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Management of root-knot nematode, *Meloidogyne incognita* infesting fig under field conditions

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Abstract
A statistically designed field experiment with ten treatments including an untreated control replicated thrice in Randomized Block Design was conducted in root- knot nematode infested fig (cv. Poona fig) orchard. All the treatments were significantly superior over an untreated control in reducing root- knot nematode population, number of root galls and egg masses and increasing the yield of fig. However, soil application of carbofuran 3G at 2 kg a.i./ha was found to be most effective in reducing root-knot nematode population (53.66%), number of root galls (50.19%) and number of egg masses (45.36%) at intermediate stage and increasing the fruit yield of fig (37.85%) with 1:17.79 ICBR at termination. This treatment was followed by the treatment of phorate 10 G at 2kg a.i./ ha. The reduction in root- knot nematode population, number of root galls and egg masses and increase in fruit yield recorded in this treatment were 49.46, 50.11, 42.31 and 28.19%, respectively with 1: 33.64 ICBR. While, at termination stage, the treatment of Phule *Trichoderma* plus at 20 kg/ha was found to be most effective in reducing nematode population (40.36%), number of root galls (37.08%) and number of egg masses (41.02%) and increasing the fruit yield of fig (13.54%) with 1: 11.20 ICBR. This was followed by the treatments with rest of the biocontrol agents. The reduction in root- knot nematode population, number of root galls and number of egg masses and increase in fruit yield of fig recorded in these treatments ranged from 32.03 to 38.50, 29.31 to 36.00, 31.90 to 35.97 and 11.54 to 20.75%, respectively with 1: 9.80 to 1: 20.04 ICBR.

Keywords: *Meloidogyne incognita, ficus carica,* bioagents, nematicides, organic amendment, farm yard manure

Introduction
Fig, *Ficus carica* Linn. is a middle sized laticiferous deciduous tree, widely distributed in all tropical and sub-tropical countries. In the world, the total area under fig is 93,000 ha with annual production of 18,02,000 metric tonnes. In India, the total area under fig is 5775 ha with annual production of 63503 metric tonnes. In Maharashtra, it is grown on 2242 ha with annual production of about 7894 metric tonnes (Anonymous, 2017) [3]. Such an important fruit crop is attacked by several insect and non-insect pests as well as diseases caused by phytonematodes. The root-knot nematodes (*Meloidogyne spp.*) are one of them causing considerable yield losses in fig.

The control of root-knot nematodes has been primarily accomplished by the use of chemical nematicides. In the backdrop of hazards imposed by chemical control methods, use of resistant varieties, organic amendments and biocontrol agents can be important components for integrated nematode management. Biological control with microbial agents is now gaining importance as it is an eco-friendly and economically feasible approach and it does not allow the nematodes to develop into new races or biotypes. Keeping in view to the above facts, the present study was planned under field conditions.

The nematicide, carbofuran 3 G at 1 to 6kg a.i./ha was reported to be most effective for the management of root-knot nematodes (*Meloidogyne* spp.) infesting papaya (Ramkrishnan and Rajendran, 1998 [11]; Shrivastava, 2002 [14] and Kumar, 2009 [8]), pomegranate (Siddique and Khan, 1986 [15]; Anomymous, 2014 [2]; Darekar *et al.,* 1989[6] and Tadvi, 2008 [17]), banana (Vyas *et al.,* 2001) [18] and grapevine (Mhase, 2002) [9]. The bioagents, *Pseudomonas fluorescense, Paecilomyces lilacinus and* Phule *Trichoderma* plus were also reported effective for managing the root- knot nematode in grapes (Shanti *et al.,* 1998 [13]; Sundarababu *et al.,* 1999 [16] and Chormule *et al.,* 2017 [4]), acid lime (Rao, 2008) [12] and pomegranate (Pawar *et al.,* 2013 [10] and Walunj, 2013 [19]). The effectiveness of neem cake was also reported in

pomegranate (Kadam, 2014 [7] and Anonymous, 2000 [1]).

Materials and Methods

A statistically designed field experiment was conducted during November, 2017 in naturally root-knot nematode infested fig orchard at All India Co-ordinated Research Project on Arid Zone Fruit Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, and Rahuri. The granular nematicide (carbofuran 3G, phorate 10G and cartap hydrochloride 4G), bioagents (*Pseudomonas fluorescens, Paecilomyces lilacinus, Trichoderma viride,* Phule *Trichoderma* plus *and Pochonia chlamydosporium*) and organic amendment (neem cake) were assessed as soil application for the management of root- knot nematode infesting fig (cv. Poona fig). There were ten treatments including an untreated control replicated thrice in Randomized Block Design. The initial, intermediate and at termination, sampling of the soil and roots with the help of soil auger at 30 to 60cm depth was done from the individual treatment from the field to count the root-knot nematode population, root galls and egg masses. The 200g of composite soil and root samples were collected from each treatment at the time of each observation. The soil samples were processed by Cobb's Decanting and Sieving Method (Cobb, 1918) [5]. The residues of 350 mesh sieves were collected in plastic beaker and kept on wire mess fitted with double layer of tissue paper, put on petri dish containing half-filled water for nematode isolation. For nematode count, the average of 10 counts of 1ml suspension was recorded after thorough mixing and from it was calculated to 200ml of suspension. The 5g roots collected at the time of each observation were washed under clean tap water to remove the adhering soil particles to the roots. Number of root galls and egg masses on roots were recorded. From these observations, per cent decrease in root galls and egg masses over an untreated control were worked out. To count egg masses easily, staining of galled roots was done by dipping the galled roots in 1.0% solution of trypan blue for 2 minutes. After dipping, the roots were washed carefully with tap water to remove the stain of the roots. The fig fruit yield was obtained from the individual tree of each treatment in the field at termination and expressed in tonnes/ha. From these observations, the per cent increase in the fruit yield over an untreated control were ascertained. The data obtained were subjected to statistical analysis and the analysis of variance was done to find out the significance of difference in different treatments.

Results and Discussion

It could be seen from the Table 1 to 4 and fig 1 to 3 that all the treatments were significantly superior over an untreated control in reducing the root-knot nematode population, number of root galls and egg masses at intermediate (three months after application) and termination stage of the crop and increasing the fruit yield at termination of the experiment. However, at intermediate stage soil application of carbofuran 3G at 2 kg a.i./ha was found to be most effective than other treatments in reducing the root-knot nematode population (53.66%), number of root galls (50.19%) and egg masses (45.36%) and increasing the fruit yield (37.85%) with 1:17.79 ICBR at termination. This was followed by the treatment of phorate 10G at 2 kg a.i./ha. The reduction in root- knot nematode population, number of root galls and egg masses and increase in fruit yield recorded in this treatment were 49.46, 50.11, 42.16 and 28.19%, respectively with 1:33.64 ICBR.

While, at termination stage the treatment of Phule *Trichoderma* plus at 20 kg/ha was found to be most effective in reducing the root- knot nematode population (40.36%), number of root galls (37.08%) and egg masses (41.02%) and increasing the fruit yield (13.54%) with 1:11.20 ICBR. This was followed by the treatments with rest of the bioagents. The reduction in root- knot nematode population, number of root galls and egg masses and increase in fruit yield recorded in these treatments ranged from 32.03 to 38.50, 29.71 to 36.00, 32.26 to 35.97 and 11.54 to 20.75%, respectively with 1:9.80 to 20.04 ICBR.

The results of the present investigation are in agreement with the findings of Ramkrishnan and Rajendran (1998) [11], Shrivastava (2002) [14] and Kumar (2009) [8] who, also reported soil application of carbofuran 3G at 1 kg a.i./ha before planting and at flowering in papaya in reducing root-knot nematode population and increasing the fruit yield from 18.7 to 59.8 kg/plant. The results obtained under study are in line with Siddique and Khan (1986) [15], Anonymous (2014) [2], Darekar *et al.* (1989) [6] and Tadavi (2008) [17] in pomegranate where, soil application of carbofuran 3 G at 1 to 6 kg a.i./ha was found to be most effective in reducing root-knot nematode population and increasing the fruit yield from 18.38 to 52.00%. Significantly lowest root-knot index (1.8) with higher plant height (18 feet) and maximum fruit yield of banana (42.02 t/ha) were also reported by Vyas *et al.* (2001) [18] with soil application of carbofuran 3G at 1 kg a.i./ha at planting of banana. Similarly, soil application of carbofuran 3G at 2 to 4 kg a.i./ha at October pruning in grapevine was reported to be most effective in reducing root- knot nematode population (53.90 to 54.32%) and number of root galls (36.60 to 45.80%) and increasing the yield (27.20 to 33.90%) by Mhase (2002) [9] and Chormule *et al.;* (2017) [4].

Shanthi *et al.* (1998) [13] reported *Pseudomonas fluorescens at* 4g/vine (15 $\times 10^8$ cfu/g) at the time of pruning in grapevine effective in reducing root- knot nematode root galling (39%) and number of egg masses (250%) and increasing fruit yield (166%). Soil application of *Pseudomonas fluorescens* at 20 kg/ha at October pruning in grapevine was found to be most effective in reducing root- knot nematode population (38.6%), number of root galls (26.1%) and number of egg masses (28.8%) and increasing the fruit yield of grapes (27.2%) with 1:18.37 ICBR at termination by Chormule *et al.* (2017) [4]. Effectiveness of soil application of *P. fluorescens* @ 20 kg/ ha at 'Bahar' in pomegranate in reducing the root- knot nematode population (31.28%) and number of root galls (29.28%) and increasing the fruit yield of pomegranate (18.99%) was reported by Pawar *et al.* (2013) [10]. Walunj (2013) [19] also reported split application of Phule *Trichoderma* plus (10 kg/ha each at Bahar and 90 days after Bahar) for the control of root-knot nematode in pomegranate. The reduction in root-knot nematode population, number of root galls and egg masses and increase in fruit yield recorded in this treatment at termination were 31.4, 37.53, 22.86 and 57.77%, respectively with 1: 24.20 ICBR.

Conclusion

Soil application of carbofuran 3G at 2 kg a.i./ha was found to be effective in reducing the root-knot nematode population (53.66%), number of root galls (50.19%) and egg masses (45.36%) at intermediate and increasing the fruit yield (37.85%) with 1.17.79 ICBR at termination stage of the crop. While, at termination stage of the crop, the treatment of Phule *Trichoderma* plus at 20 kg/ha was found to be most effective in reducing the root- knot nematode population (40.36%),

number of root galls (37.08%) and egg masses (41.02%) and increasing the fruit yield of fig (13.54%) with 1: 11.20 ICBR.

Table 1: Effect of different treatments on soil population of root-knot nematode, *M. incognita* infesting fig.

Sr. No	Treatments	Root-knot nematode population (J_2)/ 200 cm^3 of soil			Decline in RKN population (%)*	
		Initial	Intermediate	Termination	Intermediate	Termination
1	*Pseudomonas fluorescens* @ 20 kg/ha	520.00	273.33	333.33	47.53 (43.58)	35.49 (36.57)
2	*Paecilomyces lilacinus* @20 kg/ha	520.00	333.33	320.00	35.83 (36.77)	38.50 (38.35)
3	*Trichoderma viride* @20 kg/ha	540.00	333.33	366.67	38.22 (38.18)	32.03 (34.47)
4	Phule *Trichoderma* plus @20 kg/ha	493.33	306.67	293.33	37.70 (37.88)	40.36 (39.44)
5	*Pochonia chlamydosporium* @20 kg/ha	446.67	280.00	300.00	36.98 (37.45)	32.67 (34.86)
6	Phorate 10G @2 kg a.i./ha	580.00	293.33	433.33	49.46 (44.69)	25.23 (30.15)
7	Carbofuran 3G @2 kg a.i./ha	606.67	280.00	453.33	53.66 (47.10)	25.06 (30.04)
8	Cartap hydrochloride 4G @2 kg a.i./ha	500.00	260.00	380.00	47.89 (43.79)	23.87 (29.24)
9	Neem cake @2 t/ha	546.67	333.33	380.00	38.87 (38.57)	30.52 (33.53)
10	Untreated control	460.00	526.67	573.33	0.00 (0.00)	0.00 (0.00)
S. E. (±)		12.23	14.89	16.91	2.03	1.96
C. D. at 5%		NS	44.24	50.25	6.08	5.84

*Figures in parentheses are arc sin transformed values

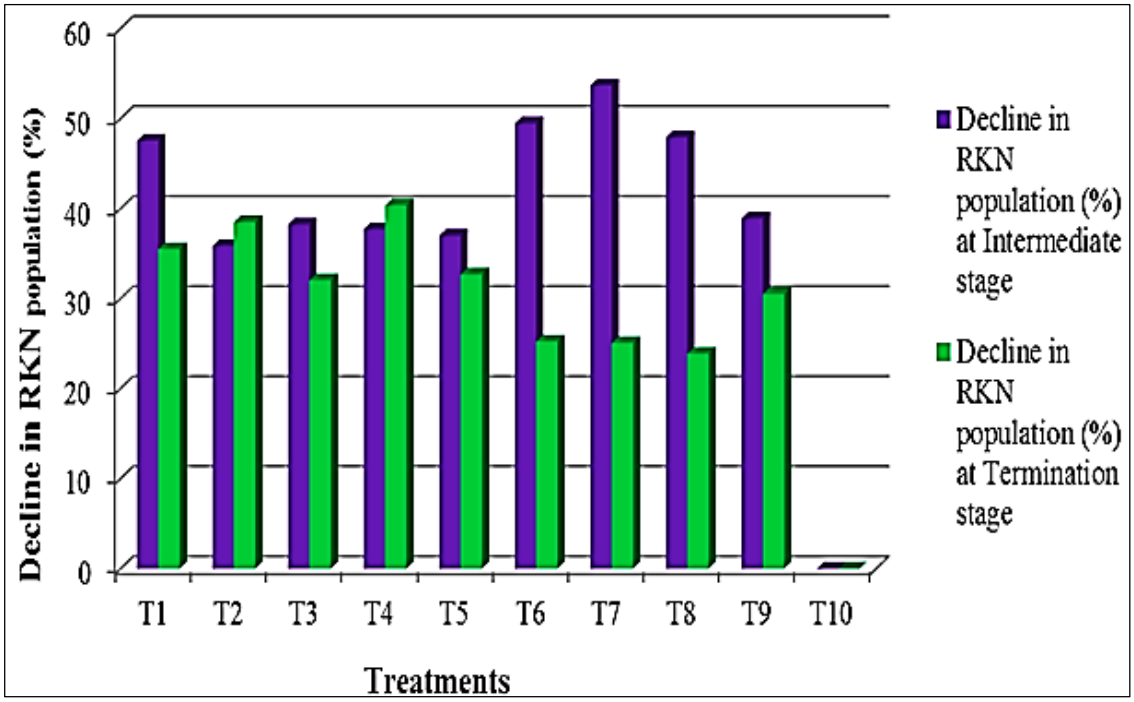

Fig 1: Effect of different treatments on soil population of root-knot nematode, *M. incognita* infesting fig.

Table 2: Effect of different treatments on number of root galls of root-knot nematode, *M. incognita* infesting fig.

Sr. No	Treatments	Number of root galls/5 g roots			Decline in root galls (%)*	
		Initial	Intermediate	Termination	Intermediate	Termination
1	*Pseudomonas fluorescens* @ 20 kg/ha	23.00	13.00	15.00	43.25 (41.12)	33.95 (35.64)
2	*Paecilomyces lilacinus* @ 20 kg/ha	24.00	15.33	15.33	35.60 (37.76)	36.00 (36.87)
3	*Trichoderma viride* @ 20 kg/ha	28.44	17.67	20.00	37.34 (37.67)	29.71 (33.06)
4	Phule *Trichoderma* plus @ 20 kg/ha	20.67	13.67	13.00	33.66 (35.46)	37.08 (37.51)
5	*Pochonia chlamydosporium* @ 20 kg/ha	20.67	15.33	14.00	25.73 (30.48)	32.08 (34.50)
6	Phorate 10 G @ 2 kg a.i./ha	26.00	13.00	19.00	50.11 (45.06)	26.38 (30.90)
7	Carbofuran 3 G @ 2 kg a.i./ha	26.00	12.67	19.00	50.19 (45.11)	26.74 (31.14)
8	Cartap hydrochloride 4 G @ 2 kg a.i./ha	23.33	12.67	18.33	47.93 (42.09)	20.92 (27.22)
9	Neem cake @ 2 t/ha	23.00	14.00	16.00	39.11 (38.71)	29.69 (33.02)
10	Untreated control	24.00	30.00	37.33	0.00 (0.00)	0.00 (0.00)
S. Em. (±)		2.23	1.81	1.67	1.98	1.80
C. D. at 5%		NS	5.38	4.97	5.91	5.30

*Figures in parentheses are arc sin transformed values

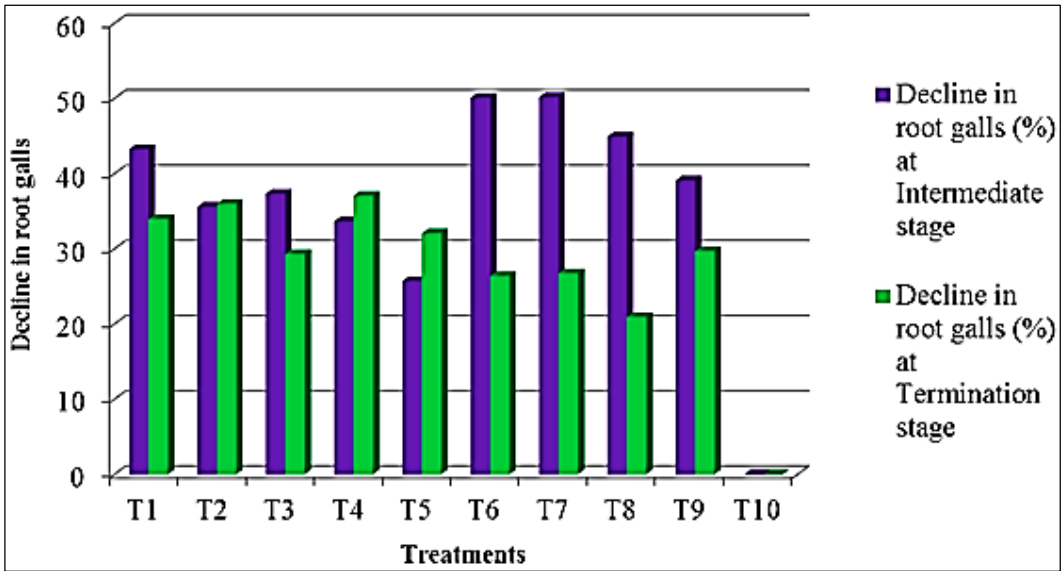

Fig 2: Effect of different treatments on number of root galls of root-knot nematode, *M. incognita* infesting fig.

Table 3: Effect of different treatments on number of egg masses of root-knot nematode, *M. incognita* infesting fig and fruit yield at termination.

Sr. No	Treatments	Number of egg masses/5 g roots			Decline in egg masses (%)*		Yield (t/ha)**
		Initial	Intermediate	Termination	Intermediate	Termination	
1	*Pseudomonas fluorescens* @ 20 kg/ha	17.00	10.67	11.22	38.06 (38.09)	33.74 (35.51)	10.88 (20.75)
2	*Paecilomyces lilacinus* @ 20 kg/ha	19.33	13.00	12.33	32.19 (34.57)	35.97 (36.85)	10.38 (15.21)
3	*Trichoderma viride* @ 20 kg/ha	20.67	14.00	14.00	32.56 (34.79)	32.26 (34.61)	10.05 (11.54)
4	Phule *Trichoderma* plus @ 20 kg/ha	21.33	13.33	12.67	36.97 (37.45)	41.02 (39.83)	10.23 (13.54)
5	*Pochonia chlamydosporium* @ 20 kg/ha	21.33	14.33	14.33	32.36 (34.61)	32.92 (35.01)	10.09 (11.99)
6	Phorate 10 G @ 2 kg a.i./ha	17.33	10.00	12.67	42.61 (40.75)	26.44 (30.94)	11.55 (28.19)
7	Carbofuran 3 G @ 2 kg a.i./ha	17.00	9.00	12.89	45.36 (42.34)	23.77 (29.18)	12.42 (37.85)
8	Cartap hydrochloride 4 G @ 2 kg a.i./ha	17.33	10.33	13.00	39.60 (39.00)	24.95 (29.97)	11.10 (23.20)
9	Neem cake @ 2 t/ha	16.00	10.67	10.67	32.92 (35.01)	31.90 (34.39)	10.97 (21.75)
10	Untreated control	20.00	23.33	27.67	0.00 (0.00)	0.00 (0.00)	9.01 (0.00)
S. Em. (±)		1.65	1.21	1.23	1.44	1.93	0.72
C.D. at 5%		NS	3.62	3.67	4.30	5.95	2.15

*Figures in parentheses are arc sin transformed values
** Figures in parentheses are per cent increase in yield over an untreated control.

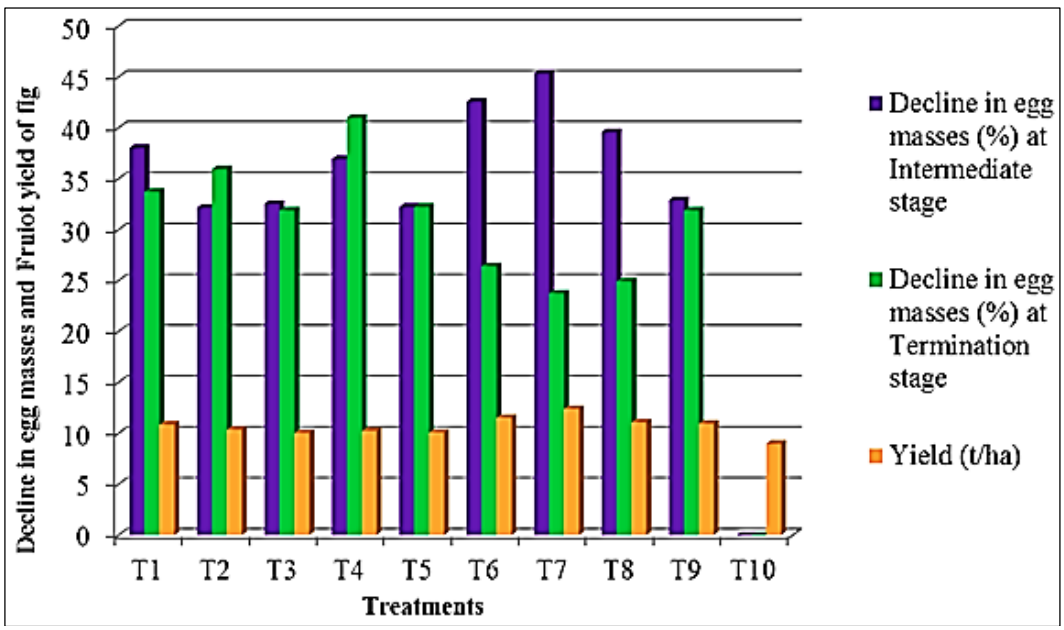

Fig 3: Effect of different treatments on number of egg masses of root-knot nematode, *M. incognita* infesting fig and fruit yield at termination.

Table 4: Effect of different treatments on incremental cost benefit ratio of fig

Sr. No.	Treatments	Yield (t/ha)	Additional yield over untreated control (t/ha)	Gross profit (Rs/ha)	Additional Profit (Rs/ha)	Cost of treatment & Labour charges (Rs/ha)	Net profit (Rs/ha)	ICBR
1	*Pseudomonas fluorescens* @ 20 kg/ha	10.88	1.87	489600	84150	4000	80150	1:20.04
2	*Paecilomyces lilacinus* @ 20 kg/ha	10.38	1.37	467100	61650	4000	57650	1:14.41
3	*Trichoderma viride* @ 20 kg/ha	10.05	1.04	452250	46800	4000	42800	1:10.70
4	Phule *Trichoderma* plus @ 20 kg/ha	10.23	1.22	460350	54900	4500	50400	1:11.20
5	*Pochonia chlamydosporium* @ 20 kg/ha	10.09	1.08	454050	48600	4500	44100	1:9.80
6	Phorate 10 G @ 2 kg a.i./ha	11.55	2.54	519750	114300	3300	111000	1:33.64
7	Carbofuran 3 G @ 2 kg a.i./ha	12.42	3.41	558900	153450	8167	145283	1:17.79
8	Cartap hydrochloride 4 G @ 2 kg a.i./ha	11.10	2.09	499500	94050	5500	88550	1:16.10
9	Neem cake @ 2 t/ha	10.97	1.96	493650	88200	15500	72700	1:4.69
10	Untreated control	9.01		405450				

Market rates

1. *P. fluorescens, P. lilacinus* and *T. viride* @ Rs. 125/kg
2. Phule *Trichoderma* plus and *P. chlamydosporium* @ 150/kg
3. Phorate 10 G @ Rs. 90/kg
4. Carbofuran 3 G @ Rs. 100/kg
5. Cartap hydrochloride 4 G @ Rs. 80/kg
6. Neem cake @ Rs. 700/q
7. Fig fruit yield @ Rs. 45000/t
8. Labour charges @ Rs. 1500/ha.

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