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Integrated Management of *Aphelenchoides besseyi* infesting Tuberose in Gangetic Plains of West Bengal

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ABSTRACT

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An experiment was conducted over two years from 2014 to 2016 to find out the suitable management tactics against *Aphelenchoides besseyi* Christie in tuberose. The experiment was planned in 'Strip Factorial Design'. Three nematode management modules, two susceptible crop cultivars and two spacings were used in the experiment. Management modules were adopted in order to manage the population of *A. besseyi* in tuberose to minimize the infestation for sustainable production of tuberose floral spikes. The IPM module of foliar nematode management comprising of bulb treatment, field sanitation and three rounds of prophylactic spray with nematicides for the 1st and 2nd year crop in the present experiment kept the *A. besseyi* population significantly lower than the farmers' practice module (bulb treatment + four rounds of prophylactic spray with nematicides for the 1st and 2nd year crop) and untreated control. Hence, adoption of IPM module possibly made the crop to achieve good growth and development as judged by the several attributes (spike length, rachis length, number of nodes/spike, flower yields etc.) measured during the course of experimentation. The maximum return per rupee investment for managing *A. besseyi* in tuberose was observed with the IPM module being, Rs. 17.84. To enhance the flower yield of tuberose, Calcutta Single cultivar can be planted in 30cm × 25cm spacing adopting IPM module of foliar nematode management. Validation and promotion of developed IPM module of foliar nematode management for the farmers raising tuberose in the Gangetic plains of West Bengal need to be done.

Introduction

Tuberose (*Polianthes tuberosa* L.) is one of the important tropical bulbous flowering plants grown for production of eternal floral spikes. It is a very popular cut flower in the eastern part of India (West Bengal and Odisha), and also in the northern plains and parts of the south. Its production is constrained mainly by plant parasitic nematodes, insect-pests and diseases. Among nematodes, the foliar nematode, *Aphelenchoides besseyi* Christie has emerged as a serious threat to

sustainable tuberose production in West Bengal. Widespread occurrence of foliar nematode infecting rice, tuberose, gladiolus and onion was also reported from West Bengal.

Nematode may survive on bulbs, leaves, scapes, bracts, tepals and anthers but not in the soil (Roy *et al.*, 2010; Roy *et al.*, 2011). Second year onwards tuberose crop suffers most from the infestation of foliar nematode, this may lead to annual yield loss of 30 to 40% in the 'Calcutta Double' cultivar as against

59% in 'Calcutta Single' cultivar (Khan and Pal, 2001; Pathak and Khan, 2009). International quarantine exists against *A. besseyi*, hence, their presence on cut flowers may limit the potential of flower export. Anhydrobiotic nature of *A. besseyi* creates a barrier against permeability of nematicides into nematode's body, hence making the nematicidal application unfruitful.

Considering the importance of nematodes in the integrated pest management system and increasing concern of environment, adoption of low input plant protection technologies like, summer ploughing, soil solarization, organic manuring, adjustment of dates of sowing/planting, spacing, adoption of resistant varieties, clean cultivation and judicious use of pesticides are gaining significance. Integration of two or more above mentioned methods could be adopted, for managing nematode like, *A. besseyi*.

In view of its widespread occurrence and increasing importance in the changing agricultural scenario, their integrated management tactics in tuberose was undertaken.

Materials and Methods

The experiment was conducted over two years from 2014 to 2016 at the Central Research Farm of BCKV, Gayeshpur, Nadia, West Bengal. The farm was located at 22°87'N latitude, 88°20' E longitude with an elevation of 9.75m above mean sea level. The experimental design followed for the experiment was Strip Factorial. Two susceptible crop cultivar were used such as V₁: Calcutta Single, V₂: Calcutta Double and they were planted at two different spacings S₁: 30 cm × 20 cm and S₂: 30 cm × 25 cm, the plot size was 2m×1.2m. Date of sowing of bulbs was 19.04.2014 and the treatments were replicated 3 times.

Treatment Details: M₁: Untreated Control, M₂: Farmers' Practice module: *Bulb treatment*: Overnight pre-soaking of bulbs followed by dipping in monocrotophos 36 SL @ 720ppm for 4hrs before planting.

Prophylactic spray

Four rounds of foliar sprays with monocrotophos 36 SL @ 360 g *a.i.*/ha at 14 days interval commencing from initiation of infestation for the 1st and 2nd year crop.

M₃: Integrated foliar nematode management module: *Bulb treatment*: Overnight pre-soaking of bulbs followed by dipping in cartap hydrochloride 50 SP @1000ppm for 4hrs before planting.

Field sanitation

Removal of debris from plant and plot periodically (twice in a month) to restrict the migration of nematode and inoculum load.

Prophylactic spray

First prophylactic spray with cartap hydrochloride 50 SP @ 500g *a.i.* /ha + Active 80 (adjuvant) @ 5ml/15 litres of water at the time of spike emergence.

Second prophylactic spray with chlorfenapyr 10 SC @ 100g *a.i.* /ha + Active 80 (adjuvant) @ 5ml/15 litres of water at 14 days after 1st spray.

Third prophylactic spray with cartap hydrochloride 50 SP @ 500g *a.i.* /ha + Active 80 (adjuvant) @ 5ml/15 litres of water at 14 days after 2nd spray.

Second year crop received first, second and third spray with above mentioned nematicides and adjuvant at 14 days interval commencing from the spike emergence of tuberose.

Initial Nematode Population

| Varieties | Population of <i>A. besseyi</i> /bulb | | |
|-----------------|---------------------------------------|--------------------------------------|--------------------------------------|
| | Untreated (M ₁) | Treated (M ₂) | Treated (M ₃) |
| | Before planting | After bulb treatment before planting | After bulb treatment before planting |
| Calcutta Single | 3.3 | 1.2 | 0.5 |
| Calcutta Double | 1.4 | 0.7 | 0.2 |

Observations recorded

Initial population of *A. besseyi* / bulb to ascertain presence of nematode, foliar nematode population per 20g of plant parts (leaves + flowers) at 14 days interval commencing from appearance symptom, observation on spike length (cm), length of rachis (cm), number of nodes/spike, weight of flowers/spike, spike yield (number/plot and number/ha), weight of flowers (kg/plot and q/ha), days to first blooming and 100% blooming, flower yield in kg/plot and q/ha and dry yield of bulb and bulb-lets (kg/plot and q/ha)

Statistical analysis

Analysis of variance was worked out following Strip Factorial design for comparison of means (Gomez and Gomez, 1984). Incremental cost benefit ratio for the assessment of the module was also worked out.

Results and Discussion

Effect of management module, variety and spacing on spike length (cm) of tuberose during 2014-15 and 2015-16

The effect of management module, variety and spacing on spike length of tuberose during 2014-15 and 2015-16 has been presented in the table 1. There was no significant difference in spike length among the management modules during the 1st year but during 2nd year a significant variation in spike length among management modules was

noticed and the maximum length was observed in the M₃ (IPM module) being, 92.1 cm. Pooled data also revealed significant difference in spike length among management modules with the maximum being, 91.0 cm was recorded in the M₃ i.e. IPM module (Table 1). Significant difference in spike length among varieties was observed only during 1st year, where Calcutta Single had maximum spike length (94.6 cm). Non-significant effect of variety on the spike length of tuberose was noticed in the 2nd year. Pooled data revealed significant influence of variety on the spike length. Based on pooled data highest spike length was noted with the Calcutta Single variety being, 89.9 cm (Table 1). The spacings adopted to raise the tuberose crop did not reveal significant influence on the spike length (Table 1). Usually, spike length was observed maximum when Calcutta Single variety was planted in wide spacing and adopted IPM module.

Effect of management module, variety and spacing on rachis length (cm) of tuberose during 2014-15 and 2015-16

The effect of management module, variety and spacing on rachis length of tuberose during 2014-15 and 2015-16 has been presented in the table 2. Significant difference in rachis length among the management modules was observed in both the years with the maximum in the IPM module (M₃). Considering pooled data, maximum length of tuberose rachis was recorded in the M₃ i.e. IPM module being, 36.7 cm (Table 2). Tuberose variety also had a significant influence on the rachis length

during study period. Calcutta Double was found superior to Calcutta Single in achieving rachis length. Significant maximum rachis length in both the years was observed with the Calcutta Double variety being, 33.6 cm and 28.7 cm, respectively. Likewise, pooled data also revealed similar trend with regard to the rachis length.

Spacing revealed significant impact on the rachis length only during second year of the study. Wide spaced crop had comparatively more rachis length than the narrow spaced crop (Table 2).

Effect of management module, variety and spacing on number of nodes/spike of tuberose during 2014-15 and 2015-16

Node is an important botanical part of tuberose spike. Here, flower buds originate from the node. More number of nodes means more sites to accommodate flowers. Hence, observation on number of nodes/spike has the value to judge the performance of treatments on the tuberose crop.

The effect of management module, variety and spacing on number of nodes/spike of tuberose during 2014-15 and 2015-16 has been presented here in the table 3. Foliar nematode management module had non-significant impact on the production of nodes/spike in the 1st year crop. In contrast, the 2nd year crop had significant difference in the number of nodes/spike between management modules. The highest number of nodes/spike was always recorded in the IPM module. Mean number of nodes/spike in the IPM module was 14.0 (pooled).

Unlike nematode management module, variety too had an influence on the production of number of nodes/spike. Calcutta Double variety produced more number of nodes/spike than the Calcutta Single variety. Mean number of nodes/spike in the Calcutta Double variety was 14.0 (pooled).

Spacing didn't reveal any effect on number of nodes/spike.

Effect of foliar nematode management module, variety and spacing on number of flowers/spike of tuberose during 2014-15 and 2015-16

Effect of foliar nematode management module, variety and spacing on production of flowers/spike in tuberose during 2014-15 and 2015-16 has been presented below in the table 4. Production of flowers/spike was maximum in the IPM module as confirmed by the pooled result of two years study. Number of flowers/spike was 28.7 (pooled).

Variety exhibited significant influence on the production of flowers/spike during the period of experimentation. In reference to the mentioned yield attribute, the variety Calcutta Double was superior to the Calcutta Single. Flower yield (number) of Calcutta Double variety was 28.6/spike (pooled).

Spacing showed significant influence on flower yield only in the 1st year crop, but the ultimate effect of spacing on yield of flowers (number/spike) was non-significant. In a general perspective, irrespective of the variety and the nematode management module the wide spaced crop bore more flowers/spike (Table 4).

Effect of management module, spacing and variety on days to 1st and 100% blooming of tuberose flower

Effect of management module, spacing and variety on days to 1st blooming and 100% blooming of tuberose flower has been presented in the table 5. The foliar nematode management modules and spacings in the experiment had non-significant impact on the number of days required to attain 1st as well as 100% blooming of tuberose flower. Data showed comparatively lesser requirement of

time to attain 1st and 100% blooming of flowers in the plots received IPM module or where bulbs were planted in narrow spacing (S₁).

The varieties played significant role on the blooming of flowers as observed from the data (Table 5). Calcutta Single took longer time to start its blooming i.e. 192.6 days after planting while, 100% blooming of spikes in the variety was observed at 435.1 days after planting. In contrast, the Calcutta Double took only 117.2 days to start blooming and 100% blooming was attained in 415.0 days after planting of bulbs.

Desai *et al.*, (2016) reported that spacing had non-significant effect on flowering of tuberose cv. Shringar. Mishra *et al.*, (2000) observed that tuberose cultivars (Single and Double) with closer spacing took longer time to produce spikes than wide-spaced plants. Malam *et al.*, (2010) reported that days to spike emergence and days to first flower opening decreased with increase in spacing of tuberose cv. Double. Ratoon crop flowers early as compared to the first year crop. In the present study, early emergence of spike and flowers in narrow-spaced tuberose crop might be due to reduction of growth that possibly directed the plant towards the reproductive phase earlier than the plant that acquired more vegetative growth at wider spaces. Similar observations on the mentioned aspect were earlier cited by several workers (Mohanty *et al.*, 2002; Ahmed *et al.*, 2010, Sheoran *et al.*, 2015).

Effect of management module, variety and spacing on weight of flowers (g/spike) and flower yield of tuberose during 2014-15 and 2015-16

Effect of management module, variety and spacing on weight of flowers (g/spike) of tuberose during 2014-15 and 2015-16 has been presented below in the table 6.

Significant difference in the weight of flowers (g/spike) among foliar nematode management module was observed during 2nd year. The ultimate effect of management module on the weight of flowers was significant. The maximum weight of flowers was recorded in the IPM module (M₃) being, 45.6 g/spike (pooled).

Calcutta Double variety has significantly maximum weight of flowers being, 63.4 and 58.9 g/spike in the 1st and 2nd year, respectively. Pooled data also showed similar influence of variety on the weight of flowers/spike (Table 6).

Spacing had significant effect on weight of flowers/spike only during 1st year where wide-spaced crop gave more weight of flowers (g/spike) than the narrow spaced crop (Table 6).

Impact of management module, variety and spacing on the flower yield (kg/plot and q/ha) of tuberose was significant in both the years (Table 7 and 8). Flower yield per plot as well as per ha was observed significantly maximum in the IPM module being, 2.6 kg and 109.1 q, respectively (pooled).

Effect of spacing and variety on the yield of flowers (kg/plot or q/ha) was significant in both the years (Table 7 and 8). Flower yield was more in the wider spacing (30cm × 25cm) than the narrower spacing (30cm × 20cm).

Loose flower yield of tuberose was maximum in the wide spaced crop being, 85.5 and 88.2 q/ha in the 1st and 2nd year, respectively (Table 8). Flower yield of tuberose was observed maximum in the Calcutta Single variety being, 88.7 and 91.1 q/ha in the 1st and 2nd year, respectively (Table 8). In spite of having more weight of flowers/spike, Calcutta Double cultivar couldn't produce more flower yield (kg/plot and q/ha). Flower yield depends more importantly on the number of floral spike

production per unit area. Production of tuberose spike/unit area was more in the Calcutta Single than the Calcutta Double. Thus, despite less weight of flowers/spike, the flower yield in Calcutta Single cultivar was more than the Calcutta Double cultivar. Nematode management module and spacing posed significant impact on the flower yield (kg/plot and q/ha) of tuberose as confirmed by the pooled result (Table 7, 8). Here, adoption of IPM module along with wide spacing fetched more flower yield.

Effect of management module, spacing and variety on bulb yield of tuberose

Bulb yield (kg/plot and q/ha) of tuberose varied significantly due to adoption of foliar nematode management modules. Irrespective of spacings and varieties, the IPM module played an important role in achieving maximum bulb yield of tuberose being, 10.9 kg/plot and 454.7q/ha (Table 9). Among

varieties used in the experiment, the Calcutta Double yielded maximum bulb which was 8.9 kg/plot and 369.8 q/ha (Table 9). In the present study, spacing had non-significant impact on the bulb production of tuberose.

Effect of management module, spacing and variety on spike yield of tuberose during 2014-15 and 2015-16

Adoption of foliar nematode (*A. besseyi*) management module, variety and spacing played an important role in influencing the spike yield (number/plot and number/ha) of tuberose. Maximum yield (number) of tuberose spike was obtained from the IPM module (M₃) being, 84.7/2.4 m² plot and 3,52,777.8/ha during 2014-15 (Table 10). Second year and pooled result showed non-significant effect of nematode management module on the spike yield but the M₃ yielded more number of spikes per plot as well as per ha.

Table.1 Effect of management module, variety and spacing on spike length of tuberose during 2014-15 and 2015-16

| Treatments | Spike length (cm) | | |
|---------------------------------|-------------------|-------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 87.1 | 80.2 | 83.6 |
| M ₂ | 86.8 | 85.7 | 86.3 |
| M ₃ | 89.9 | 92.1 | 91.0 |
| SEm (±) | 1.32 | 1.57 | 1.17 |
| LSD (0.05) | NS | 4.84 | 3.45 |
| V ₁ :Calcutta Single | 94.6 | 85.3 | 89.9 |
| V ₂ :Calcutta Double | 81.3 | 86.7 | 84.0 |
| SEm (±) | 0.70 | 0.73 | 0.85 |
| LSD (0.05) | 2.16 | NS | 2.51 |
| S ₁ :(30 × 20) cm | 87.0 | 85.8 | 86.4 |
| S ₂ :(30 × 25) cm | 88.9 | 86.2 | 87.5 |
| SEm (±) | 1.62 | 1.29 | 1.17 |
| LSD (0.05) | NS | NS | NS |

Table.2 Effect of management module, variety and spacing on rachis length of tuberose during 2014-15 and 2015-16

| Treatments | Rachis length (cm) | | |
|---------------------------------|--------------------|-------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 25.6 | 16.6 | 11.5 |
| M ₂ | 25.4 | 25.9 | 21.4 |
| M ₃ | 27.4 | 38.6 | 36.7 |
| SEm (±) | 0.40 | 0.88 | 0.55 |
| LSD (0.05) | 1.23 | 2.71 | 1.62 |
| V ₁ :Calcutta Single | 18.7 | 25.3 | 22.0 |
| V ₂ :Calcutta Double | 33.6 | 28.7 | 31.1 |
| SEm (±) | 0.39 | 0.55 | 0.26 |
| LSD (0.05) | 1.20 | 1.69 | 0.77 |
| S ₁ :(30 × 20) cm | 25.4 | 26.4 | 25.9 |
| S ₂ :(30 × 25) cm | 26.8 | 27.6 | 27.2 |
| SEm (±) | 0.43 | 0.12 | 0.39 |
| LSD (0.05) | NS | 0.37 | NS |

Note: M₁= Untreated control, M₂= Farmer's practice module and M₃= Integrated pest management module

Table.3 Effect of management module, variety and spacing on number of nodes/spike of tuberose during 2014-15 and 2015-16

| Treatments | Number of nodes/spike | | |
|---------------------------------|-----------------------|-------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 10 | 9 | 10 |
| M ₂ | 11 | 14 | 12 |
| M ₃ | 11 | 17 | 14 |
| SEm (±) | 0.31 | 0.26 | 0.23 |
| LSD (0.05) | NS | 0.80 | 0.68 |
| V ₁ :Calcutta Single | 8 | 12 | 10 |
| V ₂ :Calcutta Double | 13 | 15 | 14 |
| SEm (±) | 0.12 | 0.24 | 0.12 |
| LSD (0.05) | 0.37 | 0.74 | 0.35 |
| S ₁ :(30 × 20) cm | 11 | 13 | 12 |
| S ₂ :(30 × 25) cm | 11 | 14 | 12 |
| SEm (±) | 0.17 | 0.18 | 0.16 |
| LSD (0.05) | NS | NS | NS |

Table.4 Effect of foliar nematode management module, variety and spacing on number of flowers/spike of tuberose during 2014-15 and 2015-16

| Treatments | Number of flowers/spike | | |
|----------------------------------|-------------------------|-------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 22.1 | 18.9 | 20.5 |
| M ₂ | 21.8 | 28.0 | 24.9 |
| M ₃ | 23.5 | 33.9 | 28.7 |
| SEm (±) | 0.64 | 0.53 | 0.46 |
| LSD (0.05) | NS | 1.63 | 1.36 |
| V ₁ : Calcutta Single | 17.0 | 24.6 | 20.8 |
| V ₂ : Calcutta Double | 28.0 | 29.2 | 28.6 |
| SEm (±) | 0.37 | 0.48 | 0.23 |
| LSD (0.05) | 1.14 | 1.48 | 0.68 |
| S ₁ : (30 × 20) cm | 22.0 | 26.5 | 24.3 |
| S ₂ : (30 × 25) cm | 22.9 | 27.4 | 25.1 |
| SEm (±) | 0.15 | 0.35 | 0.33 |
| LSD (0.05) | 0.46 | NS | NS |

Table.5 Effect of management module, spacing and variety on days to 1st and 100% blooming of tuberose flower (mean of two crop seasons)

| Treatments | Days to first blooming | Days to 100% blooming |
|----------------------------------|------------------------|-----------------------|
| M ₁ | 160.5 | 428.0 |
| M ₂ | 152.2 | 425.8 |
| M ₃ | 151.9 | 421.3 |
| SEm (±) | 12.91 | 2.58 |
| LSD(0.05) | NS | NS |
| V ₁ : Calcutta Single | 192.6 | 435.1 |
| V ₂ : Calcutta Double | 117.2 | 415.0 |
| SEm(±) | 8.62 | 1.79 |
| LSD(0.05) | 26.56 | 5.52 |
| S ₁ : (30 × 20)cm | 146.1 | 423.6 |
| S ₂ : (30 × 25)cm | 163.7 | 426.6 |
| SEm (±) | 11.81 | 2.00 |
| LSD (0.05) | NS | NS |

Note: M₁= Untreated control, M₂= Farmer's practice module and M₃= Integrated pest management module

Table.6 Effect of management module, variety and spacing on weight of flowers (g/spike) of tuberose during 2014-15 and 2015-16

| Treatments | Weight of flowers (g/spike) | | |
|----------------------------------|-----------------------------|-------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 38.5 | 28.8 | 33.7 |
| M ₂ | 37.7 | 42.3 | 40.0 |
| M ₃ | 41.3 | 49.9 | 45.6 |
| SEm (±) | 1.09 | 1.15 | 0.93 |
| LSD (0.05) | NS | 3.54 | 2.74 |
| V ₁ : Calcutta Single | 14.9 | 21.8 | 18.3 |
| V ₂ : Calcutta Double | 63.4 | 58.9 | 61.2 |
| SEm (±) | 0.73 | 0.81 | 0.48 |
| LSD (0.05) | 2.25 | 2.50 | 1.42 |
| S ₁ :(30 × 20) cm | 37.9 | 39.9 | 38.9 |
| S ₂ :(30 × 25) cm | 40.4 | 40.8 | 40.6 |
| SEm (±) | 0.16 | 0.86 | 0.65 |
| LSD (0.05) | 1.48 | NS | NS |

Table.7 Effect of management module, variety and spacing on flower yield (kg/plot) of tuberose during 2014-15 and 2015-16

| Treatments | Flower yield (kg/plot) | | |
|----------------------------------|------------------------|-------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 1.5 | 1.0 | 1.2 |
| M ₂ | 1.8 | 1.9 | 1.9 |
| M ₃ | 2.4 | 2.9 | 2.6 |
| SEm (±) | 0.17 | 0.18 | 0.23 |
| LSD (0.05) | 0.52 | 0.55 | 0.68 |
| V ₁ : Calcutta Single | 1.6 | 1.7 | 1.9 |
| V ₂ : Calcutta Double | 2.1 | 2.2 | 1.9 |
| SEm (±) | 0.14 | 0.10 | 0.02 |
| LSD (0.05) | 0.43 | 0.31 | NS |
| S ₁ : (30 × 20) cm | 1.7 | 1.8 | 1.7 |
| S ₂ : (30 × 25) cm | 2.1 | 1.9 | 2.1 |
| SEm (±) | 0.03 | 0.05 | 0.19 |
| LSD (0.05) | 0.09 | 0.15 | NS |

Table.8 Effect of management module, variety and spacing on flower yield (q/ha) of tuberose during 2014-15 and 2015-16

| Treatments | Flower yield (q/ha) | | |
|----------------------------------|---------------------|--------------|--------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 61.4 | 43.0 | 52.2 |
| M ₂ | 73.8 | 80.5 | 77.1 |
| M ₃ | 98.1 | 120.1 | 109.1 |
| SEm (±) | 7.15 | 7.57 | 9.60 |
| LSD (0.05) | 22.03 | 23.33 | 28.32 |
| V ₁ : Calcutta Single | 88.7 | 91.1 | 79.9 |
| V ₂ : Calcutta Double | 66.8 | 71.2 | 79.0 |
| SEm (±) | 5.67 | 4.04 | 1.08 |
| LSD (0.05) | 17.47 | 12.45 | NS |
| S ₁ : (30 × 20) cm | 69.9 | 74.2 | 72.0 |
| S ₂ : (30 × 25) cm | 85.5 | 88.2 | 86.9 |
| SEm (±) | 1.06 | 2.43 | 7.86 |
| LSD (0.05) | 3.27 | 7.49 | NS |

Note: M₁= Untreated control, M₂= Farmer's practice module and M₃= Integrated pest management module

Table.9 Effect of management module, spacing and variety on bulb yield of tuberose

| Treatments | Bulb yield (kg/2.4m ² plot) | Bulb yield (q/ha) |
|----------------------------------|--|-------------------|
| M ₁ | 5.3 | 221.1 |
| M ₂ | 7.8 | 334.2 |
| M ₃ | 10.9 | 454.7 |
| SEm (±) | 0.31 | 12.91 |
| LSD (0.05) | 0.96 | 39.78 |
| V ₁ : Calcutta Single | 7.3 | 303.5 |
| V ₂ : Calcutta Double | 8.9 | 369.8 |
| SEm (±) | 0.34 | 14.47 |
| LSD (0.05) | 1.05 | 44.59 |
| S ₁ : (30 × 20) cm | 8.1 | 337.1 |
| S ₂ : (30 × 25) cm | 8.1 | 336.2 |
| SEm (±) | 0.16 | 6.81 |
| LSD (0.05) | NS | NS |

Table.10 Effect of management module, spacing and variety on spike yield (number/plot) of tuberose during 2014-15 and 2015-16

| Treatments | Spike yield (number/2.4m ² plot) | | |
|----------------------------------|---|--------------|-------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 55.4 | 49.3 | 52.4 |
| M ₂ | 69.1 | 60.6 | 64.8 |
| M ₃ | 84.7 | 76.2 | 80.5 |
| SEm (±) | 5.41 | 5.97 | 6.70 |
| LSD (0.05) | 16.67 | NS | NS |
| V ₁ : Calcutta Single | 106.5 | 96.0 | 101.3 |
| V ₂ : Calcutta Double | 32.9 | 28.1 | 30.5 |
| SEm (±) | 4.21 | 3.75 | 3.15 |
| LSD (0.05) | 12.97 | 11.55 | 9.29 |
| S ₁ : (30 × 20) cm | 64.8 | 59.0 | 61.9 |
| S ₂ : (30 × 25) cm | 74.6 | 65.1 | 69.8 |
| SEm (±) | 0.93 | 0.91 | 5.11 |
| LSD (0.05) | 2.87 | 2.80 | NS |

Table.11 Effect of management module, spacing and variety on spike yield (number/ha) of tuberose during 2014-15 and 2015-16

| Treatments | Spike yield (number/ha) | | |
|----------------------------------|-------------------------|-----------------|-----------------|
| | 2014-15 | 2015-16 | Pooled |
| M ₁ | 230903 | 205556 | 218229 |
| M ₂ | 287847 | 252431 | 270139 |
| M ₃ | 352778 | 317361 | 335070 |
| SEm(±) | 22527.59 | 24125.83 | 27928.01 |
| LSD(0.05) | 69414.41 | NS | NS |
| V ₁ : Calcutta Single | 443750 | 400000 | 421875 |
| V ₂ : Calcutta Double | 137269 | 116898 | 127083 |
| SEm(±) | 17535.41 | 15604.84 | 13137.89 |
| LSD(0.05) | 54031.98 | 48083.30 | 38756.75 |
| S ₁ : (30×20) cm | 270139 | 245833 | 257986 |
| S ₂ : (30×25) cm | 310880 | 271065 | 290972 |
| SEm(±) | 3870.00 | 3807.13 | 21307.78 |
| LSD(0.05) | 11924.66 | 11730.93 | NS |

Table.12 Effect of management module, variety and spacing on population of *A. besseyi* in tuberoses at different days after spray during 2014-15

| Treatments | Population of <i>A. besseyi</i> / 20g of plant parts | | | | | | |
|---------------------------------------|--|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|
| | 2014-15 | | | | | | |
| | Before spray | 7 days after 1 st spray | 14 days after 1 st spray | 7 days after 2 nd spray | 14 days after 2 nd spray | 7 days after 3 rd spray | 14 days after 3 rd spray |
| M₁ | 10.6 (141.0) | 10.6 (113.8) | 10.8 (115.8) | 11.0 (120.9) | 10.7 (114.5) | 9.7 (94.6) | 9.4 (87.4) |
| M₂ | 10.0 (100.3) | 9.2 (88.2) | 8.7 (75.9) | 8.9 (78.8) | 7.2 (52.7) | 4.9 (24.3) | 7.0 (49.3) |
| M₃ | 8.7 (79.5) | 9.2 (83.9) | 8.3 (68.9) | 7.7 (59.8) | 4.0 (15.9) | 2.1 (5.0) | 1.0 (0.9) |
| SEm (±) | 0.55 | 0.25 | 0.30 | 0.20 | 0.14 | 0.21 | 0.26 |
| LSD (0.05) | NS | 0.77 | 0.92 | 0.62 | 0.43 | 0.65 | 0.80 |
| V₁: Calcutta Single | 10.1 (118.6) | 10.1 (104.2) | 9.4 (90.5) | 9.6 (93.8) | 7.7 (67.9) | 5.8 (43.4) | 5.2 (37.1) |
| V₂: Calcutta Double | 9.5 (95.2) | 9.2 (86.4) | 9.0 (83.4) | 8.8 (79.1) | 6.9 (54.2) | 5.3 (39.1) | 4.7 (29.9) |
| SEm (±) | 0.82 | 0.38 | 0.27 | 0.22 | 0.21 | 0.28 | 0.16 |
| LSD (0.05) | NS | NS | NS | 0.68 | 0.65 | NS | 0.49 |
| S₁: (30 × 20) cm | 11.1 (110.4) | 10.0 (102.2) | 9.3 (88.7) | 9.3 (89.4) | 7.6 (65.2) | 5.5 (42.3) | 5.1 (35.6) |
| S₂: (30 × 25) cm | 8.4 (103.4) | 9.3 (88.4) | 9.1 (85.1) | 9.0 (83.5) | 7.0 (56.8) | 5.6 (40.2) | 4.7 (31.4) |
| SEm (±) | 0.43 | 0.48 | 0.12 | 0.19 | 0.09 | 0.16 | 0.26 |
| LSD (0.05) | 1.32 | NS | NS | NS | 0.28 | NS | NS |

Table.13 Effect of management module, variety and spacing on population of *A. besseyi* in tuberoses at different days after spray during 2015-16

| Treatments | Population of <i>A. besseyi</i> / 20g of plant parts | | | | | | |
|---------------------------------------|--|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|
| | 2015-16 | | | | | | |
| | Before spray | 7 days after 1 st spray | 14 days after 1 st spray | 7 days after 2 nd spray | 14 days after 2 nd spray | 7 days after 3 rd spray | 14 days after 3 rd spray |
| M₁ | 10.5 (115.8) | 10.8 (121.3) | 10.5 (113.0) | 10.0 (100.8) | 10.4 (110.5) | 10.1 (102.5) | 8.8 (77.8) |
| M₂ | 9.7 (94.9) | 9.1 (83.7) | 9.4 (69.3) | 7.4 (57.6) | 7.6 (58.4) | 6.6 (44.5) | 4.5 (20.5) |
| M₃ | 8.2 (68.5) | 8.6 (75.1) | 7.2 (51.9) | 4.8 (21.7) | 4.1 (17.4) | 2.7 (8.1) | 1.4 (2.1) |
| SEm (±) | 0.85 | 0.77 | 0.32 | 0.27 | 0.47 | 0.37 | 0.27 |
| LSD (0.05) | NS | NS | 0.99 | 0.83 | 1.45 | 1.14 | 0.83 |
| V₁: Calcutta Single | 9.9 (101.9) | 10.0 (102.5) | 9.5 (94.2) | 7.7 (64.6) | 7.9 (69.5) | 6.8 (55.5) | 5.2 (37.1) |
| V₂: Calcutta Double | 9.0 (84.2) | 9.0 (84.2) | 8.5 (74.3) | 7.1 (54.6) | 6.8 (54.7) | 6.1 (47.9) | 4.7 (29.9) |
| SEm (±) | 0.39 | 0.35 | 0.27 | 0.17 | 0.30 | 0.29 | 0.16 |
| LSD (0.05) | NS | NS | 0.83 | 0.52 | 0.92 | NS | 0.49 |
| S₁: (30 × 20) cm | 9.6 (95.4) | 9.8 (98.1) | 9.3 (89.8) | 7.5 (61.3) | 7.3 (63.1) | 7.0 (52.3) | 5.1 (35.6) |
| S₂: (30 × 25) cm | 9.3 (90.7) | 9.2 (88.6) | 8.7 (78.7) | 7.3 (57.9) | 7.4 (61.1) | 6.2 (51.1) | 4.7 (31.4) |
| SEm (±) | 0.63 | 0.17 | 0.14 | 0.16 | 0.45 | 0.40 | 0.26 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | NS |

Note: Data shown are $\sqrt{x+0.5}$ transformed values, figures in parentheses indicate original values, M₁= Untreated control, M₂= Farmer's practice module and M₃= Integrated pest management module

Table.14 Effect of management module, variety and spacing on population of *A. besseyi* in tuberose at different days after spray (Pooled)

| Treatments | Population of <i>A. besseyi</i> / 20g of plant parts | | | | | | |
|----------------------------------|--|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|
| | Pooled | | | | | | |
| | Before spray | 7 days after 1 st spray | 14 days after 1 st spray | 7 days after 2 nd spray | 14 days after 2 nd spray | 7 days after 3 rd spray | 14 days after 3 rd spray |
| M ₁ | 10.6 (128.4) | 10.7 (117.5) | 10.6 (114.4) | 10.5 (110.9) | 10.5 (112.5) | 9.9 (98.5) | 9.1 (82.6) |
| M ₂ | 9.8 (97.6) | 9.1 (85.9) | 9.0 (70.5) | 8.1 (68.2) | 7.4 (55.5) | 5.7 (34.4) | 5.8 (34.9) |
| M ₃ | 8.4 (74.0) | 8.9 (79.5) | 7.7 (60.4) | 6.3 (40.7) | 4.0 (16.7) | 2.4 (6.5) | 1.2 (1.5) |
| SEm (±) | 0.65 | 0.50 | 0.33 | 0.20 | 0.24 | 0.21 | 0.16 |
| LSD (0.05) | NS | NS | 0.97 | 0.59 | 0.71 | 0.62 | 0.47 |
| V ₁ : Calcutta Single | 10.0 (110.3) | 10.0 (103.4) | 9.5 (92.4) | 8.7 (79.2) | 7.8 (68.7) | 6.3 (49.5) | 5.5 (43.1) |
| V ₂ : Calcutta Double | 9.2 (89.7) | 9.1 (85.3) | 8.8 (78.8) | 8.0 (66.8) | 6.9 (54.4) | 5.7 (43.5) | 5.1 (36.2) |
| SEm (±) | 0.35 | 0.06 | 0.13 | 0.15 | 0.17 | 0.19 | 0.14 |
| LSD (0.05) | NS | 0.18 | 0.38 | 0.44 | 0.50 | NS | NS |
| S ₁ : (30 × 20) cm | 10.3 (102.9) | 9.9 (100.2) | 9.3 (89.3) | 8.4 (75.4) | 7.5 (64.2) | 6.1 (47.3) | 5.5 (41.3) |
| S ₂ : (30 × 25) cm | 8.9 (97.1) | 9.3 (88.5) | 8.9 (81.9) | 8.2 (70.7) | 7.2 (59.0) | 5.9 (45.7) | 5.2 (38.0) |
| SEm (±) | 0.55 | 0.34 | 0.28 | 0.11 | 0.18 | 0.20 | 0.15 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | NS |

Note: Data shown are $\sqrt{x+0.5}$ transformed values, figures in parentheses indicate original values, M₁= Untreated control, M₂= Farmer's practice module and M₃= Integrated pest management module.

Table.15 Comparative economics of adopted foliar nematode management modules in tuberose over the growing period of 2014-16

| Module | Total yield of loose flowers in two years (q/ha) | Yield of bulb after yield over control | | Gain in bulb yield over control (q/ha) | Value of additional flowers and bulb yield (Rs./ha) | Total chemical used per ha in two years | Cost of treatment in two years (Rs./ha) | | Total cost of treatment in two years (Rs./ha) | Net gain (Rs./ha) | Incremental Cost: Benefit |
|--------------------------|--|--|---------------------|--|---|---|---|---------|---|-------------------|---------------------------|
| | | 2 nd year (q/ha) | in two years (q/ha) | | | | Chemical | Labour | | | |
| | | | | | | | | | | | |
| Farmers' practice module | 154.30 | 334.20 | 49.90 | 113.10 | 111110.00 | Monocrotophos 36 SL 17 litres | 5950.00 | 1944.00 | 7894.00 | 103216.00 | 1:14.08 |
| IPM module | 218.20 | 454.70 | 113.80 | 233.60 | 250960.00 | Cartap hydrochloride 50 SP 13kg + Chlorfenapyr 10 SC 2 litres + Active 80 l litre | 12608.00 | 1458.00 | 14066.00 | 236894.00 | 1:17.84 |
| Untreated control | 104.4 | 221.1 | - | - | - | - | - | - | - | - | - |

Note: Market price of monocrotophos 36SL @ Rs.350/litre, cartap hydrochloride 50 SP @ Rs.650/kg, chlorfenapyr 10 SC @ Rs. 900/kg, tuberose flowers (loose) @ Rs. 2000/q, tuberose bulbs @ Rs. 100/q, labour wages @ Rs. 243/-manday.

Nematode management module may not influence the spike yield significantly (based on pooled result) but the flower yield (kg/plot and q/ha) which was worked out based on spike yield was varied significantly due to adoption of the integrated foliar nematode management tactics as evident from the result (Table 7 and 8).

The variety Calcutta Single yielded significantly maximum number of spikes in both the years which was 106.5 and 96.0/plot and 4,43,750 and 4,00,000/ha during 2014-15 and 2015-16, respectively (Table 10 and 11). Pooled data also showed similar outcome.

Planting of bulbs in wide spacing (30cm × 25cm) yielded significantly maximum number of spikes i.e. 3,10,880 and 2,71,065/ha for the 1st and 2nd year, respectively (Table 11). Though the effect of spacing on spike yield was non-significant considering pooled data but the trend was similar to that of individual year-wise observation (Table 10 and 11).

Effect of management module, variety and spacing on population of *A. besseyi* in tuberose at different days after spray during 2014-15 and 2015-16

Effect of foliar nematode management module, variety and spacing on population of *A. besseyi* in tuberose was studied at different days after spray during 2014-15 and 2015-16. Total number of foliar spray of nematicides was three and four respectively for the IPM module and farmers' practice, respectively in each year. In farmers' practice, spray was initiated at the commencement of *A. besseyi* infestation; while, in IPM module spray was initiated at the time of floral spike emergence. For the ease of comparison of performance of the nematicidal spray included in the management module, nematode population (number /20g of plant parts) data at regular interval after three round of spray has been presented in tabular form below (Table 12-14). Significant difference in population (number/20g plant parts) of *A. besseyi* between management modules at 7 and 14 days after each round of spray was observed in the 1st year (Table 12). All time except 7 days after 1st round of spray, the nematode population varied significantly between management modules as found in the second year

and pooled result (Table 13 and 14). Population of *A. besseyi* in tuberose before spray didn't vary significantly (Table 12-14). Population of *A. besseyi* / 20g of plant parts at seven days after 1st round of spray with cartap hydrochloride 50 SP @ 500g *a.i.* /ha + Active 80 (adjuvant) @ 5ml/15 litres of water in M₃ (IPM module) was found statistically at par with the spray of monocrotophos 36 SL @ 360 g *a.i.*/ha in M₂ (farmers' practice module) in each year (Table 12 and 13).

The variation in foliar nematode population between M₂ and M₃ was significant at 14 days after 1st round of spray with the least being, 51.9/20g plant parts in M₃ in the 2nd year (Table 13). In the first year, significant variation in foliar nematode population between M₂ and M₃ was observed first at 7 days after second round of spray of nematicides, the least was 59.8/20g plant parts recorded in M₃ which involves spray of chlorfenapyr 10 SC @ 100g *a.i.* /ha + Active 80 (adjuvant) @ 5ml/15 litres of water. Thereafter, a significant gradual decline in the nematode population at regular interval was observed due to adoption of nematicidal sprays in the 'farmers' practice' and 'IPM' module. Least nematode population was noted at 14 days after third round of spray with cartap hydrochloride 50 SP @ 500g *a.i.* /ha + Active 80 (adjuvant) @ 5ml/15 litres of water i.e. M₃ (Table 12-14).

Out of two varieties of tuberose, Calcutta Single had more population of foliar nematode than the Calcutta Double in general. Based on pooled analysis of two years data, significantly low population of *A. besseyi* was recorded in the Calcutta Double variety all time except at 7 days after 3rd round of spray. Population of nematodes between varieties didn't vary before spray of nematicides.

Population of nematodes between spacings didn't vary significantly due to spray of nematicides (pooled, Table 14) but wide spaced crop had comparatively lesser population than the narrow spaced crop and this probably helped the wide-spaced crop to achieve better growth. The better plant growth contributed a better flower yield in wide-spaced crop (Table 8).

Population of *A. besseyi* per 20g of plant parts before spray was also least with the IPM module (M₃) where overnight pre-soaking of bulbs followed by dipping in cartap hydrochloride 50 SP @1000ppm for 4 hrs before planting was practiced. This was followed by the farmers' practice module (M₂) where overnight pre-soaking of bulbs followed by dipping in monocrotophos 36 SL @ 720ppm for 4 hrs before planting was adopted. That is why nematode population before spray was lesser in the modules having bulb treatment than the untreated one. Even after three rounds of spray, much decline in nematode population was not noticed in the farmers' practice module. So, a fourth round of spray with monocrotophos 36 SL @ 360 g *a.i./ha* was given here.

Bulb treatment with cartap hydrochloride 50 SP @1000ppm was found more helpful than the bulb treatment with monocrotophos 36 SL @ 720ppm to keep the nematode population low (Table 14).

Comparative economics of adopted foliar nematode management modules in tuberose over the growing period of 2014-16

The IPM module was much better in increasing the production of flowers and bulbs of tuberose and securing net gain almost double to that of farmers' practice module. The incremental cost benefit ratio was found more in IPM module than the farmers' practice module. The maximum return per rupee investment for managing *A. besseyi* in tuberose was observed with the IPM module being, Rs. 17.84 (Table 15).

Despite more treatment cost high incremental benefit of treatment was obtained in the IPM module of foliar nematode management than the farmers' practice module. The maximization of flower and bulb yields due to adoption of foliar nematode management treatments was observed in the IPM module. That possibly helped to achieve maximum incremental benefit in the IPM module. Farmers' practice module also achieved benefit due to adoption of nematode management protocol but was inferior to that of IPM module. Significant cumulative effect of foliar nematode management module, spacing and variety on the spike length, rachis length, number of nodes/spike

and days to 1st and 100% blooming was not observed in the study. Individually the management module and the variety had shown positive impact on the spike length, rachis length and the number of nodes/spike of tuberose crop. Only variety had significant effect on the days to 1st and 100% blooming of tuberose. Spacings on the other hand revealed non-significant influence on the spike length, rachis length, number of nodes/spike, days to 1st and 100% blooming and number of flowers/spike.

In the present study, spike length, rachis length, number of nodes/spike and flower yield (number and weight basis) were usually observed maximum when widely spaced crop was raised adopting IPM module. The effect was not statistically significant. Widely grown plants harbour less foliar nematode population and also availability of more nutrients to each plant made the spacing superior over narrow-spaced crop.

Kumar *et al.*, (2002) observed increased leaf number, flower production, spike and rachis length from wider spaced (30cm×30cm) bulbs of tuberose cv. Single. Improved flower production and heavier individual florets was observed with wider spaced (30cm×30cm) tuberose plants (Khobragade *et al.*, 1997; Singh and Sangama, 2000; Kumar *et al.*, 2002). The IPM module of foliar nematode management comprising of bulb treatment, field sanitation and prophylactic spraying with nematicides in the present experiment kept the *A. besseyi* population (as judged by the population per 20g of plant parts at different time interval after spray) significantly lower than the farmers' practice module and untreated control. Hence, adoption of IPM module possibly made the crop to achieve good growth and development as judged by the several attributes (spike length, rachis length, number of nodes/spike, flower yields etc.) measured during the course of experimentation.

In conclusion, the IPM module of foliar nematode management comprising of bulb treatment, field sanitation and prophylactic spraying with nematicides in the present experiment kept the *A. besseyi* population significantly lower than the farmers' practice module and untreated control. Hence, adoption of IPM module possibly made

the crop to achieve good growth and development as judged by the several attributes (spike length, rachis length, number of nodes/spike, flower yields etc.) measured during the course of experimentation. The maximum return per rupee investment for managing *A. besseyi* in tuberose was observed with the IPM module being, Rs. 17.84. To enhance the flower yield of tuberose, Calcutta Single cultivar can be planted in 30cm × 25cm spacing adopting IPM module of foliar nematode management. Validation and promotion of developed IPM module of foliar nematode management for the farmers raising tuberose in the Gangetic plains of West Bengal need to be done.

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