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Effect of BAU-biofungicide and Selected Plant Extracts against Root-knot (*Meloidogyne javanica*) of Brinjal

Mst. Shahina Aktar[1], Md. Mobinul Islam[1*], S. M. Emdadul Hassan[1], Sk. Md. Mobarak Hossain[1] and Shahriar Rahman Shovon[2]

[1]Department of Plant Pathology, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.
[2]Faculty of Agriculture, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Author SMEH designed the study, wrote the protocol and supervised the research work. Author SMMH co-supervised the research work. Authors SMMH, MSA and MMI did statistical analyses and overall monitoring of the research work. Author MSA did the field experiment, collected data and wrote the first draft of the manuscript. Authors MMI and SRS managed the literature searches and helps in conducting field experiment. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Seven treatments viz. BAU-biofungicide (*Trichoderma* spp.), basak (*Adhatoda vasica*), mustard (*Brassica campestris*) oil-cake, mango (*Mangifera indica*) inflorescences, shaknote (*Amaranthus viridis*) and dholkalmi (*Ipomoea fistulosa*) leaf extracts (S) along with a control were tested against root-knot of brinjal caused by *Meloidogyne javanica*. The treatments were used as seed treatment, root dipping and soil drenching (7 days before) planting. Among the treatments, BAU-biofungicide and basak leaf extract gave superior results as they increased shoot and root length as well as fresh weight of shoot, root and yield correspondingly with the lowest galling incidence. BAU-biofungicide and basak leaf extract (S) also suppressed the population of eggs, L_2 and adult female

**Corresponding author: E-mail: mobin.hstu@gmail.com;*

of *M. javanica* in brinjal. Negative correlations between gall number with shoot and root length, shoot and root weight of brinjal as well as positive correlations between gall number with eggs, L_2 and adult female nematode under different treatments indicated the superior effect of the treatments expressed in lower galling and the suppressive activities of the nematode.

Keywords: BAU-biofungicide; plant extracts; root-knot nematode; brinjal.

1. INRODUCTION

Meloidogyne incognita (Kofoid and White) Chitwood is the most widespread species of the genus *Meloidogyne* [1,2]. *Meloidogyne* spp., the root knot nematodes are the most harmful nematodes in agriculture [3]. Among the plant parasitic nematodes, root-knot nematodes (*Meloidogyne* spp.) infect over 2,000 species of plants [4] and are responsible for approximately 50% of overall nematode damage. Around the globe more than $100 billion crop is ruined by plant parasitic nematodes annually [5]. These parasites produce immense physiological as well as morphological disorders and reduce yield around the globe [6]. On a global basis, out of the approximately 35% crop losses annually caused by crop pests; 12% is due to diseases caused by fungi, bacteria and viruses, while (11, 7 and 3) % are due to nematodes, insects and weeds respectively [7]. Brinjal (*Solanum melongena* L.) is one of the most common, popular and cheap vegetable in Bangladesh. In Bangladesh, 22.5 thousand and 37.5 thousand hectares cultivated with brinjal yielded a total production of 124 thousand and 124 thousand metric tonnes approximately in both kharif and rabi seasons, respectively [8].

The nematode population in the soils of Bangladesh is appreciably high. Different synthetic chemicals are effectively used for managing nematodes. But such nematicides are very expensive beyond the means of Bangladesh farmers. In addition their harmful effects are responsible for air, soil and water pollution [9]. Identification of natural nematicides from plant is a sustainable approach [10,11]. Nematicidal activity has been found in plants including, glucosinolates, isothiocyanates, phenols alkaloids, diterpenes, fatty acids, polyacetylenes, sesquiterpenes and thienyls etc [12,13]. A large number of plants / plant parts have been identified for their nematicidal activities [14,15]. Leaves, stem, fruits, flowers and seeds of many plants have also been found to be toxic to plant parasitic root knot nematodes [16,17]. Organic soil amendments such as; manures, fresh chopped leaves of different plants and non-edible deoiled cakes of neem, mustared, castor seed, and cotton and many others plants part have given promising results in reducing nematodes population [18-24].

In Bangladesh, plant products like leaves of basak, shaknote, dholkalmi, mango inflorescence, mustard oil-cake and a *Trichoderma* based preparation BAU-biofungicide are available with minimum cost and can be used to manage root-knot diseases caused by *Meloidogyne* spp. Particularly in the northern region of Bangladesh, very limited work has been done regarding the use of BAU-biofungicide and some plant extracts to manage nematode. The present investigation looks at the effect of the use of BAU-biofungicide, plant extracts (basak, shaknote, dholkalmi and mango inflorescence) and mustard oil-cake on root-knot (*Meloidogyne javanica)* and brinjal growth.

2. MATERIALS AND METHODS

2.1 Experimental Site and Time

The experiment was conducted in the research field of the Department of Plant Pathology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur. The location falls under agro-ecological zone (AEZ-1), Old Himalayan Piedmont Plain. The land type was medium high with loamy soil texture and low in organic matter. The experiments were conducted during November, 2014 to June, 2015.

2.2 Collection of Seed Sample

Seed samples of brinjal (*Solanum melongena* L), cv. singhnath were collected from local market. BAU-biofungicide was collected from Disease Resistance Laboratory of Prof. Dr. Ismail Hossain, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh.

2.3 Preparation of Leaf Extracts and Mustard Oil Cake

Leaf extracts of basak, shaknote and dholkalmi leaf and mango inflorescence were collected from the HSTU campus. Twenty grams each of

the sample leaves were macerated in an electric blender and soaked separately in l00 ml distilled water in several conical flask and were kept for 24 h. After 24 h they were filtered. At first, 20g mustard oil-cake was taken in a beaker and mixed with 100 ml water until it was well dissolved. Mustard oil-cake paste thus prepared was allowed to stay for seven (7) days in the beaker.

2.4 Seed Treatment with BAU-biofungicide, Mustard Oil-cake, Mango Inflorescence and Some Plant Extracts

A Petri-dish was taken and was surface sterilized with methylated spirit before placing seeds for treatment with BAU-biofungicide @ 1:40 w/w (BAU-biofungicide: seed) following the methods [25]. Standard (S) basak leaf extract was taken in a Petri-dish. The Petri-dish was surface sterilized with methylated spirit before placing brinjal seeds for treatment with extracts. The seeds were thoroughly soaked in the basak leaf extract (20 ml) for 20 minutes. The treated seeds were air-dried under shade and the seeds were sown in the seedbed on the same day on 21 November, 2014. The same procedure was followed for the other treatments; leaf extracts of basak, shaknote and dholkalmi and mustard oil-cake and mango inflorescence extracts.

2.5 Experimental Design and Layout

Three sets of experiments were carried out in the field viz. seed treatment, root dipping and soil drenching (7 days after transplanting). The plots were arranged in Randomized Complete Block Design (RCBD). Altogether seven treatments viz. BAU- biofungicide, standard mustard oil-cake, mango inflorescence solution, and standard leaf extracts (basak, shaknote and dholkalmi) including the control were maintained in the experiment. Each of the treatments was replicated three times.

2.6 Root Dipping of the Seedlings with BAU-biofungicide, Mustard Oil-cake, Mango Inflorescence Solution and Some Plant Leaf Extracts

The roots of the seedlings were thoroughly dipped in the BAU-biofungicide, mustard oil-cake (S), standard mango inflorescence solution and basak, shaknote and dholkalmi leaf extracts (720 ml) within the beaker for 20 minutes. The treated seedlings were placed in a cool and shady place and the seedlings were transplanted in the field on the same day on 31 December, 2014.

2.7 Transplanting and after Care of the Seedlings

At first, healthy and uniform sized seedlings of 30 days old were uprooted from the seed bed and then placed singly in each pit of the plot on 31 December, 2014.

2.8 Application of Solutions in Soil Drenching Method

For each of the treatments, 20 ml solution was taken in a test tube and then poured in 5 holes, 2.5 cm deep around each plant.

2.9 Preparation of Inoculum and Inoculation

Egg masses were collected from the roots of tomato cv. Raton which had previously been inoculated individually with a single egg mass of *Meloidogyne javanica*. For inoculation, ten reddish brown mature egg masses were placed in and around the standing plant in 2 holes (2.5 cm deep), five egg masses on each side of the plant. Inoculation was done on whole sets of field plants at 7 days after transplanting.

2.10 Application of Plant Extracts

BAU-biofungicide, leaf extract of basak, mustard oil-cake and mango inflorescence extracts and shaknote and dholkalmi leaf extracts (the treatments were designated as); T_0 = Control (without extract), T_1 = BAU-Biofungicide (2%), T_2 = Basak leaf extract (S), T_3 = Mustard oil-cake extract (S), T_4 = Mango inflorescence extract (S), T_5 = Shaknote leaf extract (S), T_6 = Dholkalmi leaf extract (S). The plant extracts were applied to the respective plants just after 7 days of transplanting in soil drench method.

2.11 Parameters Studied in Relation to Plant Growth

After 30, 60 and 90 days of inoculation, plants were uprooted carefully to record the Shoot length (cm), Root length (cm), Shoot weight (g), Root weight (g), Gall number / g fresh root, Fruit number / plant, Fruit weight / plant, No. of eggs/10 galls, No. of L_2/10 galls. No. of adult females/10 galls.

2.12 Measurement of Shoot and Root Length, Fresh Weight of Shoot and Root

The field was watered to make it moist for easy uprooting of the plants. Then the whole plant along with the soil attached to its root was lifted from the field and dipped in water. Then the roots were separated from the soil and further cleaned under gently running tap water. The length of shoot was measured from the base of the stem to the growing point of the youngest leaf. Similarly, length of the root was measured from the starting point of root to the longest available lateral root apex. The shoot and root portions were blotted dry with five tissue papers and fresh weight was recorded by electrical balance before the materials desiccate.

2.13 Counting of Galls

After washing the roots, the root system is cut into 1 g pieces. One piece, weighing 1 g is sampled and the number of galls counted and recorded.

2.14 Staining the Galled Roots, the Following Steps were Followed

a) Preparation of lactophenol solution: Measured quantities of liquid phenol (500 ml), lactic acid (500 ml), glycerine (100 ml) and distilled water (500 ml) were poured orderly into the 2.00 litre capacity conical flask and shaken thoroughly for mixing them well. Then cotton blue was added to the beaker to such an amount that turned the solution into the desired blue colour.
b) A quantity of 150-175 ml prepared lactophenol cotton-blue solution was taken in a beaker.
c) The beaker containing 150-175 ml lactophenol cotton-blue solution was heated to the boiling point.
d) Ten (10) galls per treatment were taken in a special type of cloth-bag whose end was loosely woven with a lace. At the time of boiling, the cloth-bag having galls was rinsed for about one minute. Then, the bag was lifted from the beaker with the galls, the bag washed with gentle running tap water to remove excess blue colour. Fresh lactophenol was poured onto 11 Petri-dishes where galls were retained for 7-10 days.
e) Ten (10) galls per treatment were crushed one after another with fine pointed needles. Eggs, L_2, adult of *M. javanica*, if any, found under stereo binocular microscope were counted accordingly.

2.15 Statistical Analysis

Data was analysed using GenStat 8.1 package. Means were separated using Duncan's Multiple Range Test (DMRT) at P =0.05.

3. RESULTS

Effect of seed treatment, soil drenching, root dipping with BAU-biofungicide, mustard oil cake, basak leaf extract, mango inflorescence extract, shaknote leaf extract and dholkalmi leaf extract on the root-knot development caused by *Meloidogyne javanica* and plant growth characters of brinjal (*Solanum melongena* L.) was evaluated.

3.1 Shoot Length and Root Length

BAU-biofungicide showed the best performance by recording the highest growth of shoot, weight of shoot; number of pods per plant, number of nodules per plant correspondingly with higher yield per plant expressed by higher weight of seeds. It also recorded decreased galling incidence and lower number of adult females, egg masses, J_2, J_3 and J_4.

Initially seed treatment with BAU-biofungicide followed by basak leaf extract showed the highest shoot length of 25.11 cm and 21.38 cm respectively at 30 DAT but soil treatment at 60 DAT and 90 DAT showed highest shoot length (38 cm, 32 cm and 54.20 cm, 48.89 cm) respectively (Tables 1, 2 and 3). On the other hand, the control showed the lowest shoot length throughout the experimental period. Regarding root length, seed treatment with BAU-fungicide and basak leaf extract recorded the best performance at 30 DAT whereas soil treatment recorded the highest root length at 60 and 90 DAT respectively. The application of various treatments significantly reduced the incidence of root knot nematode; however the severity of root galls was minimum with increase in plant growth (root length number, shoot length as well as fresh and dry weight) in plants treated with BAU-biofungicide. In Tables 1, 2 and 3, the control treatment recorded the highest gall formation (11.93) whereas BAU-biofungicide significantly reduced gall formation.

Table 1. Effect of seed treatment, soil drenching, root dipping with BAU-biofungicide and mustard oil-cake extract and standard leaf extracts for 30 minutes on growth and galling incidence of brinjal plant after 30 days of inoculation with *Meloidogyne javanica*

Treatment	Seed treatment							Soil drenching							Root dipping						
	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant
T_0	5.17 c	2.96 c	3.64 e	0.97 d	6.84 a	0.45 e	0.31 c	13.23 e	7.70 d	3.00 d	1.12 d	3.34 a	0.41 g	0.37 d	5.33 f	8.11 de	3.61 d	1.61 c	2.89 a	1.50 e	1.56 c
T_1	25.11 a	13.82 a	22.57 a	6.33 a	1.73 d	3.18 a	3.00 a	18.51 a	10.48 a	7.00 a	2.74 a	0.70 c	3.00 a	2.67 a	16.63 a	10.52 a	6.35 a	2.83 a	0.01 d	3.18 a	3.00 a
T_2	21.38 ab	13.41 a	16.23 b	4.73 b	3.33 c	2.85 ab	2.75 a	17.57 b	10.45 a	6.11 ab	2.22 ab	0.85 c	2.81 b	2.00 b	15.97 b	9.56 b	5.64 a	2.39 b	0.56 c	2.85 ab	2.75 a
T_3	20.86 ab	11.73 ab	11.08 c	3.35 c	3.58 c	2.83 ab	2.00 b	15.78 c	10.00 ab	5.68 bc	1.80 b	1.15 c	2.00 c	1.12 c	6.96 d	8.89 c	5.91 a	1.96 c	1.59 b	2.03 cd	2.00 b
T_4	18.74 b	10.80 ab	10.14 cd	2.50 c	4.66 bc	2.43 c	1.80 b	14.51 d	9.70 b	4.97 c	2.07 b	1.15 c	1.59 d	1.00 c	12.00 c	8.41 cde	4.93 b	2.46 b	1.74 b	2.83 ab	1.80 bc
T_5	17.80 b	10.61 ab	7.45 cde	2.72 c	4.22 bc	2.03 cd	1.92 b	15.02 d	9.78 b	4.69 c	1.72 bc	2.00 b	1.00 e	0.99 c	6.19 e	7.78 e	4.48 bc	1.93 c	1.66 b	2.43 bc	1.92 b
T_6	16.32 b	8.62 b	6.41 de	2.87 c	5.66 ab	1.80 d	1.89 b	13.78 e	8.37 c	3.20 d	1.19 cd	2.33 b	0.67 f	0.98 c	6.00 e	8.50 cd	4.03 cd	1.85 c	1.89 b	1.80 de	1.89 bc
LSD	5.39	3.04	3.79	0.81	1.51	0.47	0.30	0.66	0.15	0.98	0.53	0.44	0.16	0.21	0.23	0.05	0.05	0.05	0.05	0.05	0.05

Each value is an average of 3 (three) replications. In a column, values having same letter do not differ significantly at P = 0.05 level

Table 2. Effect of seed treatment, soil drenching, root dipping with BAU-biofungicide and mustard oil-cake extract and standard leaf extracts for 60 minutes on growth and galling incidence of brinjal plant after 60 days of inoculation with *Meloidogyne javanica*

Treatment	Seed treatment							Soil treatment							Root dripping						
	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant
T_0	17.00 g	0.51 g	0.31 g	0.40 f	3.78 a	0.23 f	0.44 g	18.37 g	8.00 g	12.07 g	2.00 b	3.92 a	0.04 d	0.10 d	23.11 g	10.15 f	14.13 e	1.78 d	11.93a	0.02 c	0.98 e
T_1	37.22 a	14.20a	24.11a	5.35 a	0.59 c	2.11 a	42.22 a	34.34 a	16.08 a	35.30 a	4.89 a	1.22 e	3.11 a	17.39 a	38.00 a	17.30 a	35.98 a	4.93 a	2.00 g	1.96 a	7.15 a
T_2	28.00 b	12.55b	20.36 b	3.75 b	1.00 c	1.78 b	18.97 b	29.22 b	14.76 b	30.00 b	3.11 b	1.89 d	0.89 b	15.10 b	32.00 b	14.14 b	27.08 b	3.78 b	3.03 f	0.93 b	5.28 b
T_3	25.67 c	11.01 c	18.29 c	3.11 cd	1.11 c	1.33 c	16.26 c	27.71 c	13.23 c	26.15 c	2.63 b	2.11 d	0.33 c	3.89 c	30.86 c	12.82 c	20.00 c	3.15 bc	4.04 e	0.51 b	4.00 c
T_4	23.00 d	10.06d	14.13 d	3.30 c	2.67 b	1.78 b	14.19 e	25.63 d	11.52d	22.82 d	2.78 b	2.67 c	0.11d	1.00 d	28.00 d	12.00 d	19.10 c	2.78 bcd	5.11 d	0.59 b	2.96 d
T_5	21.60 e	9.10 e	10.17 e	2.74 de	3.49 a	0.99 d	15.17 d	23.00 e	10.20 e	21.03 e	2.55 b	2.89 bc	0.09 d	0.23 d	26.45 e	11.37 e	17.13 d	2.26 cd	6.00 c	0.30 c	1.00 e
T_6	17.89 f	8.19 f	9.63 f	2.50 e	3.59 a	0.63 e	2.96 f	20.00 f	9.15 f	16.85 f	2.08 b	3.11 b	0.07 d	0.21 d	25.67 f	11.00 e	16.10 d	2.05 cd	7.77 b	0.07 c	0.50 e
LSD	0.41	0.503	0.25	0.39	0.59	0.177	0.397	0.44	0.43	0.71	1.40	0.38	0.09	0.16	0.32	0.62	1.42	1.02	0.36	0.40	0.14

Each value is an average of 3 (three) replications. In a column, values having same letter do not differ significantly at P = 0.05 level

Table 3. Effect of seed treatment, soil drenching, root dipping with BAU-biofungicide and mustard oil-cake extract and standard leaf extracts for 30 minutes on growth and galling incidence of brinjal plant after 60 days of inoculation with *Meloidogyne javanica*

Treatment	Seed treatment							Soil treatment							Root dipping						
	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant	Shoot length (cm)	Root length (cm)	Shoot weight (g)	Root weight (g)	No. of gall/g root	Fruit no./ plant	Fruit weight (g)/ plant
T_0	28.1 g	7.00 f	0.17 g	0.18 g	6.92 a	0.18 d	0.18 d	29.00 g	11.00 g	29.00 g	3.23 g	7.59 a	0.34 d	1.00 d	29.52 g	9.157g	19.38 g	2.85 f	7.00 a	0.77 d	5.86 g
T_1	45.29 a	25.00 a	56.26 a	12.00 a	0.50 e	3.00 a	3.00 a	44.96 a	28.00 a	72.21 a	16.33 a	1.45 f	2.85 a	3.60 a	54.70 a	23.08 a	67.34 a	13.27 a	0.15 g	3.00 a	57.00 a
T_2	39.15 b	23.00 b	48.19 b	9.56 b	0.64 de	2.11 b	2.11 b	40.44 b	23.00 b	50.53 b	12.00 b	1.78 f	0.95 b	6.37 b	48.89 b	2.00 b	34.00 b	13.27 a	0.52 f	2.00 b	34.00 b
T_3	35.00 c	19.00 c	39.00 c	8.00 c	1.00 d	1.00 c	1.00 c	38.22 c	21.00 c	43.40 c	10.00 c	2.44 e	0.67 bcd	3.25 c	45.19 c	1.70 bc	29.00 c	9.14 b	1.32 e	1.70 bc	29.00 c
T_4	33.00 d	15.67 d	35.22 d	6.45 d	2.55 c	1.00 c	1.00 c	36.22 d	19.00 d	39.00 d	8.52 d	3.44 d	0.55 cd	3.00 c	42.00 d	3.34 d	50.00 d	5.00 d	3.22 d	1.51 c	19.34 d
T_5	32.00 e	15.00 e	31.00 e	5.12 e	2.70 bc	0.99 c	0.99 c	32.00 e	16.89 e	35.00 e	7.33 e	4.38 c	0.70 bc	2.84 c	39.78 e	12.22 e	48.00 e	4.23 e	3.74 c	1.10 d	12.00 e
T_6	31.03 f	14.72 e	29.00 f	4.00 f	3.00 b	1.00 c	1.00 c	31.00 f	15.00 f	30.15 f	5.64 f	5.07 b	0.70 bc	1.43 d	35.00 f	11.26 f	36.45 f	4.23 e	4.93 b	1.07 d	8.00 f
LSD	0.15	0.51	0.16	0.18	0.38	0.19	0.19	0.69	0.12	0.32	0.44	0.44	0.31	0.51	0.579	0.332	0.239	0.292	0.324	0.373	0.137

Each value is an average of 3 (three) replications. In a column, values having same letter do not differ significantly at P = 0.05 level.
T_0 = Control (without extract); T_1 = BAU-biofungicide (2%); T_2 = Basak leaf extract (S); T_3 = Mustard oil-cake extract (S);
T_4 = Mango inflorescence extract (S); T_5 = Shaknote leaf extract; T_6 = Dholkalmi leaf extract (S)

3.2 Shoot and Root Dry Weight

The nematicidal activities of the treatments used in this investigation, had significant lethal effect on nematode incidence. Both shoot dry weight (22.57 g) and root dry weight (6.35 g) showed the best performance at 30 DAT with seed treatment. That was followed by shoot dry weight for the soil drenching and finally by root dipping which recorded 35.30 g and 35.99 g at 60 DAT and 35.98 g and 67.34 g at 90 DAT respectively with BAU-biofungicide application (Tables 1, 2 and 3). Root dry weight also showed a similar trend as found in Tables 1, 2 and 3.

3.3 Number and Weight of Fruit

Seed treatment, soil drenching and root dipping with BAU-biofungicide followed by leaf extract recorded the highest fruit setting at 30, 60 and 90 DAT. Both seed treatment and root dipping showed highest fruit setting (3.18) at 60 DAT (Table 2). Root dipping with BAU-biofungicide recorded the highest fruit weight (57 g) followed by basak leaf extract (34 g) while the control recorded the least fruit weight (5.86 g) at 90 DAT (Table 3).

3.4 Number of Gall and Egg

It was observed that there is a negative correlation and treatment with fungicide. Untreated plants showed the highest root-gall formation per g whereas root dipping with BAU-biofungicide showed the least gall formation particularly at 30 and 60 DAT.

Treated with BAU-biofungicide, mustard oil-cake and plant extracts in seed treatment, soil drenching and root dipping , No. of eggs, L_2 and adult females in per 10 galls were highest in control treatment but lowest in the leaf extract treatments at 30 DAT (Fig. 1). Overall, soil drenching recorded slightly lower populations than seed treatment and root dipping in No. of eggs and L_2 per 10 galls but highest in adult females at 30 DAT with control treatment (Fig. 1).

Among the treatments, the control treatment was markedly highest in No. of eggs, L_2 and females per 10 galls whereas basak leaf extract showed lowest No. of eggs, L_2 and female adults at 60 DAT (Fig. 2).

It was observed that No. of eggs, L_2 and female adults /10 galls rapidly increased with the control treatment (Fig. 3). Basak leaf extract on the other hand recorded significantly lower populations in the parameters studied.

4. DISCUSSION

The results of the present investigation revealed that maximum length of shoot and root, fresh weight of shoot and root and number of fruits and weight of fruit were obtained with treatment T_1 (BAU-biofungicide) followed by T_2, T_3, T_4, T_5 and T_6. On the other hand, the control treatment T_0 recorded significant reduction in all the parameters studied since there was no protection. Moreover, the highest galling incidence was also observed in the control treatment. Release of toxic compounds from plant tissues have been reported to reduce plant parasitic nematode infection. Several plant terpenoids and phenolic compounds are known to have nematicidal properties [26,27].

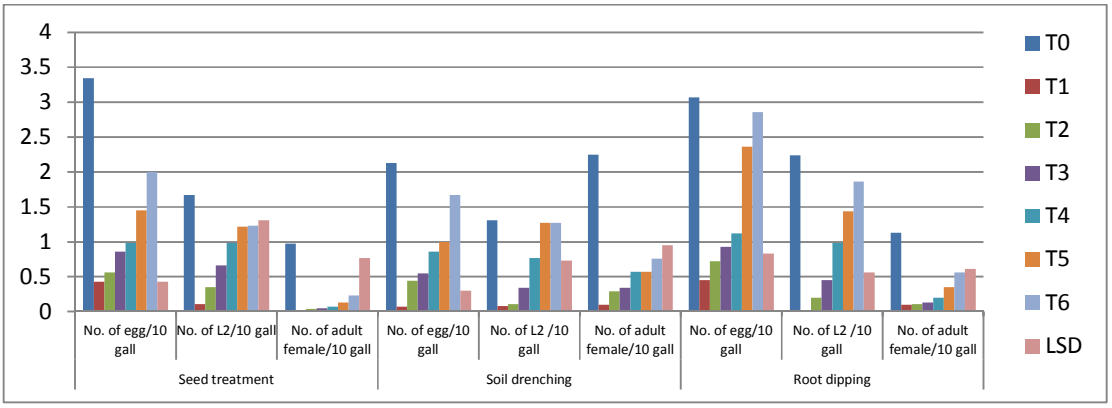

Fig. 1. Effect of seed treatment, soil drenching and root dipping with BAU-biofungicide, mustard oil-cake and plant extracts on brinjal plant after 30 days of inoculation with *Meloidogyne javanica*

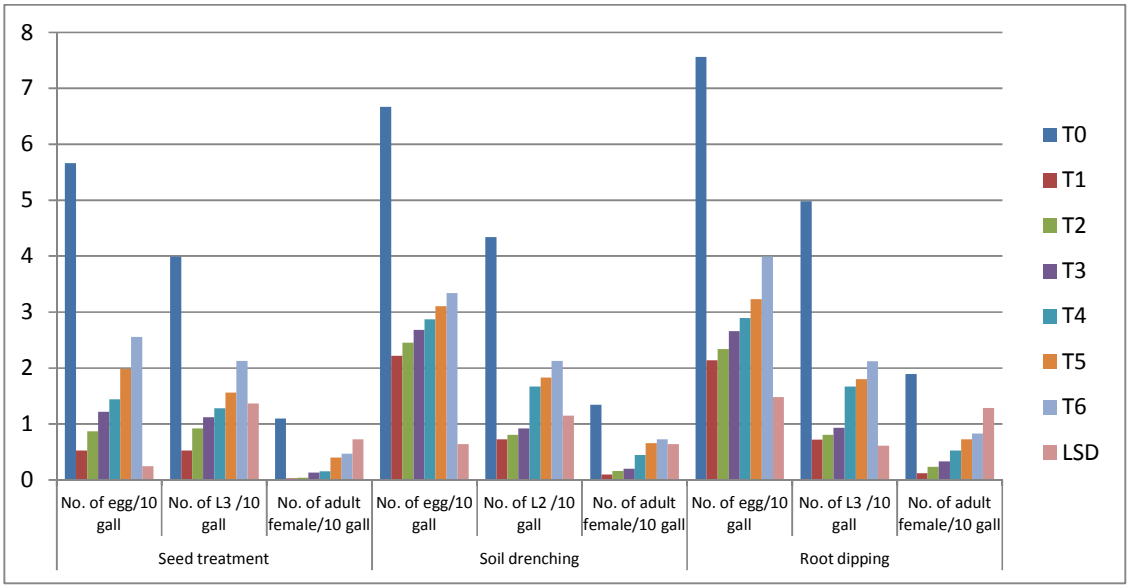

Fig. 2. Effect of seed treatment, soil drenching and root dipping with BAU-biofungicide, mustard oil-cake and plant extracts on brinjal plant after 60 days of inoculation with *Meloidogyne javanica*

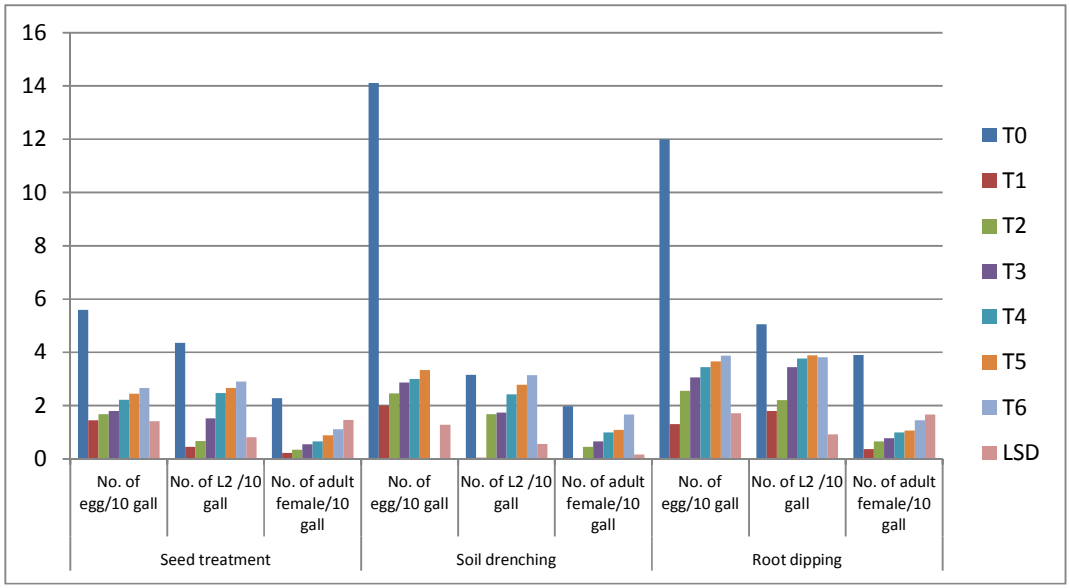

Fig. 3. Effect of seed treatment, soil drenching and root dipping with BAU-biofungicide, mustard oil-cake and plant extracts on brinjal plant after 90 days of inoculation with *Meloidogyne javanica*

In control treatments, the brinjal plants suffered a severe damage by the root knot development caused by *M. incognita* with highest increase in number of root galls and reduction in number of root length and shoot length [28]. Islam [29] conducted an experiment on the efficacy of some biological treatments (BAU-biofungicide, allamanda tablet and neem oil) against root-knot (*M. incognita*) of soybean.

BAU-biofungicide (*Trichoderma* spp.) gave best response with highest growth of shoot and root, weights of shoot and root, number of fruits as well as in the reduction of galls, eggs, L_2 and

adult females. It also had significantly lower galling incidence compared to the control` treatment. The effectiveness of *Trichoderma* spp. may be attributed to the fact that the fungi occupy the niche before nematode infection and thereby hinder the establishment of the nematode pathogen as stated by Bettiol [30] and Khan et al. [31].

Standard leaf extracts of basak resulted in highest effect followed by the treatments (T_3, T_4, T_5 and T_6) to enhance the growth of brinjal plants, viz. length of shoot and root, weight of shoot and root with higher number of fruits and yield as well as in the reduction of galls, eggs number and adult females of *M. javanica* which supports the findings of Mian and Rodriguez-Kabana [32], Hussain et al. [33], Prot and Kornprobst [34]. Besides various authors have reported that leaf and seed extracts of indigenous plants were effective in managing plant parasitic nematodes of different crop plants [35-38].

Treatment 1 recorded the best performance regarding shoot and root length, shoot and root weight and highest yield of brinjal. It also significantly reduced galling as well as suppressed number of eggs, L_2, and adult females of *M. javanica* than the rest of the treatments. Mustard oil-cake extracts have been found to be effective as a soil amending agent to control root knot nematode (*Meloidogyne aerenaria*) due to toxic principles in it like phenolic compounds and other acidic substances [32]. Presence of such toxic substances in the treatments used in the present study might have contributed to the suppression of the nematode activity resulting in better plant growth. Ahmad and Karim [17] reported that standard (S) and half standard (S/2) solutions of dholkalmi (*Ipomoea fistulosa*) suppressed the activity of *M. javanica* significantly resulting in lower galling incidence and corresponding higher shoot and root length, fresh weight of shoot and root of brinjal.

5. CONCLUSION

It was observed from the investigation that BAU-biofungicide had the most positive effect on all the parameters studied on brinjal in relation to *M. javanica* infestation. Among the four plant extracts used in this study, basak leaf extract was the most effective in reducing galling incidence and nematode development. Mustard oil cake extract also showed good effect in controlling galling incidence. Very similar effect was found with mango inflorescence, shaknote and dhalkalmi leaf extract. It could therefore be stated that all the six treatments had nematicidal principles capable of managing *M. javanica* of brinjal but that BAU-biofungicide was the most effective.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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