MANAGEMENT OF RENIFORM NEMATODE ON COWPEA, *VIGNA UNGUICULATA*

A.K. Mukhopadhyay[1] and K. Roy

Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya P.O., Krishi Viswavidyalaya – 741 252, Nadia, West Bengal, India

Summary. Experiments to control the reniform nematode, *Rotylenchulus reniformis*, in cowpea, *Vigna unguiculata*, were conducted in two consecutive years. Two formulations of carbosulfan for seed dressing (3% a.i. w/w) and seed soaking (0.1% a.i. for four hours), and soil applications of carbofuran 3G (1 kg a.i./ha) and neem cake (1,000 kg/ha at planting), were tested as either single or combined treatments. In general, increase of yield and number of *Rhizobium* nodules/plant and reduction of nematode egg mass index, root and soil populations were greater in the combined treatments than in the single applications. The greatest performance was obtained by dressing the seeds with carbosulfan at 3% a.i. w/w and applying neem cake at 1,000 kg/ha at planting. Negative correlations were observed between egg mass index, root and soil populations of the nematode and all growth indicators and yield. The largest gain was obtained from dressing the seeds with carbosulfan (3% a.i. w/w) and applying 1,000 kg neem cake/ha at planting, while the ratio between additional benefit and treatment cost was greatest from soaking the seeds in 0.1% carbosulfan.

Key words: Carbosulfan, carbofuran, *Rotylenchulus reniformis*, control.

Cowpea, *Vigna unguiculata* (L.) Walp., is a grain legume grown in the tropics and subtropics, with the majority grown in West and Central African countries and the Americas (Brazil, U.S.A.). It has the ability to tolerate drought and can fix atmospheric nitrogen, which allows it to grow on, and improve, poor soils. Cowpea can fix up to 88 kg N/ha (Fatokum *et al.*, 2000) and in an effective cowpea-rhizobium symbiosis more than 150 kg/ha of nitrogen is fixed, which can supply 80-90% of plants' total nitrogen requirement. FAO (2006) estimated that the twenty highest producing countries produced nearly 3.9 and 4.3 million tonnes of cowpea dry grains from 8.6 and 8.9 million hectares in 2004 and 2005 respectively. The crop is cultivated around the world primarily for seed and fodder production, but also as a vegetable (for leafy greens, green pods, fresh shelled green peas, and shelled dried peas) and a cover crop. Cowpea seeds are a rich source of protein, vitamins and minerals. Root-knot (*Meloidogyne* spp.) and reniform (*Rotylenchulus reniformis* Linford *et* Oliveira) nematodes are the major constraints to cowpea cultivation in India and other parts of the world (Singh and Khera, 1978; Sikora *et al.*, 2005). Cowpea cultivars resistant to root-knot nematodes have been selected and are used successfully in areas infested with these pests (Fery *et al.*, 1994; Roberts *et al.*, 1998). However, there is no cowpea cultivar resistant to the reniform nematode. This pest is widely distributed and damages many crops belonging to different botanical families (Robinson *et al.*, 1997). In India, *R. reniformis* has been reported from almost all vegetable growing tracts of the country and crop losses caused to cowpea were estimated to be of 10% (Anonymous, 2004). Cowpea genotypes have been found to be good hosts for *R. reniformis* in India (Rao and Ganguly, 1996) but there is morphological variation in reniform nematode populations from different parts of the country (Rao and Ganguly, 1998). Mohanty *et al.* (1999) and Patel *et al.* (2003) investigated the damage potential of the nematode for cowpea varieties in India. Experiments using nematicides like aldicarb 10G and carbofuran 3G (Rathore, 1995), fenamiphos 35 EC, monocrotophos SL (Rathore and Yadav, 1996) or aqueous extracts of neem and karanj seed kernel (Ram and Baheti, 2004) have sought to provide management options for the nematode in India.

Nevertheless, the efforts to solve this problem have been scanty. Moreover, the use of toxic chemicals in a fodder or vegetable crop could pose serious problems. Therefore, an experiment was undertaken on the management of reniform nematodes in cowpea with the aim of reducing the use of chemicals through different methods of application. The efficacy of neem cake as a substitute for chemicals or in combination with low dosages of chemicals was also investigated, and the economics of different reniform nematode management methods in cowpea were worked out.

MATERIALS AND METHODS

Two trials were conducted during August-November in 2003 and 2004 in a field severely and uniformly in-

* Corresponding author e-mail: akm_ento@rediffmail.com

fested with 605 and 708 immature females of *R. reniformis*/200 cm^3 soil in 2003 and 2004, respectively, at Nadia, West Bengal, India. The field was located at 23 °N latitude, 89 °E longitude and 9.75 m above sea level. The soil was a typical alluvial soil (Entisol) having a sandy clay loam texture with good drainage, slightly acidic pH and moderate fertility. Environmental conditions during the experiment were 14.5-35.2 °C and 16.7-33.8 °C monthly air temperature, 23.2-31.5 °C and 22.6-31.1 °C monthly rhizospheric temperature at 15 cm depth, 61.3-98.5% and 68-92% monthly relative humidity, 3.5-172.8 mm and 1.2-324.1 mm monthly rainfall in 2003 and 2004, respectively.

The field was divided into 36 plots, each of 6 m^2 (3 m × 2 m) and which received the same treatments in both years. For estimating initial population of nematodes, three composite samples, each consisting of nine subsamples covering the entire experimental area, were collected just before land preparation on the same day and kept in the laboratory at room temperature for 7 days, to allow hatching of the eggs present in the soil and moulting of the inactive 3^{rd} and 4^{th} stage juveniles to motile vermiform adult stages (Muraellidharan and Sivakumar, 1975). Then the soil samples (200 cm^3 from each of the composite samples) were processed according to Cobb's decanting and sieving technique combined with a modified Baermann's funnel method (Christie and Perry, 1951). Nematodes (only the immature females) in water suspension were counted using a stereo microscope and the results expressed as vermiform females/200 cm^3 soil. Nitrogen, phosphorus and potassium fertilizers were applied at the rate of 20 : 50 : 50 kg/ha. Seeds of a popular local variety of cowpea were sown at 15 kg/ha in rows, at a spacing of 50 cm × 15 cm, in the afternoon.

There were eight treatments and an untreated check (Tables I-III), each replicated four times according to a randomized block design. The field was irrigated lightly after application of nematicides to soil. Seed soaking and seed dressing treatments were made early in the morning of the sowing dates (30.8.2003 and 11.8.2004). Cowpea seeds were dipped in an adequate volume of carbosulfan 25EC at 0.1% a.i., allowed to soak for four hours, and then dried in the shade. For the purpose of seed dressing, seeds were mixed thoroughly with a paste, made up of carbosulfan 25DS at 3.0% a.i. w/w and a small quantity of synthetic glue, so that each seed was covered by the paste. The seeds were then dried in the shade. The neem cakes were thoroughly mixed with the soil of the plots at the time of plot preparation while carbofuran 3G granules were broadcast and incorporated into the soil around the root zone of the plants three weeks after sowing.

The crop was grown following recommended practices in both years. Pods were plucked between 22.10.03-08.11.03 and 15.10.04-09.11.04. Yields (pod weight/plot) were recorded as plucking proceeded. At the time of last pod harvest, plant growth parameters were recorded of ten plants from each of the treated and untreated plots and expressed as fresh and dry shoot and root weight (g)/plant. Healthy *Rhizobium* nodules were counted with the naked eye and, if necessary, with the help of a stereo microscope. To evaluate the effects of the treatments on the final nematode levels, roots of another ten plants and soil cores from around them were collected randomly from each plot after plant harvest. Soil samples collected from each of the plots were mixed separately and a 200 cm^3 aliquot processed for nematode extraction. Final soil nematode densities were assessed as mentioned earlier. The roots were washed free of soil and egg mass index was rated according to a 1-9 scale [1 = 0 egg mass/plant, 2 = 1-5, 3 = 6-10, 4 = 11-15, 5 = 16-20, 6 = 21-30, 7 = 31-40, 8 = 41-50 and 9 = >50 egg masses (Sharma, 1995)]. Root populations of nematodes, both immobile and vermiform stages, were assessed after differential staining by the NaOCl - acid fuchsin method (Byrd *et al.*, 1983).

Data were analyzed and means were compared according to Duncan's Multiple Range Test at the 5% level of probability. The data for the two years were also subjected to correlation analysis.

An economic analysis was also made. The value of the yield increase over the control and the cost of the treatments were estimated based on prices in the local market. From this information, the yield gain/treatment cost ratios were calculated.

RESULTS AND DISCUSSION

Greatest fresh shoot weight gains over the untreated check were recorded for T_7, seed dressing with carbosulfan 25 DS at 3% a.i. w/w + neem cake, 1000 kg/ha at planting, in both years, followed by T_8 (Table I). The latter treatment also produced the greatest dry shoot weight in 2003. Treatment T_2 gave the greatest fresh root weight in 2003, but this was not significantly greater than that of T_4, T_7 and T_8 (Table I). But, in 2004, the greatest fresh root weight was produced by T_8 (Table I). Rathore (2000) compared the efficacy of carbosulfan 25 ST (= carbosulfan 25 DS) and carbofuran 35 SD in managing reniform nematodes through seed dressing and concluded that carbofuran 35 SD at 6% a.i. w/w was best at improving plant growth indicators of cowpea. In contrast, in our experiment, seed dressing with the lower rate of carbosulfan 25 DS (3% a.i. w/w) was the most effective treatment when combined with neem cake, 1,000 kg/ha at planting, as it increased fresh shoot weight by 2.9 and 3.0 times and fresh root weight by 1.3 and 1.5 times in 2003 and 2004, respectively.

The number of healthy *Rhizobium* nodules was increased by most of the treatments in 2003 while only T_1, T_7, and T_8 increased it in 2004 (Table II). The yield was not affected by any of the treatments in 2003, but in 2004 most of the treatments, especially those that received a combination of them, increased it by 27.3-

Table I. Effects of the treatments on shoot and root weight of cowpea (averages of four replicates) in fields infested with *Rotylenchulus reniformis*.

Treatment	Fresh shoot weight/plant (g)		Dry shoot weight/plant (g)		Fresh root weight/plant (g)		Dry root weight/plant (g)	
	2003	2004	2003	2004	2003	2004	2003	2004
T_1: Carbofuran 3G at 1 kg a.i./ ha 3 WAS[1]	85.7 d*	85.3 cd	21.2 ab	15.0 ab	11.6 cd*	11.2 b	2.0 bc	1.6 b
T_2: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w	111.4 c	117.3 bc	24.2 a	16.8 ab	15.7 a	11.4 b	2.3 abc	2.3 ab
T_3: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs	110.3 c	102.7 cd	22.3 ab	18.4 ab	13.3 bc	13.6 ab	2.3 abc	2.2 ab
T_4: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w + carbofuran 3G at 1 kg a.i./ha 3 WAS	137.6 b	128.8 abc	22.9 ab	18.6 ab	14.6 ab	14.1 ab	2.8 a	2.8 a
T_5: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs +carbofuran 3G at 1 kg a.i./ha 3 WAS	144.1 b	135.3 abc	22.8 ab	19.8 ab	12.8 bcd	14.7 ab	2.2 abc	2.1 ab
T_6: Neem cake, 1000 kg/ha at planting	126.0 bc	101.6 cd	19.4 ab	17.9 ab	12.7 bcd	13.0 ab	2.3 abc	2.1 ab
T_7: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w + neem cake, 1000 kg/ha at planting	194.1 a	176.9 a	24.8 a	21.5 a	14.0 ab	16.1 ab	2.4 ab	2.8a
T_8: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs + neem cake, 1000 kg/ha at planting	179.8 a	171.1 ab	24.9 a	20.6 ab	14.0 ab	16.7 a	2.4 ab	2.7 a
T_9: Untreated Control	67.1 d	58.3 d	17.6 b	13.2 b	10.5 d	10.9 b	1.7 c	1.7 b
S. Em[2] ±	6.5	17.6	1.9	2.2	0.7	1.6	0.2	0.2
C.D. $_{\text{at } 0.05}$	19.0	51.5	5.6	6.4	2.1	4.6	0.6	0.7

* Figures marked by a common letter are not significantly different according to Duncan's Multiple Range Test at P < 0.05.
[1] WAS = Weeks after sowing; [2] S. Em = Standard error of the treatment means.

Table II. Effects of treatments on numbers of *Rhizobium* nodules and yield of cowpea (averages of four replicates) in fields infested with *R. reniformis*.

Treatment	*Rhizobium* nodules/plant		Yield (kg/plot)	
	2003	2004	2003	2004
T_1: Carbofuran 3G at 1 kg a.i./ ha 3 WAS[1]	15.6 bc*	13.4 a	2.4	2.0 bc
T_2: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w	22.5 a	7.6 ab	2.6	2.5 ab
T_3: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs	15.8 bc	7.3 ab	2.6	2.2 abc
T_4: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w + carbofuran 3G at 1 kg a.i./ha 3 WAS	20.3 ab	7.8 ab	2.8	2.6 a
T_5: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs +carbofuran 3G at 1 kg a.i./ha 3 WAS	21.1 a	9.3 ab	2.5	2.7 a
T_6: Neem cake, 1000 kg/ha at planting	23.0 a	8.4 ab	2.2	2.5 ab
T_7: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w + neem cake, 1000 kg/ha at planting	21.4 a	13.4 a	2.7	2.8 a
T_8: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs + neem cake, 1000 kg/ha at planting	23.9 a	8.8 a	2.7	2.8 a
T_9: Untreated Control	13.6 c	5.7 b	2.2	1.9 c
S.Em[2] ±	1.6	1.8	0.2	0.2
C.D. $_{\text{at } 0.05}$	4.7	5.4	NS	0.5

* Figures marked by a common letter are not significantly different according to Duncan's Multiple Range Test at $P < 0.05$.
[1] WAS = Weeks after sowing; [2] S. Em = Standard error of the treatment means.

47.4% (Table II). *Rhizobium* nodulation in leguminous crop plays an important role in the fixation of atmospheric nitrogen and thereby contributes importantly to increased yield. In 2004, the number of *Rhizobium* nodules per plant was less than in 2003 and this might have affected the yield of the crop in 2004. The data on both yield and number of *Rhizobium* nodules per plant in the two years clearly showed that the combined treatments performed better than the single treatments, except for that of neem cake on nodule formation.

In both years, the final egg mass index and nematode population in roots were significantly reduced by T_1, T_4, T_5, T_7 and T_8 (Table III). These treatments, along with treatment T_2, also significantly suppressed the soil populations of *R. reniformis* in both years (Table III). In each case, seed dressing with carbosulfan 25 DS at 3% a.i. w/w + neem cake at 1,000 kg/ha at planting was the best treatment. These results corroborate the findings of Shekhar *et al.* (1996), who reported reductions of egg mass index and soil population of reniform nematodes of 64% and 71%, respectively, through seed dressing with carbosulfan 25 ST (= carbosulfan 25 DS). However, these workers mentioned that carbosulfan 25 DS at 3% a.i. w/w did not show improved plant growth because there was a phytotoxic effect at this concentration. In the present investigation, no such effect was noticed in the field. Possible reasons for this difference might be differences in variety used or variation in climatic conditions during the time of the experiment. Chemical nematicides, *viz.* carbofuran and carbosulfan, were probably found to be effective in suppressing nematode multiplication because the population was reduced to a very low density within a short period. Panda and Shesadri (1979) mentioned that the combination of seed treatment followed by application of granular nematicides gave the best control of *Rotylenchulus reniformis*. Our trial agrees with these findings. It was surprising that, in this study, neem cake alone failed to reduce the nematode population. Our observation differs from those of several workers (Rathore, 1994; Anjum *et al.*, 1996; Anver and Alam, 1996). The reasons perhaps lie in the slow decomposition of neem cake and slow release of its toxic principles to the soil solution to become effective against nematodes (Gaur and Mishra, 1989). When chemical nematicides were used in combination with neem cake, they performed better in improving plant growth and reducing the nematode population. This probably occurred because the chemicals provided important early protection against the nematodes, at the time of the latent period of decomposition of the organic matterials; thereafter, the neem cake began to control the nematode. The bitter principles of neem cake, *viz.* nimbidin and thionimone, were very toxic to nematodes and caused much mortality (Khan *et al.*, 1974). The roots of the emerging seedlings might have absorbed some of the degradation products of

Table III. Effects of treatments on egg-mass index, soil and root population of *R. reniformis* in cowpea (averages of four replicates).

Treatment	Egg-mass Index*		Population of *R. reniformis*/ g of root**		Population of *R. reniformis*/200 cm^3 of soil***	
	2003	2004	2003	2004	2003	2004
T_1: Carbofuran 3G at 1 kg a.i./ ha 3 WAS[1]	3.0 bc****	1.6 bc	29.8 bcde	24.8 c	723.2 b	513.8 b
T_2: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w	3.3 abc	2.0 abc	33.3 abcd	26.8 bc	768.0 b	566.7 b
T_3: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs	3.3 abc	2.1 abc	37.0 abc	27.5 bc	1043.3 a	560.8 b
T_4: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w + carbofuran 3G at 1 kg a.i./ha 3 WAS	2.8 bc	1.4 c	25.8 de	23.3 c	603.0 bc	492.7 b
T_5: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs +carbofuran 3G at 1 kg a.i./ha 3 WAS	2.8 bc	1.6 bc	27.0 cde	28.0 bc	689.1 b	563.5 b
T_6: Neem cake, 1000 kg/ha at planting	3.8 ab	2.6 ab	39.5 ab	35.5 b	1057.0 a	872.0 a
T_7: Seed dressing with carbosulfan 25DS at 3.0% a. i. w/w + neem cake, 1000 kg/ha at planting	2.0 c	1.1 c	15.8 f	18.0 c	408.7 d	328.7 b
T_8: Seed soaking with carbosulfan 25EC at 0.1% a.i. for 4 hrs + neem cake, 1000 kg/ha at planting	2.5 bc	1.3 c	21.0 ef	21.5 c	495.9 cd	446.8 b
T_9: Untreated Control	4.5 a	3.0 a	43.0 a	47.5 a	1131.1 a	1015.0 a
S.Em[2] ±	0.4	0.3	3.2	3.2	54.3	72.0
C.D. $_{\text{at } 0.05}$	1.2	0.9	9.4	9.3	158.4	210.2

* Egg-mass Index : 1 = 0 egg mass/plant, 2 = 1-5, 3 = 6-10, 4 = 11-15, 5 = 16-20, 6 = 21-30, 7 = 31-40, 8 = 41-50 and 9 = >50 egg masses.
** Females (both immobile and vermiform stages).
*** Initial nematode population was 605/200 cm^3 of soil in 2003 and 708/200 cm^3 of soil in 2004.
**** Figures marked by a common letter are not significantly different according to Duncan's Multiple Range Test.
[1] WAS = Weeks after sowing; [2] S. Em = Standard error of the treatment means.

Table IV. Correlations between shoot and root weight, *Rhizobium* nodule, egg mass index, nematode population in soil and root and yield of cowpea in 2003.

Variable	Correlation coefficient (r)								
	(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)	(X_8)	(X_9)
X_1	1								
X_2	0.765817*	1							
X_3	0.55808	0.809592*	1						
X_4	0.596991	0.620113	0.751553*	1					
X_5	0.750835*	0.612615	0.702689*	0.525968	1				
X_6	-0.83587*	-0.88632*	-0.56586	-0.62702	-0.51683	1			
X_7	-0.84939*	-0.82908*	-0.47791	-0.5332	-0.50593	0.958571*	1		
X_8	-0.78485*	-0.83485*	-0.5288	-0.52684	-0.53633	0.92368*	0.980696*	1	
X_9	0.644083	0.915419*	0.803438*	0.783767*	0.407792	-0.82395*	-0.76199*	-0.76685*	1

* Significant at $P < 0.05$.
N.B. X_1 - Fresh shoot weight/plant (g), X_2 - Dry shoot weight/plant (g), X_3 - Fresh root weight/plant (g), X_4 - Dry root weigh/plant (g), X_5 - Effective nodule/plant, X_6 - Egg-mass Index, X_7 - Population of *R. reniformis*/ g of root, X_8 - Population of *R. reniformis*/ 200 cm^3 of soil, X_9 - Yield (kg/plot).

Table V. Correlations between shoot and root weight, *Rhizobium* nodule, egg mass index, nematode population in soil and root and yield of cowpea in 2004.

Variable	Correlation coefficient (r)								
	(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)	(X_8)	(X_9)
X_1	1								
X_2	0.933862*	1							
X_3	0.906998*	0.937073*	1						
X_4	0.839336*	0.77909*	0.768499*	1					
X_5	0.406888	0.327431	0.266114	0.071652	1				
X_6	-0.82464*	-0.72235*	-0.69268*	-0.64568	-0.65532	1			
X_7	-0.80181*	-0.73863*	-0.63361	-0.65939	-0.63706	0.947972*	1		
X_8	-0.78514*	-0.70449*	-0.62198	-0.62056	-0.62903	0.960515*	0.980577*	1	
X_9	0.906553*	0.904405*	0.810954*	0.807334*	0.216537	-0.64557	-0.65048	-0.58074	1

* Significant at $P < 0.05$.
N.B. X_1 - Fresh shoot weight/plant (g), X_2 - Dry shoot weight/plant (g), X_3 - Fresh root weight/plant (g), X_4 - Dry root weigh/plant (g), X_5 - Effective nodule/plant, X_6 - Egg-mass Index, X_7 - Population of *R. reniformis*/ g of root, X_8 - Population of *R. reniformis*/ 200 cm^3 of soil, X_9 - Yield (kg/plot).

Table VI. Economics of treatments tested for the management of *R. reniformis* in cowpea*.

Treatment	Yield (t/ha)	Gain in yield (t)	Value of additional yield (Rs.)	Total chemical used	Cost of treatment (Rs.)			Additional gain for treatment** (Rs./ha)	Additional benefit/ Additional cost
					Chemical	Labour	Total		
T_1: Carbofuran 3G at 1 kg a.i./ ha 3 WAS[1]	3.7	0.3	1800.0	33.3 kg	1850.00	62.10	1912.10	-112.1	-0.9
T_2: Seed dressing with carbosulfan 25 DS at 3.0% a. i. w/w	4.3	0.9	5400.0	2.4 kg	4800.00	62.10	4862.10	537.9	1.1
T_3: Seed soaking with carbosulfan 25 EC at 0.1% a.i. for 4 hrs	4.0	0.6	3600.0	80 ml.	150.00	62.10	212.10	3388.0	17.0
T_4: Seed dressing with carbosulfan 25 DS at 3.0% a. i. w/w + carbofuran 3G at 1 kg a.i./ha 3 WAS	4.5	1.1	6600.0	33.3 kg +2.4 kg	6650.00	124.20	6774.20	-174.2	-1.0
T_5: Seed soaking with carbosulfan 25 EC at 0.1% a.i. for 4 hrs +carbofuran 3G at 1 kg a.i./ha 3 WAS	4.3	0.9	5400.0	33.3 kg +80 ml.	2000.00	124.20	2124.20	3275.8	2.5
T_6: Neem cake, 1000 kg/ha at planting	4.0	0.6	3600.0	1000 kg	4500.00	186.30	4686.30	-1086.3	-0.8
T_7: Seed dressing with carbosulfan 25 DS at 3.0% a. i. w/w + neem cake, 1000 kg/ha at planting	4.6	1.2	7200.0	1000 kg + 2.4 kg	9300.00	248.00	9548.00	-2348.4	-0.8
T_8: Seed soaking with carbosulfan 25 EC at 0.1% a.i. for 4 hrs + neem cake, 1000 kg/ha at planting	4.5	1.1	6600.0	1000 kg + 80 ml.	4650.00	248.00	4898.00	1701.6	1.3
T_9: Untreated Control	3.4								

* Calculation based on pooled yield data of 2003 and 2004 presented in Table III.
** Cost of labour @ Rs. 62.10 per man-day and price of cowpea pod @ Rs. 6000 per ton in local market.
[1] WAS = Weeks after sowing.
N.B.: 1 Indian Rs = 0.0246202 USD or 0.0179826 EUR as on the 8th September, 2007.

neem cake, resulting in a possible increase in the phenol contents of the roots and thereby providing a degree of tolerance against nematode attack (Khan and Hussain, 1988). In addition, organic amendments change the physical as well as the trophic structure of soil, and this affects pathogen development and overall plant growth performance (Akhtar and Mahmood, 1996).

Tables IV and V show that the correlation coefficients between the variables measured were significant in the majority of cases. It is noteworthy that correlation coefficients between nematode egg-mass index, root and soil populations of nematodes and all growth indicators and yield were negative in both years. This suggests that the observed yield increases were mostly due to nematode control by the treatments.

The economic analysis, made on pooled yield data for the two years, clearly shows that all treatments gave yield gain over the control. The largest gain was obtained with treatment T_7, while the ratio between the additional benefit and the additional treatment cost was largest for treatment T_3, followed by treatments T_5, T_8 and T_2 (Table VI). The reason for the high monetary return from carbosulfan seed soaking was the low application cost and the low price of the chemical, combined with increased yield obtained as a result of reduction of nematode infestation. Obviously, the economics would change with a lowering of treatment costs, particularly the cost of the chemicals and the neem cake.

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