Journal of Scientific Research and Reports

Volume 30, Issue 11, Page 316-325, 2024; Article no.JSRR.125922
ISSN: 2320-0227

Floral Infestation of Tuberose with *Aphelenchoides* and Its Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i112563

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/125922

Original Research Article

Received: 22/08/2024
Accepted: 26/10/2024
Published: 02/11/2024

ABSTRACT

In the field experiment conducted on cv. Calcutta Double, the symptoms of floral malady and efficacy of treatment modules on foliar nematode population, percent infestation and resulting yields of the crop has been observed. The symptoms appear on the leaves and progress until flowering. Typical symptoms observed were browning of leaves and flowers. In serious condition, the plant becomes stunted along with prickles on the stalks and flowers. The flowers become brittle. The results of the present study showed that the percent infestation was directly proportional to the nematode population. The percent infestation and the population were higher in untreated plot (M7) as compared to all treated plots. The treatment module (M4) involving overnight drenching of bulb

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Cite as: *Kadam, Veronica, Jeevan H., Bablu Hrangkhawl, Euphema N., Kushal Roy, A.K. Mukhopadhyay, and Rojeet Thangjam. 2024. "Floral Infestation of Tuberose With Aphelenchoides and Its Management". Journal of Scientific Research and Reports 30 (11):316-25. https://doi.org/10.9734/jsrr/2024/v30i112563.*

in water followed by dipping in monocrotophos 36SL @750ppm for 4 hrs + Spraying of monocrotophos 36SL @360g a.i./ha alternated with cartap hydrochloride 50SP @375g a.i./ha at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop was the most economical (ICBR 1: 8) and effective means of managing *Aphelenchoides besseyi* population. It also yielded higher number of marketable flower stalks viz. 4, 43,908.19 per hectare.

Keywords: Aphelenchoides besseyi; browning of leaves and flowers; floral malady; tuberose.

1. INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) is one of the most important tropical, ornamental, bulbous, flowering plants cultivated for production of long-lasting flower spikes. It is popularly known as Rajanigandha. It belongs to the family Amaryllidaceae and is native of Mexico. It is commercially cultivated in many countries of the world like Vietnam, China, Brazil, Italy, Iran, UK, USA, etc. including India. Tuberose is famous among cut flowers. Many pests have been reported to attack this crop. The plant parasitic nematode (PPN) is one of the most important pests attacking tuberose and reducing quality and quantity of flower production. Among the PPN, the most important are foliar and Root Knot nematode. Nematodes cause serious problem in tuberose by reducing almost 50% of earnings of the flower growers of the state Mukhopadhyay (1997). As a result of severe infestation by nematode, the flower stalks become stunted, reduced in weight, epidermis becomes irregular and rugged, with aging pricked and tough (Kadam, *et al*., 2019). Diagnosis of symptoms is important in considering strategies for management. Regarding cultural practices, rotation/succession with nonhost crops is one of the main tools available to manage PPNs (de Souza *et al*. 2024) *Aphelenchoides* can also be manage by crop rotation with non-host crops, tillage of soil, maintaining good hygienic planting material along with some hot water treatment of bulbs. High-temperature treatments can also be used to eradicate nematodes from infested planting materials (Westerdahl and Bello). As an above-ground pathogen, *A*. *besseyi* migrates from roots to the upper parts of the plant, spending less time in soil than other root-parasitic nematodes and so difficult to manage it. Therefore, a management programme with variable treatment modules was designed to manage the nematode population as well as invent the economically feasible treatment.

2. MATERIALS AND METHODS

A field experiment was carried out using cv. Calcutta Double for observation of symptom development from emergence to mature plant and then managing the foliar nematodes. Progressive manifestation of symptoms in infested tuberose stalks and flowers was closely monitored, from emergence of the stalk head to harvesting of flowers. Infected bulbs (2.0-2.5 cm diameter) were collected from fields (Ranaghat, West Bengal) and soaked overnight in plain water. The plants were tagged for observation of the symptoms and the plants were observed meticulously every week after emergence. The developed symptoms were recorded along with the increase in age of the plant. In the next phase, infected bulbs were soaked overnight in plain water, followed by soaking in nematicides at different doses and duration according to the treatment schedule. *Paecilomyces lilacinus* and NSKP (Neem Seed Kernel Powder) were also used as treatment before planting and treatment after sprouting of bulbs respectively. The infected bulbs were planted in the plot (3×1.5) m^2 at a spacing of 50 × 37.5 cm^2. There were 7 treatment modules; each replicated 4 times in a Randomized Block Design. Details of the modules are as follows;

M_1-
a) Overnight drenching of bulb in water followed by dipping in Carbosulfan 25 EC @ 1000ppm for 4 hrs. b) Spraying of chlorfenapyr 10SC @75g a.i./ha alternated with cartap hydrochloride 50SP @375g a.i./ha at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop.

M_2-
a) Overnight drenching of bulb in water followed by dipping in carbosulfan 25 EC @1000ppm for 4 hrs. b) Spraying of cartap hydrochloride 50SP @375g a.i./ha alternated with carbosulfan 25 EC @500g a.i./ha at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop.

M_3-
a) Overnight drenching of bulb in water followed by dipping in monocrotophos 36SL @750ppm for 4 hrs. b) Spraying of cartap hydrochloride 50SP @375g a.i./ha alternated with chlorfenapyr 10SC

@75g a.i./ha at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop.

M_4-
a) overnight drenching of bulb in water followed by dipping in monocrotophos 36SL @750ppm for 4 hrs. b) Spraying of monocrotophos 36SL @360g a.i./ha alternated with cartap hydrochloride 50SP @375g a.i./ha at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop.

M_5-
a) Overnight drenching of bulb in water followed by dipping in *Paecilomyces lilacinus* (spore load 24×10^7) spore suspension.
b) Prophylactic spraying with NSKP @ 50g/l of water at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop.

M_6-
a) Overnight dipping of bulbs in water.
b) Spraying of water along with sticker at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop.

M_7- Control, DAS-Days after sowing

Sticker along with water was added during all nematicides application. Initial nematode population, nematode population per 20g of flowers from each treatment at the time of blooming, percent infested plant and yield were observed during the programme and incremental cost benefit ratio were also calculated. Initial nematode population of foliar nematode was carefully examined in 49 bulbs (7 bulbs for each treatment). The initial nematode population was estimated by counting the population under stereoscopic binocular microscope. The initial nematode population was extracted from the slash bulb keeping in wire gauge assembly followed by killing and fixing of the nematodes (Seinhorst, 1962). In case of population study, infested 20g of flowers were chopped into small pieces with the help of a sharp knife. Then, the chopped flowers were placed on wire gauge fitted over a petri plate containing clean water just touching the bottom of the wire gauge assembly. The assembly was covered with another Petri dish to prevent the water loss and was kept undisturbed for 12 hours. During the period, the nematode came out from the chopped flower materials and migrated freely in the water. Then, the prepared suspension was passed through 20 and 400 mesh sieves serially under tap water for cleaning the remaining plant toxic substances released and nematodes were collected in a beaker from the residues and subsequently killing and fixing of the nematodes (Seinhorst, 1962) were done. Estimation of nematodes was done with the help of multi chambered counting disc under stereoscopic binocular microscope. For the observation of percent infested plants the total number of plants were taken per plot and then out of that total plants , the nematode infested plants showing the symptoms were taken and accordingly it was calculated by using the following formula Percent Infested Plants = (numbers of nematode infested plants per plot / Total number of plants per plot) X100.The yields were taken in terms of flower stalk by harvesting the stalk and incremental cost benefit ratio was then calculated to observe the best results in terms of cost.

3. RESULTS AND DISCUSSION

Progressive manifestation of symptoms in infested tuberose stalks and flowers was closely observed continuously right from emergence of the stalk head to harvesting of flowers. After planting the bulb, the growth appearances of the tuberose crops were found changing with the infestation by the nematode (*A. besseyi*), the changed on growth attributes directly affect the market value of the tuberose plant due to its unthrifty appearance comparing to the healthy tuberose crops. The symptoms on leaves were initially marked by emergence of yellowish green or pale green leaves from base to tip of the leaves and later turn brown. Formation of prickle like structures was a very first visible morphological changes as a result of nematode infection. The prickle could be observed both on stalk as well as on flowers similar to the findings by Kadam, *et al.* (2019). The nematodes while feeding entered in developed flower head and also fed on the epidermal layer of the newly formed stalk. Due to their profuse feeding on the stalk epidermis, the stalk became irregular and rugged. In the infested plant, symptom occurs just after the emergence of the stalk head. In addition, there was twisting in the stalk and the bracts were crinkled. The plants thus infested at early stage, suffered seriously from retardation of growth and remain stunted. Sometimes spike developed but the flowers did not bloom whereas, development of apparently normal spike with partial blooming of either lower most or the top most few flowers was also observed. In a few cases the flower stalks emerged with a

blind flower head where no spike developed. But both the quality as well as quantity of the important growth attribute was better in treated plots over the untreated ones in both the years of experiment (Kadam, *et al.,* 2020). Therefore, the treatments in modules were aimed towards managing foliar nematode in tuberose and it was found that incorporation of different formulations significantly reduced nematode attack as compared to untreated plots. The infestations caused by foliar nematode (*Aphelenchoides besseyi*) in tuberose (cv. Calcutta double) were found to be more in flowers. Percent Infested Plants (P.I.P) were restricted within 9.84-34.44 during the period from August, 1st flowering – February, 2nd year flowering (Tables 2-6) where populations of nematodes remained restricted within 500 except a single instance and assumed 1000 or more value in February. Low population of nematodes as well as PIP might be due to the initial stage of the experiment at experimental location accompanied by the effect of nematode management activities and gradual reduction in atmospheric moisture and temperature from November onwards. However, in relation to both the mentioned parameters, the treatment modules had immense positive impact in general and particularly the treatment module M_4 was recorded almost the best one during this period. From March to June, 2nd year of flowering PIP in all the plots including the untreated ones showed a steady growth which was clearly observed with a sharp rise in nematode populations too. Since July onwards there was gradual declination in nematode populations consequent to which PIP in the plots from September onwards declined. This might be the reason behind of July as a rainy season an impact on nematode activity gets obstruct resulting sudden fall in PIP and nematode populations in that month.

Table 1. Initial nematode population (INP) before bulb treatment (cv. Calcutta Double)

Treatment modules*	Nematode population/ 7 bulbs
M1	44.96
M2	62.67
M3	68.78
M4	53.44
M5	66.78
M6	62.00
M7	67.67
SEm±	4.18
CD (5%)	12.87 (S)

**In each nematocidal application sticker along with water was added*

***Figure marked by common letter are not significantly different according to Duncan's Multiple Range Test at P<0.05. Figures in the parenthesis indicate angular transformed values*

Interestingly, during this period under discussion, *i.e*., March to November, 2nd year flowering, the treatment module M_4 was more or less the best performer among the allies. In most of the cases during the management programme, it was recorded that the nematodes population were directly correlated with the infestation. The yield results were found to be best in the treatment modules M_4 with 4,43,908.19 numbers of stalks per hectare (Tables 7). Whereas in untreated plot, the yield obtained was very less i.e. 65938.56 numbers of stalks per hectare in M_7 which showed that the treatment module was found to be effective and increased the yield of the crops. Considering incremental cost benefit ratio (ICBR), the combinations module of monocrotophos 36SL and cartap hydrochloride 50SP (M_4) proved most economical (ICBR ranged from 1: 8 to 1: 1for all treatment modules)

Plate Nos. 1. Prickles on stalks (2) Prickles and rugged stalks. (3). Hard, prickled and stunted plant with flowers-partially bloom. (4) Distorted and bending in plant (5) Comparison between nematode infested and healthy plant (6) Yellowing and browning of leaves

Table 2. Effect of treatment modules on Percent Infested Plants (P.I.P) and population of foliar nematodes per 20g of tuberose flowers (cv. Calcutta Double) during 1st year of flowering

Treatment in modules*	P.I of flower stalk during August	Population of nematodes/20g flower during August	P.I of flower stalk during September	Population of nematodes/20g flower during September	P.I of flower stalk during October	Population of nematodes/20g flower duringOctober
M1	18.75 (25.89)^{a**}	69.37 (8.28)^{bcd}	27.65 (31.88) ^{a}	57.65 (7.42)^{ab}	31.14 (34.15)^{ab}	142.31 (11.93)^{abc}
M2	29.07 (31.94)^{a}	38.38 (6.17)^{ab}	26.25 (30.21) ^{a}	118.00 (10.59)^{bc}	24.34(29.77)^{a}	159.38 (12.38)^{bc}
M3	15.94 (23.70)^{a}	51.49 (7.20)^{abc}	25.52 (30.24) ^{a}	32.74 (5.67)^{a}	24.89(30.20)^{a}	178.85 (13.07)^{bc}
M4	14.93 (22.71) ^{a}	34.76 (4.46)^{a}	16.91 (24.15) ^{a}	91.45 (9.24)^{bc}	23.43 (29.21)^{a}	67.25 (7.18)^{a}
M5	22.06 (28.18) ^{a}	97.71 (9.81)^{cd}	28.71 (32.62) ^{a}	100.08 (9.72)^{bc}	27.38(31.78)^{a}	91.67 (9.39)^{ab}
M6	16.96 (24.53) ^{a}	99.20 (9.95)^{cd}	34.44 (36.06) ^{a}	152.31 (12.32)^{c}	31.39(34.05)^{ab}	215.63 (14.52)^{c}
M7	45.48 (42.67)^{b}	110.58 (10.52)^{d}	65.51 (55.29)^{b}	136.14 (11.65)^{c}	40.64 (39.89)^{b}	255.54 (15.74)^{c}
SEm±	3.88	1.06	4.50	1.12	2.23	1.65
CD (5%)	11.54	3.14	13.38	3.32	6.61	4.90

**In each nematocidal application sticker along with water was added. **Figure marked by common letter are not significantly different according to Duncan's Multiple Range Test at P<0.05. Figures in the parenthesis indicate angular transformed values.*

Table 3. Effect of treatment modules on Percent Infested Plants (P.I.P) and population of foliar nematodes per 20g of tuberose flowers (cv. Calcutta Double) during 1st (November) and 2nd (January and February) year of flowering

Treatments in module*	P.I of flower stalk during November	Population of nematodes/20g flower during November	P.I of flower stalk during January	Population of nematodes/20g flower during January	P.I of flower stalk during February	Population of nematodes/20g flower during February
M1	13.14 (21.21)^{a**}	243.00 (14.86)^{abc}	15.29 (23.35)^{ab}	227.75 (15.02)^{ab}	30.80 (33.90)^{cd}	845.25 (28.73)^{abc}
M2	11.65 (19.94)^{a}	328.50 (17.85)^{bc}	22.02 (28.13)^{abc}	151.06 (10.82)^{ab}	22.20 (28.37)^{c}	1109.94 (32.67)^{abc}
M3	12.25 (20.80)^{a}	214.50 (14.61)^{abc}	19.79 (26.30)^{ab}	158.38 (12.29)^{ab}	13.00 (21.12)^{ab}	472.28 (20.85)^{a}
M4	09.84 (18.58)^{a}	132.00 (11.35)^{ab}	12.14 (20.31)^{a}	110.31 (10.08)^{a}	10.44 (19.09)^{a}	688.19 (26.20)^{ab}
M5	15.50 (23.48)^{a}	79.88 (7.86)^{a}	25.33 (30.47)^{bc}	271.69 (15.93)^{ab}	20.81 (27.03)^{bc}	1092.75 (30.42)^{abc}
M6	10.44 (19.17)^{a}	154.00 (10.81)^{a}	32.00 (34.64)^{cd}	282.88 (16.77)^{b}	28.01 (32.18)^{cd}	1625.00 (39.98)^{bc}
M7	26.91 (31.56)^{b}	363.00 (18.98)^{c}	41.48 (40.28)^{d}	585.00 (23.98)^{c}	36.13 (37.22)^{d}	1944.67 (42.81)^{c}
SEm±	1.87	2.25	2.74	2.1	1.90	4.56
CD (5%)	5.56	6.68	8.13	6.33	5.63	13.54

**In each nematocidal application sticker along with water was added. **Figure marked by common letter are not significantly different according to Duncan's Multiple Range Test at P<0.05. Figures in the parenthesis indicate angular transformed values.*

Table 4. Effect of treatment modules on Percent Infested Plants (P.I.P) and population of foliar nematodes per 20g of tuberose flowers (cv. Calcutta Double) during 2nd year of flowering

Treatments in module*	P.I of flower stalk during March	Population of nematodes/20g flower during March	P.I of flower stalk during April	Population of nematodes/20g flower during April	P.I of flower stalk during May	Population of nematodes/20g flower during May
M1	35.53 (36.76)^{a**}	1602.33 (39.88)^{ab}	48.70 (44.54) ^{a}	1879.75 (43.28)^{a}	60.33 (51.31)^{b}	6489.83 (80.52)^{b}
M2	38.65 (38.71) ^{a}	2369.25 (48.52)^{c}	49.67 (45.10) ^{a}	1779.69 (41.85)^{a}	56.78 (49.23)^{ab}	4352.25 (65.94)^{a}
M3	32.38 (34.94) ^{a}	2210.88 (46.85)^{bc}	50.64 (45.65) ^{a}	1631.25 (39.29)^{a}	51.09 (45.90)^{ab}	6243.96 (78.91)^{b}
M4	29.77 (33.26) ^{a}	1422.75 (37.59)^{a}	52.40 (46.69) ^{a}	1201.38 (34.56)^{a}	44.74 (42.26)^{a}	4154.75 (64.46)^{a}
M5	32.66 (34.96) ^{a}	1672.96 (40.75)^{ab}	53.56 (47.34) ^{a}	1885.88 (43.01)^{a}	60.15 (51.29)^{b}	8050.04 (89.30)^{c}
M6	32.95 (35.24) ^{a}	2576.54 (50.29)^{c}	54.87 (48.15) ^{a}	1978.38 (44.29)^{a}	61.24 (51.81)^{b}	8482.83 (92.03)^{c}
M7	52.03 (46.45)^{b}	2621.79 (51.18)^{c}	66.24 (54.80)^{b}	2849.69 (53.38)^{b}	61.86 (52.27)^{b}	12612.96 (112.15)^{d}
SEm±	1.53	2.35	1.75	2.94	2.03	2.54
CD (5%)	4.53	6.99	5.21	8.73	6.02	7.55

**In each nematocidal application sticker along with water was added. **Figure marked by common letter are not significantly different according to Duncan's Multiple Range Test at P<0.05. Figures in the parenthesis indicate angular transformed values*

Table 5. Effect of treatment modules on Percent Infested Plants (P.I.P) and population of foliar nematodes per 20g of tuberose flowers (cv. Calcutta Double) 2nd year of flowering

Treatment in modules*	P.I of flower stalk during June	Population of nematodes/20g flower during June	P.I of flower stalk during July	Population of nematodes/20g flower during July	P.I of flower stalk during August	Population of nematodes/20g flower during August
M1	54.99 (48.16)^{ab**}	20468.44 (143.04)^{c}	44.72 (42.24)^{a}	13387.33 (115.67)^{b}	61.00 (51.69)^{ab}	9330.13 (96.35)^{b}
M2	59.05 (50.54)^{abc}	13545.94 (115.91)^{b}	52.69 (46.83)^{b}	16028.33 (126.57)^{c}	58.86 (50.45)^{a}	9503.75 (97.39)^{bc}
M3	56.18 (48.87)^{ab}	11113.44 (105.33)^{ab}	49.13 (44.79)^{ab}	9987.88 (99.76)^{a}	56.45 (49.05)^{a}	7221.31 (84.55)^{b}
M4	47.34 (43.74)^{a}	10365.00 (101.68)^{a}	44.86 (42.34)^{a}	10757.33 (103.67)^{a}	56.02 (48.78)^{a}	5710.75 (75.29)^{a}
M5	57.33 (49.55)^{ab}	13489.75 (116.10)^{b}	46.66 (43.37)^{ab}	11395.08 (106.73)^{a}	59.66 (51.01)^{a}	11775.94 (108.49)^{c}
M6	61.92 (52.26)^{bc}	18869.50 (136.88)^{c}	50.07 (45.33)^{ab}	19634.92 (140.09)^{d}	66.91 (55.33)^{ab}	27165.31 (164.67)^{d}
M7	69.02 (56.56)^{c}	20731.63 (143.88)^{c}	67.94 (55.82)^{c}	27528.25 (165.82)^{e}	73.55 (59.49)^{b}	28732.31 (169.29)^{d}
SEm±	1.42	3.94	1.18	2.26	2.32	3.85
CD (5%)	4.21	11.70	3.52	6.72	6.91	11.43

**In each nematocidal application sticker along with water was added. **Figure marked by common letter are not significantly different according to Duncan's Multiple Range Test at P<0.05. Figures in the parenthesis indicate angular transformed values*

Table 6. Effect of the treatment modules on Percent Infested Plants (P.I.P) and population of foliar nematodes per 20g of tuberose flower (cv. Calcutta Double) 2nd year of flowering

Treatment in modules*	P.I of flower stalk during September	Population of nematodes/20g flower during September	P.I of flower stalk during October	Population of nematodes/20g flower during October	P.I of flower stalk during November	Population of nematodes/20g flower during November
M1	55.26(48.34) ^{ab**}	9659.44 (98.10)^{b}	44.00(41.82)^{a}	8498.13 (91.69)^{ab}	38.41(38.55)^{b}	4710.50 (67.71)^{b}
M2	53.42(47.30)^{ab}	4449.88 (66.54)^{a}	41.37(40.31) ^{a}	7375.00 (85.54)^{a}	43.09(41.31)^{bc}	4221.96 (64.48)^{ab}
M3	45.69(42.81)^{a}	3884.06 (61.97)^{a}	44.40(42.07) ^{a}	8456.92 (91.85)^{ab}	29.25(33.00)^{a}	3636.81 (60.28)^{ab}
M4	42.87(41.13)^{a}	9431.56 (96.84)^{b}	49.25(44.87) ^{a}	6275.71 (78.58)^{a}	43.49(41.52)^{bc}	2252.38 (47.43)^{a}
M5	54.18(47.69)^{ab}	10953.75 (104.65)^{b}	59.49(50.79)^{b}	10642.38 (102.92)^{b}	50.28(45.45)^{c}	3748.13 (60.26)^{ab}
M6	63.51(53.17)^{bc}	27448.50 (165.60)^{c}	59.94(51.03)^{b}	14969.50 (121.71)^{c}	48.19(44.24)^{bc}	5462.06 (73.47)^{b}
M7	70.23(57.37)^{c}	30310.13 (173.59)^{c}	65.98(54.72)^{b}	32159.75 (179.23)^{d}	61.00(51.71)^{d}	5391.44 (71.66)^{b}
SEM	2.41	4.02	1.93	4.51	1.55	4.75
CD (5%)	7.17	11.93	5.75	13.40	4.60	14.12

**In each nematocidal application sticker along with water was added. **Figure marked by common letter are not significantly different according to Duncan's Multiple Range Test at P<0.05. Figures in the parenthesis indicate angular transformed values*

Table 7. Incremental cost benefit ratio recorded under the nematode management programme during 1st and 2nd flowering season

Treatment in modules*	Total Nematicide cost/ ha (Rs.)	Total labour cost/ha (Rs)	Total cost (Rs)	Yield/ ha (Nos. of stalk)	Incremental yield/ha (Nos. of stalk)	Incremental gross income/ha	Incremental net income/ ha	ICBR
M1	76968.54	40404	117372.5	421879.14	355940.58	711881.16	594508.62	1:5.07
M2	49368.55	40404	89772.55	397899.45	331960.89	663921.78	574149.23	1:6.40
M3	71545.65	40404	111949.7	412319.10	346380.54	692761.08	580811.43	1:5.19
M4	39695.66	40404	80099.66	443908.19	377969.63	755939.26	675839.60	1:8.44
M5	243111.1	40404	283515.1	428937.19	362998.63	725997.26	442482.16	1:1.56
M6	25197.30	40404	65601.3	133091.23	67152.67	134305.34	68704.04	1:1.05
M7	-	-	-	65938.56				

**In each nematocidal application sticker along with water was added. Labour charges- Rs.222 per day per man and price of tuberose per stalk – Rs.2/stalk*

i.e M_4 (1:8.44) and this was followed by M_2 (1:6.40), M_3 (1:5.19), M_1 (1:5.07), M_5 (1:1.56) and M_6 (1:1.05). Results of experiments clearly showed that despite having high nematode infestation, all the treatments in combined formed as module were quite effective and economic to improve the yield over untreated plots. From the above results regarding the percent plant infestation, we could also find that the treatments modules significantly decreased the infestation percentage as the infestation was highest in untreated plot (M_7) in almost all the months. The progresses of nematode infestation during both the season in untreated plots ranged from 9% to 74%. From this, we can also conclude that the infestation percentage increased in 2nd year crops as compared to 1st year crops which supported the observation of Khan *et al*., 2006 where he concluded that the disease incidence was found low (3-34%) in the treated plots whereas in the untreated plots, it was ranging between 10% and 58% in first year crop, however, it was more in second year crop. Here, the conclusion can also be made that the treatment module M_4 was found to be the most effective in almost all the months during the programme to reduce the infestation caused by foliar nematode *Aphelenchoides besseyi* with nematode infestation ranged from 0% to 61% all together in both the year which was more or less similar with the findings of Khan *et al.,* (2005) who recorded that pre-soaking of bulbs for overnight followed by hot water treatment at 50ºC for 30 minutes+dipping of bulbs in monocrotophos 36SL in 500 ppm for 6 hours+two sprayings with monocrotophos 36SL at 500 ppm in first, second and third year crop with three sprayings with monocrotophos 36SL at 500 ppm at 15 days interval (T_5) was found to be superior in terms of reduction of foliar disease with PDI value in the treated plots recorded from 2% to 66%. Khan and Ghosh, (2011) reported that among synthetic pesticides tested, monocrotophos 36 SL showed killing to the extent of 41% nematodes while cartap hydrochloride 50WP and carbosulfan 25EC had 14% killing effect at relatively higher concentration (0.2%) after 2 hrs of exposure. Kadam et al., (2020) also recorded that module combined treatment with monocrotophos 36SL @ 750, carbosulfan 25EC @ 250g and cartap hydrochloride 50SP @ 375g were found very effective in growth attribute of the crop. William and Robert, (2005) recorded that Chlorfenapyr was a foliar treatment that could be used to manage foliar (*Aphelenchoides*spp.) nematodes whereas Rajvanshi, (2012) recorded that NSKP; Neem seed kernel powder- 10%) could gave significantly better results as compared to untreated check for controlling the nematodes. In another finding, Nagesh *et al.,* 1998 revealed that split application of *P. lilacinus* in combination with oil cakes significantly reduced multiplication rate of nematodes, compared to the single application of *P. lilacinus*, oil cakes and their combinations at planting. The augmentation of nematodes population was found to be more in untreated plot as compare to treated plot (Khan *et al.,* 2006). The appearance of nematode was also found to be more during the month May, June, July and August due to high relative humidity and temperature in the atmosphere (Khan, 2004). It is further to be mentioned that performances of the treatment modules were assessed based on their comparative performance only and there was no such treatment module to check the growth of the nematode populations completely particularly during the periods of high humidity and temperature.

4. CONCLUSION

Aphelenchoides, one of the most important ornamental nematode pests is hard to manage using single method. The nematode survives in bulbs of the tuberose and can remain alive for many years in inactive mode. When bulbs are sown in the field, they become active due to the moisture and start feeding upon the plant tissues. The infestation found from the very early stages till the flowering leads to drastic economic losses. Therefore, the management were planned in modules so that it can be managed right from the sprouting till harvest of the cut or loose flowers. Many nematodes escape, and can be found during flowering stages with highest population in flowers. Such infected flowers lead to huge losses. The module M_4- consisting of overnight pre-soaking of bulbs in water followed by dipping in monocrotophos 36SL @750ppm for 4 hrs. and spraying of monocrotophos 36SL @360g a.i./ha alternated with cartap hydrochloride 50SP @375g a.i./ha at 15 days interval after onset of foliar nematode infestation in the 1st year and succeeding year crop was the best for managing the foliar nematode in tuberose and economizing the farmers earning.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image

generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/125922