JOURNAL OF PURE AND APPLIED MICROBIOLOGY, Dec. 2017. Vol. **11**(4), p. 1909-1917

Bio-management of Cucumber Wilt Complex Caused by Root-knot Nematode, *Meloidogyne incognita* and *Fusarium oxysporum f. sp. cucumerinum* in Polyhouse under Protected Cultivation

Jaydeep Patil[1]*, S.R. Goel[2] and Saroj Yadav[2]

[1]Department of Plant Protection, School of Agriculture LPU, Phagwara, Punjab - 144 401, India.
[2]Department of Nematology, College of Agriculture, CCS HAU Hisar - 125 004, Haryana, India.

http://dx.doi.org/10.22207/JPAM.11.4.31

(Received: 15 November 2017; accepted: 01 December 2017)

A polyhouse study was conducted to determine the potential of biocontrol agents *viz. Trichoderma viride*, *Pseudomonas fluorescence*, *Purpureocillium lilacinum (Paecilomyces lilacinus)* @ 0.3 and 0.5 g/kg soil and liquid formulation of bioagents, (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 0.5 and 1 ml/ kg soil, against root-knot nematode, *Meloidogyne incognita* and *Fusarium oxysporum* f. sp. *cucumerinum* disease complex on cucumber. Three main treatments, *viz.*, nematode alone, fungus alone and both inoculated simultaneously were taken. Chemical checks with Bavistin @ 2 g/ l water and carbofuran @ 0.1 mg/ kg soil as well as untreated check were also maintained. Fungus was grown on sand maize meal medium. Soil was autoclaved and infested with root-knot nematode (1000 J_2/ kg soil) and fungus (50 g/ kg soil). The bio-agents were mixed with the potted soil treatment wise. A waiting period of three days was given for multiplication of bioagents on the organic matter before sowing. All the treatments significantly improved the plant growth parameter, *viz.,* shoot length (SL), root length (RL), fresh shoot weight (FSW), fresh root weight (FRW), dry shoot weight (DSW) and dry root weight (DRW) as compared to untreated check. However, maximum improvement in plant growth parameter was recorded in case of carbofuran @ 0.1 mg /kg soil followed by higher dose liquid formulation of bioagents. Bavistin was least effective among all the treatments against root-knot nematode, *Meloidogyne incognita* and *Fusarium oxysporum* f. sp. *cucumerinum* disease complex.

Keywords: *Meloidogyne incognita*, *Fusarium oxysporum* f. sp. c*ucumerinum*, shoot length, Root length, Fresh shoot weight, and fresh root weight, shoot weight, dry root weight.

In India, growing of horticultural crops in polyhouses under protected cultivation is becoming very popular among the farmers throughout the country. Large numbers of polyhouses are being erected in Haryana under the ages of National Horticulture Mission to grow short duration crops. Cucumber (*Cucumis sativus* L.) is a widely cultivated plant in the gourd family, Cucurbitaceae. It is a creeping vine that bears cylindrical fruits that are used as culinary vegetables. There are three main varieties of cucumber: slicing, pickling, and burp less. Within these varieties, several different cultivars have emerged. The cucumber is originally from South Asia, but now grows on most continents. Cucumber is an edible cucurbit popular throughout the world due to a good source of vitamins, minerals, fiber and roughages. It having crisps texture and taste. Cucumber is

* To whom all correspondence should be addressed.
E-mail: rajhau99@gmail.com

truly a versatile vegetable because of wide range of uses from salads to pickles and digestive aids to beauty products. the caloric and nutritional value of cucumber is very low but it is a primary source of vitamins, mineral and fiber for human body (Keoprapari,1997). The annual production of cucumber in India is 698000 MT from 45000 ha area with productivity of 15.5 per ha only during 2012-13 (Anonymous, 2014). Polyhouse cultivation involves intensive cultivation of crops, optimum use of fertilizers and frequent use of irrigation, but continuous growing of the same crop with high day temperature and relative humidity within the greenhouse, polyhouse and low tunnel along with poor plant hygienic conditions inside and outside the greenhouse increase problem of soil borne pests and diseases including plant parasitic nematodes (Minuto *et al*., 2006) which results in the availability of ideal conditions for the growth and multiplication of these pests.

Under polyhouse cultivation crops, are attacked by a number of pests and diseases including nematodes which interfere with the successful cultivation under protected conditions. Among the nematodes, root-knot nematode (*Meloidogyne* spp.) is the most damaging under polyhouse conditions, parasitizing almost all the polyhouses crops. The damage becomes very severe in association with fungi. Though, yield loss due to this nematode is difficult to predict, approximate yield loss due to this nematode has been predicted by many authors in various crops. Another important biotic stress to which the crop exposed is the fungus, *Fusarium oxysporum* f. sp. *cucumerinum*. Considering the soil health, environmental safety and the long term hazards posed by the indiscriminate use of pesticides, bioagents promise to be the next best alternative for nematode management. With this aim, a study was conducted in a polyhouse to test the efficacy of certain easily available bioagents (*P. lilacinus, T. viride* and *P. fluorescence*) against *Meloidogyne incognita and Fusarium oxysporum* f. sp. *cucumerinum* disease complex on cucumber.

MATERIALS AND METHODS

Experiment was conducted in polyhouse (26.7±3) °C, 73.5±11% Relative Humidity and 0.918 kPa) in earthen pots (18 cm diameter) filled with a mixture of autoclaved sandy loam soil (sand 70%, silt 22% and clay 8%, pH 7.5). Autoclaved soil would be infested with root-knot nematode @ 1000 J_2/kg soil and fungus (50 g/kg soil) as per the treatment. The experiment was conducted in pots (1 kg capacity) containing infested soil. Inoculum of root knot nematode was obtained from the nematode infected cucumber at farmer's field in Hisar Haryana, India. Root knot nematode females collected from the cucumber roots were processed for perineal pattern to confirm the species of root knot nematode associated with the plant. The pure culture was prepared in steamed sterilized soil in pots and Inoculum was used for experimentation.

Pure culture of *F. oxysporum* isolated from the infested plants during random survey of polyhouses was maintained on PDA (Potato Dextrose Agar) in petriplates at (27±5) °C in order to mass-produce pure culture of the Fungus was grown on sand maize meal medium (700gm sand + maize meal 300gm + 150ml distilled water). The flasks were incubated in a BOD (Biological Oxygen Demand) incubator at a temperature of (27±1) °C for 15 days. During incubation, the flasks were shaken three times in a day, to ensure proper growth of the fungal mycelium on the sand maize meal medium.

Root-knot nematode and fungus was also inoculated carefully adding the homogenous suspension of the two pathogens at the root zone of the plants, as per treatment. Each pot would be infested with root-knot nematode (1000 J_2/kg soil) and fungus (50g /kg soil) and treated with (carbofuran at 1 mg a.i./kg soil, Bavistin at 1 mg a.i./kg soil, *Trichoderma viride*, *Pseudomonas fluorescence*, *Purpureocillium lilacinum (Paecilomyces lilacinus)* @ 0.3 and 0.5 g/kg soil and liquid formulation of bioagents, (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 0.5 and 1 ml/ kg soil were incorporated to the potted soil as per treatment. Also waiting period of three days was given for multiplication of bioagents on the organic matter before sowing. After seven days each pot would be sown with cucumber cv Sania @ 5 seeds as per treatment and also maintain untreated check. Uninoculated pots and nematode + fungus inoculated pots served as controls. One plant per pot was retained after 30 days. Each treatment was replicated four times in a completely randomized block design during the

months of April to June, 2015 in the polyhouse under protected conditions and watered daily so that each pot as per requirement.

Evaluations were performed 60 days after sowing. Measurements were made on the plant growth parameters (shoot length, fresh and dry shoot and root weight) observations were made on the root population of nematode *viz*., Number of galls per plant, Number of egg masses per plant, Number of eggs per egg mass, Final nematode population per pot. Nematode population in soil was processed as per the sieving method of Cobb´s sieving and decanting technique followed by Modified Baermann´s funnel technique for estimation of nematode population in soil. Per cent wilt incidence due to fungus was assessed using number of wilt infected plants /total number of plants taken for observation.

Statistical analysis

Data were analysed using analysis of variance (ANOVA). Treatment means were compared and critical differences (CD) was calculated at P=0.05 to test for significant differences between treatments (T)

RESULTS

Data indicated that shoot length in all the treatments was significantly better over untreated inoculated checks *viz*., nematode alone (87.5 cm), fungus alone (85.6 cm) and nematode + fungus simultaneously (83.9 cm). Among the various treatments, maximum shoot length was observed in liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 15 ml per kg soil (151.1 cm), followed by *Paecilomyces lilacinus* @ 0.5 g per kg soil (145.7 cm) irrespective of whether nematode inoculated individually or concomitantly. However, in plants inoculated with nematode alone, shoot length was maximum in case of liquid formulation of bio-agents (155.8 cm), followed by *P .lilacinus* (151.7 cm) as compared to untreated inoculated check (87.5 cm). Plants inoculated with fungus alone, shoot length was maximum in case of liquid formulation of bio-agents (149.6 cm), followed by *Trichoderma viride* @ 0.5 g per kg soil (143.9 cm) as compared to untreated inoculated check (85.6 cm). Plants inoculated with nematode and fungus concomitantly, shoot length was maximum in case of liquid formulation of bio-agents (147.9 cm), followed by *P. lilacinus* (146.9 cm) as compared to untreated inoculated check (83.9 cm). In general, shoot length was significantly less in all the treatments compared to untreated uninoculated check irrespective of whether inoculated individually or concomitantly both pathogens. Maximum reduction in shoot length was observed in the presence of nematode and fungus followed by fungus alone while minimum in case of nematode alone.

Fresh shoot weight in all the treatments was significantly better over untreated inoculated checks *viz.*, nematode alone (23.2 g), fungus alone (23.4 g) and nematode + fungus simultaneously (22.90 g). Among the various treatments, maximum fresh shoot weight was observed in liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 15 ml per kg soil (59.1 g), followed by *Paecilomyces lilacinus* @ 0.5 g per kg soil (55.7 g) irrespective of whether nematode or fungus inoculated individually or concomitantly. However, in plants inoculated with nematode alone, fresh shoot weight was maximum in case of liquid formulation of bio-agents (64.7 g), followed by *P. lilacinus* @ 0.5 g per kg soil (64.7 g) as compared to untreated inoculated check (23.2 g). Plants inoculated with fungus alone, fresh shoot weight was maximum in case of liquid formulation (57.2 g), followed by *T. viride* @ 0.5 g per kg soil (54.1 g) as compared to untreated inoculated check (23.4). Plants inoculated with nematode and fungus concomitantly, fresh shoot weight was maximum in case of liquid formulation of bio-agents (55.2 g), followed by *P. lilacinus* (5.6 g) as compared to untreated inoculated check. In general, fresh shoot weight was significantly less in all the treatments compared to untreated uninoculated check irrespective of whether inoculated individually or concomitantly with nematode and fungus. Maximum reduction in fresh shoot weight was observed in the presence of both nematode and fungus followed by fungus alone and minimum in case of nematode alone.

Dry root weight in all the treatments was significantly better over untreated inoculated checks *viz.*, nematode alone (2.19 g), fungus alone (2.00 g) and nematode + fungus simultaneously (1.76 g). Among the various treatments, maximum dry root weight was observed in liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P.*

lilacinus) @ 15 ml per kg soil (6.57 g), followed by *Paecilomyces lilacinus* @ 0.5 g per kg soil (5.56 g) irrespective of whether nematode or fungus inoculated individually or concomitantly. However, in plants inoculated with nematode alone, dry root weight was maximum in case of liquid formulation of bio-agents (7.27 g), followed by *P. lilacinus* (6.7 g) as compared to untreated inoculated check

Table 1. Effect of soil treatment with bio-agents on shoot length (cm) of cucumber infested with *M. incognita* and fungus

Treatments	Nematode alone	Fungus alone	Nematode + fungus	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	136.5	131.8	126.6	131.6
T2: *Trichoderma viride* @ 0.5 g/pot	145.6	143.9	137.9	142.4
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	138.1	128.6	130.8	132.5
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	149.1	141.1	140.9	143.7
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	140.4	127.7	134.6	134.2
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	151.7	138.6	146.9	145.7
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	142.6	135.9	134.8	137.8
T8: Liquid formulation of bio-agents @ 15 gm/ pot	155.8	149.6	147.9	151.1
T9: Carbofuran @ 0.1 g/ pot	159.2	121.7	155.9	145.6
T10: Drenching with Bavistin @ 2 g/l water	119.6	154.2	122.2	132.0
T11: Untreated check (inoculated)	87.5	85.6	83.9	85.7
T12: Untreated check (uninoculated)	164.8	165.4	166.1	165.4
Mean	140.9	135.3	135.7	

CD @ 5% level
Treatment: 1.4
Sub treatment: 2.8
Treatment X Sub treatment: 4.9

Table 2. Effect of soil treatment with bio-agents on dry shoot weight (g) of cucumber infested with *M. incognita* and fungus

Treatments	Nematode alone	Fungus alone	Nematode + fungus	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	12.49	11.7	10.50	13.24
T2: *Trichoderma viride* @ 0.5 g/pot	19.47	17.6	16.24	17.85
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	14.49	13.7	12.49	13.91
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	19.39	18.3	16.99	18.10
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	15.74	14.7	13.75	14.08
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	20.24	19.0	17.50	18.86
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	18.65	16.9	15.49	16.55
T8: Liquid formulation of bio-agents @ 15 gm/ pot	21.94	20.7	19.07	21.13
T9: Carbofuran @ 0.1 g/ pot	23.50	22.5	21.24	22.66
T10: Drenching with Bavistin @ 2 g/l water	11.75	24.0	12.74	16.16
T11: Untreated check (inoculated)	5.82	5.6	4.76	5.56
T12: Untreated check (uninoculated)	24.75	25.0	24.49	24.75
Mean	17.35	17.48	15.44	

CD @ 5% level
Treatment: 0.74
Sub treatment: 1.49
Treatment X Sub treatment: 2.59

(2.19 g). Plants inoculated with fungus alone, dry root weight was maximum in case of liquid formulation of bio-agents (6.70 g), followed by *T. viride* (6.30 g) as compared to untreated inoculated check (2.0 g). Plants inoculated with nematode and fungus concomitantly, dry root weight was maximum in case of liquid formulation of bio-agents (5.78 g), followed by *P. lilacinus* (4.99 g)

Table 3. Effect of soil treatment with bio-agents on dry root weight (g) of cucumber infested with *M. incognita* and fungus

Treatments	Nematode alone	Fungus alone	Nematode + fungus	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	3.86	4.2	3.20	3.75
T2: *Trichoderma viride* @ 0.5 g/pot	5.04	6.3	4.26	5.19
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	4.04	3.8	3.45	3.75
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	5.43	5.2	4.74	5.11
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	4.42	3.5	3.67	3.86
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	6.75	4.9	4.99	5.56
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	4.72	4.5	3.93	4.36
T8: Liquid formulation of bio-agents @ 15 gm/ pot	7.27	6.7	5.78	6.57
T9: Carbofuran @ 0.1 g/ pot	8.12	3.6	7.81	6.50
T10: Drenching with Bavistin @ 2 g/l water	4.09	7.3	3.72	5.01
T11: Untreated check (inoculated)	2.19	2.0	1.76	1.99
T12: Untreated check (uninoculated)	9.01	8.8	8.50	8.75
Mean	5.40	5.05	4.65	

CD @ 5% level
Treatment: 0.43
Sub treatment: 0.87
Treatment X Sub treatment: 1.51

Table 4. Effect of soil treatment with bio-agents on number of galls/plant of cucumber infested with *M. incognita* and fungus

Treatments	Nematode alone	Nematode + fungus	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	212 (14.6)	206 (14.4)	209 (14.5)
T2: *Trichoderma viride* @ 0.5 g/pot	179 (13.4)	172 (13.2)	175.5 (13.3)
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	205 (14.4)	194 (13.9)	199.5 (14.1)
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	174 (13.3)	166 (12.9)	170 (13.1)
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	192 (13.9)	185 (13.6)	188.5 (13.8)
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	167 (13.0)	161 (12.7)	164 (12.8)
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	186 (13.7)	180 (13.4)	183 (13.6)
T8: Liquid formulation of bio-agents @ 15 gm/ pot	160 (12.7)	153 (12.4)	156.5 (12.6)
T9: Carbofuran @ 0.1 g/ pot	153 (12.4)	145 (12.1)	149 (12.3)
T10: Drenching with Bavistin @ 2 g/l water	217 (14.8)	208 (14.4)	212.5 (14.6)
T11: Untreated check (inoculated)	313 (17.7)	307 (17.6)	310 (17.6)
T12: Untreated check (uninoculated)	0 (1.0)	0 (1.0)	0.0 (1.0)
Mean	12.9	12.6	

Data in parenthesis are the square root ("n+1) transformed values of respective data
CD @ 5% level
Treatment: 0.04
Sub treatment: 0.09
Treatment X Sub treatment: 0.14

as compared to untreated inoculated check (1.76 g). Maximum reduction in dry root weight was observed in the presence of nematode and fungus followed by fungus alone and minimum in case of nematode alone. In general, dry root weight was significantly lesser in all the treatments compared to untreated uninoculated check irrespective of

Table 5. Effect of soil treatment with bio-agents on number of egg masses/plant of cucumber infested with *M. incognita* and fungus

Treatments	Nematode alone	Nematode + fungus	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	222 (14.9)	204 (14.3)	213 (14.6)
T2: *Trichoderma viride* @ 0.5 g/pot	173 (13.2)	164 (12.9)	168.5 (13.0)
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	215 (14.7)	195 (14.0)	205 (14.4)
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	162 (12.8)	154 (12.4)	158 (12.6)
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	195 (14.0)	186 (13.7)	190.5 (13.8)
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	156 (12.5)	149 (12.2)	152.5 (12.4)
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	183 (13.6)	173 (13.2)	178 (13.4)
T8: Liquid formulation of bio-agents @ 15 gm/ pot	149 (12.2)	144 (12.1)	146.5 (12.1)
T9: Carbofuran @ 0.1 g/ pot	128 (11.3)	122 (11.1)	125 (11.2)
T10: Drenching with Bavistin @ 2 g/l water	345 (18.6)	342 (18.5)	343.5 (18.5)
T11: Untreated check (inoculated)	454 (21.3)	448 (21.2)	451 (21.2)
T12: Untreated check (uninoculated)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Mean	13.3	13.1	

Data in parenthesis are the square root ("n+1) transformed values of respective data
CD @ 5% level
Treatment: 0.04
Sub treatment: 0.11
Treatment X Sub treatment: 0.16

Table 6. Effect of soil treatment with bio-agents on final nematode population/200 cc soil of cucumber infested with *M. incognita* and fungus

Treatments	Nematode alone	Nematode + fungus	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	226 (15.0)	216 (14.7)	221 (14.9)
T2: *Trichoderma viride* @ 0.5 g/pot	189 (13.8)	182 (13.5)	185.5 (13.6)
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	216 (14.7)	205 (14.4)	210.5 (14.5)
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	185 (13.6)	179 (13.4)	182 (13.5)
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	205 (14.4)	198 (14.1)	201.5 (14.2)
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	180 (13.4)	176 (13.3)	178 (13.4)
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	194 (13.9)	188 (13.7)	191 (13.8)
T8: Liquid formulation of bio-agents @ 15 gm/ pot	175 (13.2)	168 (13.0)	171.5 (13.1)
T9: Carbofuran @ 0.1 g/ pot	166 (12.9)	154 (12.4)	160 (12.7)
T10: Drenching with Bavistin @ 2 g/l water	466 (21.6)	452 (21.3)	459 (21.4)
T11: Untreated check (inoculated)	644 (25.4)	637 (25.3)	640.5 (25.3)
T12: Untreated check (uninoculated)	0 (1.0)	0 (1.0)	0.0 (1.0)
Mean	14.4	14.1	

Data in parenthesis are the square root ("n+1) transformed values of respective data
CD @ 5% level
Treatment: 0.03
Sub treatment: 0.09, Treatment X Sub treatment: 0.13

whether inoculated individually or concomitantly with nematode and fungus.

Number of galls per plant in all the treatments was significantly reduced over untreated inoculated checks *viz*., nematode alone (313) and nematode + fungus simultaneously (307). Among the various treatments, minimum number of galls per plant was observed in liquid formulation

Table 7. Effect of soil treatment with bio-agents on fungus incidence (%) of cucumber infested with *M. incognita* and fungus

Treatments	After 15 days	After 30 days	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	30 (33.4)	35 (36.5)	32.5 (35.0)
T2: *Trichoderma viride* @ 0.5 g/pot	20 (26.9)	25 (30.3)	27.5 (28.6)
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	25 (30.2)	30 (33.4)	27.5 (31.8)
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	20 (26.9)	25 (30.2)	22.5 (28.5)
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	25 (30.2)	33 (34.9)	29 (32.5)
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	15 (23.0)	20 (26.9)	17.5 (25.0)
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	25 (30.2)	25 (30.2)	25 (30.2)
T8: Liquid formulation of bio-agents @ 15 gm/ pot	15 (23.0)	15 (23.0)	15 (23.0)
T9: Carbofuran @ 0.1 g/ pot	30 (33.4)	35 (36.4)	32.5 (34.9)
T10: Drenching with Bavistin @ 2 g/l water	0 (4.1)	10 (18.6)	5 (11.3)
T11: Untreated check (inoculated)	60 (51.1)	75 (60.4)	67.5 (55.7)
T12: Untreated check (uninoculated)	0 (4.1)	0 (4.1)	0.0 (4.1)
Mean	26.4	30.4	

Data in parenthesis are the angular transformed values
CD @ 5% level
Treatment: 1.5
Sub treatment: 3.7
Treatment X Sub treatment: 5.2

Table 8. Effect of soil treatment with bio-agents on nematode + fungus incidence (%) of cucumber infested with *M. incognita* and fungus

Treatments	After 15 days	After 30 days	Mean
T1: *Trichoderma viride* @ 0.3 g/pot	35 (36.5)	40 (39.5)	37.5 (38.0)
T2: *Trichoderma viride* @ 0.5 g/pot	25 (30.3)	30 (33.5)	27.5 (31.9)
T3: *Pseudomonas fluorescence* @ 0.3 g/pot	35 (36.5)	40 (39.5)	37.5 (38.0)
T4: *Pseudomonas fluorescence* @ 0.5 g/pot	25 (30.3)	25 (30.3)	25 (30.3)
T5: *Paecilomyces lilacinus* @ 0.3 g/pot	30 (33.4)	35 (36.5)	32.5 (35.0)
T6: *Paecilomyces lilacinus* @ 0.5 g/pot	15 (23.0)	20 (26.9)	17.5 (25.0)
T7: Liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 10 gm/ pot	30 (33.4)	30 (33.5)	30 (33.5)
T8: Liquid formulation of bio-agents @ 15 gm/ pot	15 (23.0)	20 (26.9)	17.5 (25.0)
T9: Carbofuran @ 0.1 g/ pot	10 (18.6)	10 (18.6)	10 (18.6)
T10: Drenching with Bavistin @ 2 g/l water	40 (39.5)	45 (42.4)	42.5 (41.0)
T11: Untreated check (inoculated)	65 (54.1)	85 (68.2)	75 (61.2)
T12: Untreated check (uninoculated)	0 (4.1)	0 (4.1)	0.0 (4.1)
Mean	30.2	33.3	

Data in parenthesis are the angular transformed values
CD @ 5% level
Treatment: 1.2
Sub treatment: 3.0
Treatment X Sub treatment: 4.2

of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 15 ml per kg soil (156), followed by *Paecilomyces lilacinus* @ 0.5 g per kg soil (164) irrespective of whether nematode inoculated individually or concomitantly. However, in plants inoculated with nematode alone, number of galls per plant was minimum in case of liquid formulation of bio-agents (160), followed by *P. lilacinus* (167) as compared to untreated inoculated check (313). Plants inoculated with nematode and fungus concomitantly, number of galls per plant was minimum in case of liquid formulation of bio-agents (153), followed by *P. lilacinus* (161) as compared to untreated inoculated check (307). Maximum reduction in number of galls per plant was observed in the presence of both nematode and fungus followed by nematode alone.

Nematode population J2/200 cc soil in all the treatments was significantly reduced over untreated inoculated checks *viz*., nematode alone (644) and nematode + fungus simultaneously (637). Among the various treatments, minimum final nematode population J_2/200 cc soil was observed in liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 15 ml per kg soil (171), followed by *Paecilomyces lilacinus* @ 0.5 g per kg soil (178) irrespective of whether nematode inoculated individually or concomitantly. However, in plants inoculated with nematode alone, final nematode population J_2/200 cc soil was minimum in case of liquid formulation of bio-agents (175), followed by *P. lilacinus* (168) as compared to untreated inoculated check (644). Plants inoculated with nematode and fungus concomitantly, final nematode population J_2/200 cc soil was minimum in case of liquid formulation of bio-agents (180), followed by *P. lilacinus* (176) as compared to untreated inoculated check (637). Maximum reduction in nematode population J_2/200 cc soil was observed in the presence of both nematode and fungus followed by nematode alone.

In general, all the treatments significantly reduced incidence of nematode and fungus concomitantly on cucumber as compared to untreated inoculated check. Data were recorded 15 and 30 days after sowing. At 15 days after sowing, disease incidence was minimum (15 %) in case of soil treated with liquid formulation of bio-agents (*T. viride* + *P. fluorescence* + *P. lilacinus*) @ 15 ml per kg soil or *P. lilacinus*) @ 0.5 g per kg soil as compared to untreated inoculated check (65 %). At 30 days after sowing, disease incidence was minimum (15 %) in case of soil treated with liquid formulation of bio-agents followed by 20 % in case of *P. lilacinus*) @ 0.5 g per kg soil as compared to untreated inoculated check (85 %).

DISCUSSION

Cucumber is highly susceptible to *M. incognita* and *F. oxysporum* disease complex as indicated by severity in root-knot development, nematode population densities, root colonization by fungus and plant growth suppression in the inoculated controls. Our results indicated that carbofuran is most effective among the treatments in improving plant growth and reducing *M. incognita* population densities in soil. Carbofuran impairs nematode neuromuscular activity by inhibiting the function of the enzyme acetyl cholinesterase resulting in reduced movement and ability of invasion and multiplication (Evans, 1973; Wright, 1981). The nematodes may also be killed while feeding on root tissues by the systemic action of these nematicides when they are absorbed by the plant roots and translocated in the plant system (van Berkum and Hoestra, 1979). Abuzar (2003) found similar effectiveness of carbofuran in suppressing *M. incognita* on *Abelmoschus esculetus.* Bavistin was found most effective in controlling root colonization by fungus. It inhibits the nuclear division of fungi by inactivating the spindle, which is composed of microtubules.

Bavistin as an important control measure against *F. oxysporum* (Prasad *et al*., 2000; Haseeb and Shukla, 2002; Abuzar, 2003, Haseeb *et at*., 2006). To maintain a low inoculum load by continuous application of systemic fungicide alone is not practical for the control of wilt disease. To cope with this, *A. indica* seed powder may be applied. It is clear from the results that besides chemicals *A. indica* seed powder were sufficiently effective against both the pathogens, this may be due to presence of active principles and toxic chemicals in *A. indica* cake (Abuzar and Haseeb, 2009; Abuzar and Haseeb, 2010). Initial investigations on antagonistic rhizobacteria against root-knot nematodes; include work by Kloepper *et al*. (1992). *P. fluorescens* was found not only effective against *M. incognita* but also against wilt

causing fungi. Results show that the *Meloidogyne incognita- Fusarium oxysporum* disease complex can cause severe yield losses in *V. radiata* as in other crops. Although chemicals *viz.* carbofuran and Bavistin showed a significant effect in increase of growth parameters and in suppression of the disease complex, these can be replaced to some extent by *A. indica* neem cake avoid the hazards of chemicals.

ACKNOWLEDGEMENT

The financial assistance provided by Department of Science and Technology (DST), government of India, New Delhi, in the form of INSPIRE Fellowship to carry out this research work is greatly acknowledged. I acknowledged to Miss Saroj for assisting me during the experiment.

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