases in the population densities of nematode antagonists in soil. Moreover, enhanced plant growth and crop nutrition after applying of amendments use could cause tolerance of plants to PPN (McSorley, 2011). Nevertheless, urea is easily converted to toxic ammonia (NH_3) by urease enzyme that is readily found in soil (Oka, 2010). Either Ammonia's nematicidal qualities may result from its plasmolyzing effect in the soil where it is applied or it is potential to selectively influence microbial antagonists of fungi, and nematodes (Chavarria-Carvajal and Rodriguez-Kabana, 1998; Santana-Gomes *et al*., 2013).

Results indicated that all treatments affected total protein, proline, and free phenolic compounds in combined treatments more than individual treatments under greenhouse conditions. Plants with high polyphenol content are generally resistant to a variety of diseases of plant (Mahmoud *et al*., 2011). The highest concentration of overall phenolic compounds may be associated with their function of strengthening the defensive mechanisms of plants against diseases are infectious and pathogen development. Toxic phenolic chemicals in cells of plant discovered to perform via enhancing host resistance by stimulating host mechanisms defense (Abdel-Baset and Abdel-Monaim, 2020). The results demonstrated that proline content reduced in each one of the treatments in comparison with the control treatment. Multifunctional amino acid proline gives plants resistance to abiotic stressors and is associated with defense mechanisms of plants against infection (Senthil-Kumar and Mysore, 2012). All of treatments aim to counter detrimental nematodes impact on plants. Furthermore, proline catabolism increased in the plant's early stages immunity and recombination in response to infection (Cecchini *et al.*, 2011).

Acknowledgement

We thank Prof. Abdelrehim Ahmed Ali Moustafa, Professor of Plant Breeding and Agronomy Department, Faculty of Agriculture, Suez Canal University, for the statistical data analysis.

Novelty Statement

The study realized many concepts as it screened different local Egyptian soybean cultivars against the root-knot nematode, *M. javanica*. In addition, it determines the effect of increasing population densities (Pi) of *M. javanica* soybean growth and nematode reproduction. Additionally evaluate different organic and inorganic amendments to manage *M. javanica* on soybean.

Author's Contribution

All authors equally participated in the development and implementation of the reviewing plan. Subsequently, they worked it out and wrote the manuscript; the first author Sahar H. Abdel-Baset wrote and discussed the different parts of the article with Mohsen E. Abo Rehab and Shimaa M. A. Mohamed and all together finalized the manuscript. All authors have read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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