

# Estimation of crop losses and eco-friendly management of maize cyst nematode

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**Abstract:** Maize cyst nematode (*Heterodera zae*) is the most important nematode pest of maize and reported to cause significant losses in Rajasthan due to monocropping, favourable soil and environmental conditions. Therefore, an experiment was carried out to estimate the avoidable yield losses caused by *H. zae* on maize with the application of carbofuran at 2 kg *a.i.*/ha in naturally infested field with test nematode. Results revealed that application of chemical significantly reduced nematode population and avoided yield losses of grain and straw to the tune of 25.1–26.3 per cent and 21.9–25.2 per cent, respectively. In another trial, efficacy of neem, karanj and mahua (deoiled cakes, dry leaves and seed kernel powder) were tested as row and broadcast application @ 0.5 t/ha for the management of this nematode. Results revealed that neem seed kernel @ 0.5 t/ha when applied as row application was most effective for the management of maize cyst nematode whereas karanj seed kernel @ 0.5 t/ha applied in rows was best to enhance yield of grain (56.4–59.6 per cent) and straw (52.6–57.6 per cent) followed by neem seed kernel and karnaj cake @ 0.5 t/ha over untreated control.

**Keywords:** *Heterodera zae* · Karnaj cake · Maize · Neem seed kernel

## Introduction

Maize (*Zea mays* L.) being queen of cereals is cultivated under the wide range of agro-climatic conditions all over the world. In India, maize occupies third rank after rice and wheat. In India, maize is extensively grown in Rajasthan, Bihar, Gujarat, Haryana, Karnataka, Delhi, Himachal Pradesh, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Maharashtra, Punjab and Uttar Pradesh etc. In Rajasthan, it is mainly cultivated in Udaipur, Rajsamand, Banswara, Bhilwara, Chittorgarh, Dungarpur, Ajmer, Kota, Bundi and Jhalawar districts of Rajasthan.

Maize is primarily a *Kharif* season crop but presently, it is also being popularized as an important *Rabi* crop in certain parts of the country including southern Rajasthan depending upon the climate, hybrid seed availability, irrigation facilities etc. In summer, it is grown as fodder crop while in *Kharif* and *Rabi*, it is mainly grown for human consumption as it provides high quality of staple food among rural masses.

In India, productivity of maize is very low because it is mainly cultivated as rainfed crop with poor management of pest and pathogens including plant parasitic nematodes. A large number of phytonematodes have been found associated with maize crop such as species of *Heterodera*, *Pratylenchus*, *Tylenchorhynchus*, *Meloidogyne*, *Hoplolaimus*, *Helicotylenchus*, *Rotylenchulus*, *Radopholus*, *Longidorus*, *Trichodorus*, *Xiphinema*, *Belanolaimus*, *Ditylenchus* and *Aphelenchus* (Yadav and Verma, 1971; Windham, 1998; Berg *et al.*, 2001; Kumar *et al.*, 2018). These nematodes apart from causing loss interact with other disease causing agents and adversely affect the quality and quantity of maize production.

Amongst phytonematodes, maize cyst nematode (*Heterodera zae*) is economically most important and

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causes severe losses to this crop. It was first discovered by Koshy *et al.* (1970) from Chhapli village of the then Udaipur district of Rajasthan. It is widely distributed in maize growing areas of Rajasthan, Bihar, Madhya Pradesh, Gujarat, Haryana, Uttar Pradesh, Maharashtra and Delhi (Koshy and Swarup, 1971; Rathore *et al.*, 2007; Meena *et al.*, 2013; Mehta *et al.*, 2016). It causes severe damage to maize (Krusberg *et al.*, 1997; Dodwadia *et al.*, 2015). Significant yield losses are caused by this nematode under favourable conditions (Srivastava *et al.*, 2001). The severity of losses caused by *H. zae* on maize is higher in Rajasthan, probably due to favourable soil conditions, monocropping and ignorance of management practices conditions (Meena and Singh, 1995). In view of disease severity and crop losses, attempts were made to manage it with use of pesticides (Sethi and Srivastava, 1986; Kaul and Sethi, 1988a; Baheti *et al.*, 2015). However, health hazards, residual toxicity, environmental pollution, high application cost, and poor adoption at farmers' fields are limiting factors. Though attempts were made (Mishra and Prasad, 1974; Bhatti, 1988; Mehta *et al.*, 2015; Kumhar *et al.*, 2018) to evolve economical and eco-friendly techniques for the management of plant parasitic nematode on various crops yet information regarding management of maize cyst nematode on maize is lacking. Therefore, present investigation was conceived so as to evolve eco-friendly management of maize cyst nematode.

## Materials and methods

### *Estimation of avoidable losses*

An experiment was designed to estimate the avoidable yield losses caused by maize cyst nematode, *H. zae* on maize. A field trial was carried out on farmer's field naturally infested with maize cyst nematode, *Heterodera zae* at Bujhda near Udaipur. Before layout, soil samples were collected and processed in the laboratory to ensure good nematode population required for experimentation. It was determined 1000 and 1140 larvae/100 cc soil during I<sup>st</sup> Year and II<sup>nd</sup> year, respectively. Two treatments viz., carbofuran 3G @ 2 kg a.i./ha (66.67 kg commercial formulation) and untreated control were taken. Chemical was weighed for each experimental plot of 10 m<sup>2</sup> size, mixed well in 1 kg of sand for uniform distribution in each experimental plot and applied at the time of sowing. Experiment was laid out in paired plot method as suggested by LeClerc (1971) and

both the treatments were replicated ten times. All intercultural operations (fertilizer application, weeding, hoeing, irrigation etc.) were done as per recommended package of practices for better growth of the crop. Fungicide and insecticide application was also applied for safeguarding the crop from pests and diseases. Crop was harvested after maturity and observations on number of cyst per plant, cyst per 100 cc soil, larvae per 100 cc soil, grain yield, and straw yield were recorded. For estimation of soil population, samples collected from the experimental plots were brought to the laboratory and thoroughly mixed. Hundred cc soil was taken in bowl, added water, stirred thoroughly and passed through 16 mesh sieve. The content obtained were then passed through 100 mesh sieve and catch of sieve was transferred in a beaker and later on a blotting paper, examined under microscope for counting of cysts. The filtrate of 100 mesh sieve was further passed through 400 mesh sieves and catch of sieve was placed over Baermann's funnel assembly. After 24 hours, the nematode suspension was drawn from the funnel in a beaker and kept for some time as such to allow the nematodes to settle down at the bottom. Nematode larvae population was counted under microscope.

After harvesting, root samples were collected from each experimental plot and brought to the laboratory. Roots were gently washed in running tap water to remove adhering soil particles. Well cleaned roots were cut into small pieces and observed thoroughly under microscope for counting of cysts population per plant. For grain yield, cobs were collected separately from each experimental plot in well aerated cotton cloth bags and kept in shade for drying. Thereafter, grains were separated from cobs with the help of maize sheller, cleaned and weighed to obtain grain yield data. For straw yield, dry plants were cut and tied with small piece of rope. Then weighed with the help of weighing balance to record straw yield. Yield data were compiled after termination of the experiment and expressed in t/ha. Avoidable losses (Treated-Untreated/Treated\*100) and per cent increase in yield and decrease in nematode population over control (Treated-Untreated/Untreated\*100) was determined.

### *Organic amendments*

In view of disease severity and crop losses caused by tiny and tough organism, attempts were made to test various pesticides for the management of nematodes including maize cyst nematode on maize and proved effective but

due to health hazards, residual toxicity, environmental pollution and high cost, their adoption at farmer's level has been limited. Therefore, present investigation was made to evolve eco-friendly management options for the maize cyst nematode, *H. zae* on maize. With this view, a field trial was planned and conducted to test the efficacy of neem, karanj and mahua cakes, leaves powder and seed kernels for the management of maize cyst nematode, *H. zae* on maize. These plant products were applied @ 0.5 t/ha as row and broadcast application. Carbofuran @ 2 kg a.i./ha was kept and maintained as standard chemical check along with untreated check. The required quantity of cakes, leaves, seed kernels and chemicals were calculated and weighed separately for each plot (10 m<sup>2</sup>). All plant products were mixed well in 1 kg sand for uniform distribution and then applied in experimental plots at the time of sowing. Soil samples were collected to estimate the initial nematode population. It was estimated 1020 and 1180 larvae/100 cc soil during Ist and IInd Year, respectively. The experiment was laid out in randomized block design with five replications. All agronomical practices were adopted throughout the cropping period. Observations viz., number of cyst per plant, cyst per 100 cc soil, larvae per 100 cc soil, grain and straw yield were recorded for comparison of treatments. Data were compiled and analyzed for interpretation of findings (Table 2–3).

## Results and discussion

### Assessment of avoidable losses

Results revealed that 28.4 cyst per plant, 9.8 cyst per 100 cc soil and 1055.4 larvae per 100 cc soil were recorded in plots treated with carbofuran @ 2 kg a.i./ha compared to 50.5, 17.0 and 1940.6 in untreated plots during I<sup>st</sup> year, respectively (Table 1). Similar trend was noticed during II<sup>nd</sup> year also.

Results revealed that application of carbofuran @ 2 kg a.i./ha in field infested with maize cyst nematode, *H. zae* significantly enhanced grain and straw yield over untreated control (Table 2).

During I<sup>st</sup> year 3.50 and 11.66 t/ha grain and straw yield was recorded in chemical treated plots while in untreated plots, it was found to be 2.58 and 8.72 t/ha, respectively. Similar trend was also noticed during II<sup>nd</sup> year where grain yield of 3.74 and 2.80 t/ha and straw yield of 12.60 and 9.84 t/ha in treated and untreated plots, respectively. Application of chemical avoided losses to the tune of 26.3 per cent in grain yield and 25.2 per cent in straw yield during I<sup>st</sup> year. During II<sup>nd</sup> year, it was recorded 25.1 and 21.9 per cent, respectively. Per cent increase in grain (35.7 per cent) and straw yield (33.7 per cent) over untreated control were obtained during I<sup>st</sup> year. During II<sup>nd</sup>

**Table 1.** Estimation of avoidable yield losses caused by maize cyst nematode, *Heterodera zae* on maize

| Treatment                                 | Nematode population |           |                  |           |                    |           | Per cent decrease over control |           |                  |           |                    |           |
|-------------------------------------------|---------------------|-----------|------------------|-----------|--------------------|-----------|--------------------------------|-----------|------------------|-----------|--------------------|-----------|
|                                           | Cyst/plant          |           | Cyst/100 cc soil |           | Larvae/100 cc soil |           | Cyst/plant                     |           | Cyst/100 cc soil |           | Larvae/100 cc soil |           |
|                                           | Ist Year            | IInd Year | Ist Year         | IInd Year | Ist Year           | IInd Year | Ist Year                       | IInd Year | Ist Year         | IInd Year | Ist Year           | IInd Year |
| Carbofuran 2 kg a.i./ha (T <sub>1</sub> ) | 28.4                | 33.2      | 9.8              | 11.6      | 1055.4             | 1170.6    | 43.8                           | 40.1      | 42.4             | 38.9      | 45.6               | 41.3      |
| Untreated control (T <sub>2</sub> )       | 50.5                | 55.4      | 17.0             | 19.0      | 1940.6             | 1995.8    | -                              | -         | -                | -         | -                  | -         |
| 't' test                                  | Sig.                | Sig.      | Sig.             | Sig.      | Sig.               | Sig.      | -                              | -         | -                | -         | -                  | -         |

**Table 2.** Estimation of yield per cent avoidable loss and per cent increase over control caused by maize cyst nematode, *Heterodera zae* on maize

| Treatment                                 | Yield (t/ha) |           |          |           | Per cent avoidable loss |           |          |           | Per cent increase over control |           |          |           |
|-------------------------------------------|--------------|-----------|----------|-----------|-------------------------|-----------|----------|-----------|--------------------------------|-----------|----------|-----------|
|                                           | Grain        |           | Straw    |           | Grain                   |           | Straw    |           | Grain                          |           | Straw    |           |
|                                           | Ist Year     | IInd Year | Ist Year | IInd Year | Ist Year                | IInd Year | Ist Year | IInd Year | Ist Year                       | IInd Year | Ist Year | IInd Year |
| Carbofuran 2 kg a.i./ha (T <sub>1</sub> ) | 3.50         | 3.74      | 11.66    | 12.60     | 26.3                    | 25.1      | 25.2     | 21.9      | 35.7                           | 33.6      | 33.7     | 28.0      |
| Untreated control (T <sub>2</sub> )       | 2.58         | 2.80      | 8.72     | 9.84      | -                       | -         | -        | -         | -                              | -         | -        | -         |
| 't' test                                  | Sig.         | Sig.      | Sig.     | Sig.      | -                       | -         | -        | -         | -                              | -         | -        | -         |

Data are the average of ten replications

**Table 3.** Effect of botanicals as soil amendment for the management of *Heterodera zeae* on maize

| Treatment                                                  | Nematode population |            |                  |            |                    |            | Yield (t/ha) |            |          |            |
|------------------------------------------------------------|---------------------|------------|------------------|------------|--------------------|------------|--------------|------------|----------|------------|
|                                                            | Cyst/plant          |            | Cyst/100 cc soil |            | Larvae/100 cc soil |            | Grain        |            | Straw    |            |
|                                                            | Ist Year            | IIInd Year | Ist Year         | IIInd Year | Ist Year           | IIInd Year | Ist Year     | IIInd Year | Ist Year | IIInd Year |
| <i>Control v/s Rest</i>                                    |                     |            |                  |            |                    |            |              |            |          |            |
| Control                                                    | 51.4                | 53.2       | 15.6             | 17.4       | 1850.8             | 2050.6     | 2.60         | 2.75       | 8.60     | 9.70       |
| Rest                                                       | 36.7                | 39.7       | 11.2             | 13.0       | 1358.5             | 1568.9     | 3.43         | 3.55       | 11.10    | 12.20      |
| 'F' test                                                   | Sig.                | Sig.       | Sig.             | Sig.       | Sig.               | Sig.       | Sig.         | Sig.       | Sig.     | Sig.       |
| <i>Method of application</i>                               |                     |            |                  |            |                    |            |              |            |          |            |
| Row (R)                                                    | 32.2                | 34.8       | 10.0             | 11.9       | 1279.7             | 1483.9     | 3.70         | 3.80       | 12.07    | 13.10      |
| Broad cast (B)                                             | 41.2                | 44.6       | 12.4             | 14.1       | 1437.3             | 1654.0     | 3.16         | 3.29       | 10.13    | 11.29      |
| SEm ±                                                      | 0.37                | 0.36       | 0.14             | 0.17       | 16.90              | 15.00      | 0.029        | 0.029      | 0.098    | 0.099      |
| CD at 5%                                                   | 1.04                | 1.03       | 0.40             | 0.47       | 47.57              | 42.22      | 0.083        | 0.083      | 0.277    | 0.278      |
| <i>Between treatment</i>                                   |                     |            |                  |            |                    |            |              |            |          |            |
| Neem cake 0.5 t/ha (T <sub>1</sub> )                       | 34.7                | 37.8       | 10.4             | 12.0       | 1260.2             | 1450.2     | 3.54         | 3.66       | 11.53    | 12.50      |
| Karanj cake 0.5 t/ha (T <sub>2</sub> )                     | 36.4                | 39.8       | 10.8             | 12.5       | 1320.4             | 1503.5     | 3.69         | 3.79       | 11.88    | 13.00      |
| Mahua cake 0.5 t/ha (T <sub>3</sub> )                      | 39.5                | 42.7       | 12.0             | 13.9       | 1447.9             | 1685.1     | 3.26         | 3.38       | 10.51    | 11.47      |
| Neem leaf 0.5 t/ha (T <sub>4</sub> )                       | 42.1                | 45.9       | 13.1             | 15.0       | 1591.5             | 1831.0     | 2.99         | 3.08       | 9.68     | 10.65      |
| Karanj leaf 0.5 t/ha (T <sub>5</sub> )                     | 42.8                | 46.5       | 13.7             | 15.7       | 1661.4             | 1902.8     | 3.09         | 3.22       | 10.03    | 10.93      |
| Mahua leaf 0.5 t/ha (T <sub>6</sub> )                      | 45.2                | 48.1       | 14.3             | 16.4       | 1725.4             | 1956.5     | 2.84         | 2.93       | 9.20     | 10.35      |
| Neem seed kernel 0.5 t/ha (T <sub>7</sub> )                | 30.7                | 32.6       | 9.4              | 10.7       | 1129.3             | 1322.8     | 3.75         | 3.83       | 12.03    | 13.18      |
| Karanj seed kernel 0.5 t/ha (T <sub>8</sub> )              | 32.7                | 35.6       | 10.0             | 11.5       | 1192.5             | 1380.1     | 3.82         | 3.98       | 12.40    | 13.65      |
| Mahua seed kernel 0.5 t/ha (T <sub>9</sub> )               | 36.7                | 40.1       | 11.2             | 12.9       | 1330.4             | 1562.2     | 3.42         | 3.53       | 11.13    | 12.10      |
| Carbofuran 2 kg a.i./ha (T <sub>10</sub> )                 | 26.3                | 28.1       | 7.3              | 9.2        | 926.1              | 1095.2     | 3.92         | 4.09       | 12.63    | 14.13      |
| SEm ±                                                      | 0.83                | 0.81       | 0.32             | 0.37       | 37.79              | 33.54      | 0.066        | 0.066      | 0.220    | 0.221      |
| CD at 5%                                                   | 2.33                | 2.29       | 0.89             | 1.05       | 106.37             | 94.40      | 0.185        | 0.185      | 0.620    | 0.621      |
| <i>Two way Interaction</i>                                 |                     |            |                  |            |                    |            |              |            |          |            |
| <i>Method × Treatment</i>                                  |                     |            |                  |            |                    |            |              |            |          |            |
| Row × Neem cake 0.5 t/ha (RT <sub>1</sub> )                | 29.8                | 32.2       | 9.0              | 10.6       | 1160.4             | 1320.2     | 3.87         | 3.95       | 12.65    | 13.50      |
| Row × Karanj cake 0.5 t/ha (RT <sub>2</sub> )              | 31.0                | 33.6       | 9.4              | 11.2       | 1220.8             | 1381.4     | 4.05         | 4.09       | 13.00    | 14.05      |
| Row × Mahua cake 0.5 t/ha (RT <sub>3</sub> )               | 33.6                | 36.4       | 10.4             | 12.4       | 1325.0             | 1540.2     | 3.54         | 3.63       | 11.52    | 12.40      |
| Row × Neem leaf 0.5 t/ha (RT <sub>4</sub> )                | 38.2                | 42.0       | 12.0             | 14.0       | 1552.4             | 1760.0     | 3.16         | 3.23       | 10.35    | 11.20      |
| Row × Karanj leaf 0.5 t/ha (RT <sub>5</sub> )              | 38.8                | 42.6       | 12.6             | 14.8       | 1622.6             | 1864.8     | 3.30         | 3.41       | 10.80    | 11.45      |
| Row × Mahua leaf 0.5 t/ha (RT <sub>6</sub> )               | 42.0                | 45.0       | 13.4             | 15.8       | 1700.8             | 1932.6     | 2.88         | 2.98       | 9.55     | 10.80      |
| Row × Neem seed kernel 0.5 t/ha (RT <sub>7</sub> )         | 26.4                | 28.6       | 8.2              | 9.4        | 1048.2             | 1245.0     | 4.10         | 4.14       | 13.25    | 14.25      |
| Row × Karanj seed kernel 0.5 t/ha (RT <sub>8</sub> )       | 28.0                | 30.2       | 8.8              | 10.4       | 1085.0             | 1290.0     | 4.15         | 4.30       | 13.55    | 14.80      |
| Row × Mahua seed kernel 0.5 t/ha (RT <sub>9</sub> )        | 31.4                | 34.0       | 9.8              | 11.6       | 1210.2             | 1448.4     | 3.73         | 3.81       | 12.20    | 13.10      |
| Row × Carbofuran 2 kg a.i./ha (RT <sub>10</sub> )          | 22.6                | 23.8       | 6.4              | 8.6        | 872.0              | 1056.6     | 4.25         | 4.45       | 13.85    | 15.45      |
| Broadcast × Neem cake 0.5 t/ha (BT <sub>1</sub> )          | 39.6                | 43.4       | 11.8             | 13.4       | 1360.0             | 1580.2     | 3.20         | 3.37       | 10.40    | 11.50      |
| Broadcast × Karanj cake 0.5 t/ha (BT <sub>2</sub> )        | 41.8                | 46.0       | 12.2             | 13.8       | 1420.0             | 1625.6     | 3.33         | 3.48       | 10.75    | 11.95      |
| Broadcast × Mahua cake 0.5 t/ha (BT <sub>3</sub> )         | 45.4                | 49.0       | 13.6             | 15.4       | 1570.8             | 1830.0     | 2.98         | 3.12       | 9.50     | 10.54      |
| Broadcast × Neem leaf 0.5 t/ha (BT <sub>4</sub> )          | 46.0                | 49.8       | 14.2             | 16.0       | 1630.6             | 1902.0     | 2.82         | 2.92       | 9.00     | 10.10      |
| Broadcast × Karanj leaf 0.5 t/ha (BT <sub>5</sub> )        | 46.8                | 50.4       | 14.8             | 16.6       | 1700.2             | 1940.8     | 2.88         | 3.02       | 9.25     | 10.40      |
| Broadcast × Mahua leaf 0.5 t/ha (BT <sub>6</sub> )         | 48.4                | 51.2       | 15.2             | 17.0       | 1750.0             | 1980.4     | 2.80         | 2.88       | 8.85     | 9.90       |
| Broadcast × Neem seed kernel 0.5 t/ha (BT <sub>7</sub> )   | 35.0                | 36.6       | 10.6             | 12.0       | 1210.4             | 1400.6     | 3.40         | 3.52       | 10.80    | 12.10      |
| Broadcast × Karanj seed kernel 0.5 t/ha (BT <sub>8</sub> ) | 37.4                | 41.0       | 11.2             | 12.6       | 1300.0             | 1470.2     | 3.48         | 3.65       | 11.25    | 12.50      |
| Broadcast × Mahua seed kernel 0.5 t/ha (BT <sub>9</sub> )  | 42.0                | 46.2       | 12.6             | 14.2       | 1450.6             | 1676.0     | 3.10         | 3.24       | 10.05    | 11.10      |
| Broadcast × Carbofuran 2 kg a.i./ha (BT <sub>10</sub> )    | 30.0                | 32.4       | 8.2              | 9.8        | 980.2              | 1133.8     | 3.58         | 3.72       | 11.40    | 12.80      |
| SEm ±                                                      | 1.17                | 1.15       | 0.45             | 0.53       | 53.45              | 47.44      | 0.093        | 0.093      | 0.311    | 0.312      |
| CD at 5%                                                   | NS                  | 3.24       | NS               | NS         | NS                 | NS         | 0.262        | 0.261      | NS       | NS         |

Data are the average of five replications

in present investigation neem, karanj, and mahua cakes, leaves and seed kernels were used @ 0.5 t/ha as organic amendment for the management of maize cyst nematode, *H. zae* on maize. Among different organic amendments, minimum cysts per plant (30.7 and 32.6) were observed with neem seed kernel followed by karanj seed kernel (32.7 and 35.6) and neem cake (34.7 and 37.8) applied @ 0.5 t/ha during *Kharif* I<sup>st</sup> year and II<sup>nd</sup> year, respectively (Table 3). However, soil application of carbofuran at 2 kg *a.i.*/ha was significantly better over botanicals tested and produced 26.3 and 28.1 cysts per plant. Results also showed that cysts per plant were significantly reduced with row application (32.2 and 34.8) in comparison to broadcast application (41.2 and 44.6) (Table 3).

Application of neem seed kernel @ 0.5 t/ha in rows reduced cyst per plant to the tune of 48.6 and 46.2 per cent whereas, in karanj seed kernel and neem cake @ 0.5 t/ha, it was observed 45.5 and 43.2 per cent and 42.0 and 39.5 per cent, respectively lesser over untreated control (Table 4). The highest reduction in cyst per plant (56.0

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**Table 4.** Per cent changes in nematode parameters and yield of maize through soil amendment with different plant products

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and 55.3 per cent) was noticed with row application of carbofuran @ 2 kg a.i./ha. Cysts per plant were observed lower in seed kernel compared to cake and leaf treatments. In the same way, neem products proved better over karanj and mahua. Similar order was noticed with regards to cyst and larvae population in soil (Table 4).

The results obtained in present investigation are also in accordance with the findings of number of earlier researchers. Mishra and Prasad (1974) also reported that effect of karanj, neem, mahua, groundnut, cotton, and linseed and sesamum cake on various nematodes attacking wheat, mungbeen and tomato. Although, all cakes were effective in reducing nematode population except cotton and linseed cake but neem cake was best among all the cakes tested. Alam and Khan (1974) reported that highest reduction in the population of stylet bearing nematodes took place in neem cake followed by cakes of mahua, mustard, groundnut and castor on spinach. Efficacy of plant products was also tested by Mojumder *et al.* (2002). They conducted an experiment on seed coating of pea with neem seed kernel, neem seed coat and neem cake (20 per cent), achool, neemark and nimbecidine (5 per cent) against *M. incognita* and *R. reniformis* and found that neem seed kernel was most effective in reducing root-knot galls, juveniles of *M. incognita* and all stages of *R. reniformis* and enhanced the plant growth and crop yield. Nangegowda *et al.* (1998) tested the efficacy of neem seed kernel, neem leaf, neem cake, nimbecidine and carbofuran against *M. incognita* in tomato nursery. They reported that all the neem products and carbofuran significantly reduced the nematode population. However, carbofuran was more effective followed by neem seed kernel and cake. Ram and Baheti (2004) tested the efficacy of neem, castor and karanj products (leaf and seed kernel) as seed treatment (10% w/w) along with soil application (0.25 t/ha) for the management of *Rotylenchulus reniformis* on cowpea (Pusa Barsati). Results revealed that plant products were effective in improving plant growth and reducing nematode reproduction over untreated check. However, neem seed kernel was found to be the most effective and superior among all the plant products. Mehta *et al.* (2015) observed maximum increase in plant growth parameters with neem (*Azadirachta indica*) leaves powder @ 4 g/plant followed by aak (*Calotropis procera*) and water hyacinth (*Eichornia crassipes*) leaves powder @ 4 g/plant as soil application over untreated control on maize infested with *H. zae*. Similar results have also been reported by Baheti *et al.*

(2015) on sweet corn, Kumar *et al.* (2018) on maize infested by various plant parasitic nematodes.

The suppression of nematodes in amended soil might be due to the effect of several combined factors. Production of volatile fatty acids, phenols, ammonia, amino acids etc. during decomposition of plant products might have caused inhibitory effect on the nematodes. The decomposed products might be either directly toxic to nematodes or the microbial metabolites produced during decomposition might have toxic effect to nematodes or enhance activity of predators and parasites attacking the nematode.

In present investigation also maize cyst nematode, *H. zae* produced less number of cysts per plant, cysts and larvae per 100 cc soil under botanical treatments over untreated control which is in accordance with the findings of the previous workers. Comparative studies were also carried out between row and broadcast application of plant products for the management of *H. zae* on maize. Results showed that all the plant products exhibited better response in row application over broadcast application.

Results pertaining to grain yield revealed that neem, karanj and mahua cakes, powdered leaves and seed kernels when applied @ 0.5 t/ha as soil amendment in *H. zae* infested field, enhanced the yield. Among different botanical treatments, maximum grain yield (3.82 and 3.98 t/ha) was obtained with karanj seed kernel applied @ 0.5 t/ha followed by neem seed kernel @ 0.5 t/ha (3.75 and 3.83 t/ha) and karanj cake @ 0.5 t/ha (3.69 and 3.79 t/ha) during I<sup>st</sup> year and II<sup>nd</sup> year, respectively. Higher grain yield was recorded in case of seed kernel application compared to cake and leaf. Similarly, karanj products proved better than those of neem and mahua. However, highest numerical grain yield (3.92 and 4.09 t/ha) was recorded with the application of carbofuran @ 2 kg a.i./ha over karanj seed kernel though statistically at par with each other during both the years.

Comparative studies of row and broadcast methods of application indicated that row application was significantly superior over broadcast application w.r.t. grain yield. It was obtained 3.70 and 3.80 t/ha in row while 3.16 and 3.29 t/ha in broadcast application during both the cropping seasons. Per cent increase in grain yield with the application of different botanicals over untreated was calculated and it was maximum (59.6 and 56.4 per cent) with karanj seed kernel @ 0.5 t/ha when applied in rows followed by neem seed kernel (57.7 and 50.6 per cent) and karanj cake (55.8 and 48.7 per cent) when applied @ 0.5 t/ha. However, highest increase in grain yield (63.5

and 61.8 per cent) was recorded with carbofuran @ 2 kg a.i./ha when applied in rows during I<sup>st</sup> year and II<sup>nd</sup> year, respectively. Similar trend was observed with respect to straw yield also. The efficacy of different botanicals has also been observed by several workers. Patel *et al.* (2000) studied the efficacy of Indian mustard, cakes of castor, neem, mahua, piludi, press-mud, poultry manure, FYM and celrich @ 1 or 2 per cent on wheat cv. Lok-1 and observed that all treatments were effective in increasing grain yield. Ravindra *et al.* (2003) evaluated the efficacy of neem and pongamia cake @ 10, 20 and 30 g/plant, applied directly to the base. Pongamia cake @ 30 g/plant recorded maximum green and cured leaf yield of tobacco. Similarly, Ram and Baheti (2006) and Khoarniya and Baheti (2020) reported the efficacy of botanicals for the management of reniform and root-knot nematode infecting pulses.

These findings support that application of botanicals as soil amendment enhanced plant growth and crop yield in nematode prone areas. This might be due to the fact that soil amendment with botanicals improve physical condition of soil, reduce population of plant parasitic nematodes, enhances the activity of beneficial soil microbes. Different plant products exert different reactions w.r.t. plant growth parameters. However, application of seed kernels led to better yield over cake and leaf because seed kernels gave better protection from nematode attack. Similarly, karanj products proved better over neem and mahua because of the fact that karanj products might be providing better nourishment to the crop or have other attributes responsible for enhancing yield.

## Conclusion

Application of carbofuran @ 2 kg a.i./ha avoided grain and straw yield losses of maize to the tune of 25.1–26.3 and 21.9–25.2 per cent, respectively in field infested with *H. zae*. Soil amendment with neem seed kernel @ 0.5 t/ha as row application was found better for the management of maize cyst nematode whereas karanj seed kernel at same dose was effective in enhancing the yield.

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