**Loss Estimation in Wheat Caused by Cereal Cyst Nematode Across Different Agro-Ecological Regions**

**ABSTRACT :-**

Avoidable losses caused by cereal cyst nematode, *H. avenae* on wheat at three different locations (Madar, Nagda and Bujhra) estimated with the application of fluopyram 34.48 % SC at 5ml/kg seed. Results revealed that application of chemical significantly reduced number of females/5 g root, cysts/200 cc soil and larvae/200 cc soil at Bujhra (10.96, 11.73 and 120.16) followed by Madar (13.73, 15.36 and 195.56) and Nagda (17.46, 19.40 and 285.09). Application of chemical significantly increased fodder (84.96, 80.26 and 77.31 q/ha) and grain yield (56.65, 53.51 and 51.54 q/ha) at Bujhra, Madar and Nagda, repectively. Avoidable yield loss in grain yield were recorded at Bujhra (27.05 %), Madar (23.02 %) and Nagda (21.95). Net profit and cost benefit ratio was also determined at Bujhra (Rs. 31372.25 and 1:5.40), Madar (Rs. 24076.00 and 1:4.15) and Nagda (Rs. 21627.75 and 1:3.72).

**INTRODUCTION :-**

India is an agriculture-oriented country and we depend on cereal as our food requirement. The decrease of agricultural land, adverse environmental conditions and continuous increase of population, the demand of nutritious food is a matter of great concern to the world. Among the cereals, wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) occupy the most prominent position in terms of production, acreage, and source of nutrition, particularly in developing countries (Nicol *et al*., 2011). India produced around 106.84 million tonnes of wheat from 30.47 million hectares of area ( Anonymous, 2022 ). Rajasthan contributed 10.41 million tonnes from 2.78 million hectares of area (Government of Raj. 2023-24 ). Productivity of wheat and barley is often compromised due to various environmental factors under abiotic stress and many types of insect-pest including nematodes under biotic stress. Among nematodes, cyst nematode genus i.e. *Heterodera* is one of the earliest discovered genera of plant-parasitic nematodes. In India, *Heterodera avenae* is the important species in wheat crops where it causes major economic losses causing “Molya Disease” in north Indian states. Plant parasitic nematodes alone cause 10 % annual cereal crop losses (Kumar *et al*., 2021). plant parasitic nematodes are very high and significantly reduce the quantity and quality of production observed by Ismail *et al*.(2012); Bhati and Baheti (2020 a.) Plant para-sitic nematodes *viz*. *Meloidogyne* spp., *Rotylenchulus* *reniformis*, *Heterodera* spp., *Pratylenchus* spp., *Hoplolaimus* spp. and *Helicotylenchus* spp. are conjoined with vegetable crops in India. Bhati and Baheti (2020 b) . In wheat, avoidable losses due to cereal cyst nematode, *Heterodera avenae*, in Rajasthan and Haryana (the major molya disease affected states) were calculated at Rs. 8967.52 million during 2014-15. Keeping this in view, Therefore, this investigation was attempted to estimate the avoidable losses caused by *H. aveane* (cereal cyst nematode) infecting wheat under naturally infested field.

**MATERIAL AND METHODS**:-

The experiment was carried out at cereal cyst nematode infested field, at different location *viz*., Madar, Nagda and Bujhra with two treatments *viz*., Fluopyram (34.48% SC at 5ml/kg seed) and untreated check. The experiment was laid out in paired plot method as suggested by Le Clerg (1971). Both the treatments were replicated fifteen times. Initial nematode population was determined at Nagda: 5-6 cyst & 6-8 cyst; Madar: 4-5 cyst & 5-6 cyst and Bujhra: 2-3 cyst & 3-4 cyst in 2022-23 and 2023-24, respectively. All agronomical practices *viz*., weeding, hoeing, irrigation etc. were performed as and when required. Observations on initial nematode population per 200cc soil, number of females/5g root, number of cysts/200 cc soil, number of larvae/200 cc soil, fodder yield (q/ha) and grain yield (q/ha) were recorded. Economics and cost benefit ratio was also determined.

**RESULTS**:-

An experimental trial was conducted to estimate the avoidable losses caused by cereal cyst nematode, *H. avenae* on wheat (Raj-4037) under field condition with the application of fluopyram 34.48 % SC at 5ml/kg seed. The investigation was carried out at farmer’s field at three locations *viz*., Madar, Nagda and Bujhra during *Rabi* 2022-23 and 2023-24. Observation on number of females/5 g roots, number of cysts/200 cc soil, number of larvae/200 cc soil, fodder yield (q/ha) and grain yield (q/ha). Economics of the treatments effect was calculated and cost benefit ratio was also determined. Experimental results are being presented in Table - 1A to 2C and illustrated through Fig – 1.

1. **Number of females/5 g root:**

Results demonstrated (Table-1A) that seed treatment with fluopyram 34.48% SC at 5 ml/kg significantly reduced the number of females/5 g root. Pooled analysis exhibited that number of females/5 g root was recorded higher in Bujhra (10.96), Madar (13.73) and Nagda (17.46) villages in treated plots. It was observed to be 25.03, 22.46 and 19.56 in Nagda, Madar and Bujhra villages respectively in untreated check.

Reduction of number of female/5 g roots was noticed with fluopyram at 5ml/kg seed at Bujhra (43.96 %), Madar (38.86 %) and Nadga (30.24 %) over untreated check.

1. **Number of cyst/200 cc soil:**

Experimental findings showed that fluopyram at 5ml/kg seed significantly reduced number of cysts/200 cc soil. Data showed in Table- 2A revealed that cyst/200 cc soil observed minimum at Bujhra (11.73) followed by Madar (15.36) and Nagda (19.40) villages. It was noticed to be 29.20, 25.86 and 20.06 in Nagda, Madar and Bujhra respectively in untreated check.

Per cent reduction in number of cyst/200 cc soil was noticed with fluopyram at 5ml/kg seed at Bujhra (41.52), Madar (40.60) and Nadga (33.56) over untreated check.

1. **Number of larvae/200 cc soil:**

Results showed that number of larvae/200 cc soil significantly decreased at the time of harvest with the application offluopyram at 5ml/kg seed over untreated check. Larvae/200 cc soil was observed at Bujhra (120.16) followed by Madar (195.56) and Nagda (285.09). It was recorded to be 447.79, 427.33 and 299.83 in Nagda, Madar and Bujhra respectively in check (Table-2A).

Percent reduction in larvae/200 cc soil was calculated with fluopyram at 5ml/kg seed at Bujhra (59.81), Madar (54.23) and Nadga (36.33) over untreated check.

1. **Fodder yield:**

Results revealed that seed treatment with fluopyram at 5ml/kg significantly increased fodder yield of wheat (Table-1B). It was recorded highest at Bujhra (84.96 q/ha) followed by Madar (80.26 q/ha) and Nagda (77.31 q/ha). However, lowest fodder yield recorded in untreated check at Nagda (60.34 q/ha) followed Madar (61.78q/ha) and Bujhra (61.98 q/ha).

Result revealed maximum fodder yield obtained at Bujhra (37.07%) followed by Madar (29.91 %) and Nadga (28.12 %) over untreated check. The avoidable yield loss (%) was estimated to be 27.04 at Bujhra, Madar (23.02) and Nagda (21.95).

1. **Grain yield:**

Results revealed that fluopyram at 5ml/kg seed significantly increased grain yield of wheat (Table-1B). It was recorded highest at Bujhra (56.65 q/ha) followed by Madar (53.51 q/ha) and Nagda (51.54 q/ha). However lowest grain yield were recorded in untreated check at Nagda (40.23 q/ha) followed by Madar (41.19 q/ha) and Bujhra (41.32 q/ha).

Result revealed that maximum grain yield obtained at Bujhra (37.10 %) field followed by Madar (29.91 %) and Nadga (28.11 %) over untreated check. The avoidable yield loss (%) was estimated (Fig-5) to be 27.05 at Bujhra, Madar (23.02) and Nagda (21.95).

1. **Cost-benefit ratio:**

Results presented in Table- 2(A-C) revealed that additional return ( Rs. 37172.25/ha) was recorded at Bujhra followed by Madar (Rs. 29876.00/ha) and Nagda (Rs.27427.75/ha). However, net profit was observed highest at Bujhra (Rs. 31372.25/ha) followed by Madar (Rs. 24076.00/ha) and Nagda (Rs. 21627.75/ha). Cost benefit ratio was also determined and it was estimated 1:5.40, 1:4.15 and 1:3.72 at Bujhra, Madar and Nagda, respectively.

**Table-1A: Estimation of avoidable losses caused by cereal cyst nematode, *Heterodera avenae* infecting wheat in different agro-ecological**

**conditions (1A)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **Treatments** | **Number of females /5g root** | | | **Number of cysts/200 cc soil** | | | **Number of larvae/200 cc soil** | | |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Madar** | **Fluopyrum 34.48 % SC**  **5ml/kg seed (T1)** | 15.13  (28.83)\* | 12.33  (47.88)\* | 13.73  (38.86)\* | 16.60  (30.25)\* | 14.13  (49.40)\* | 15.36  (40.60)\* | 208.60  (49.43)\* | 182.53  (58.71)\* | 195.56  (54.23)\* |
| **Untreated check (T2)** | 21.26 | 23.66 | 22.46 | 23.80 | 27.93 | 25.86 | 412.53 | 442.13 | 427.33 |
| **Nagda** | **Fluopyrum 34.48 % SC**  **5ml/kg seed (T1)** | 18.53  (23.42)\* | 16.40  (36.58)\* | 17.46  (30.24)\* | 20.80  (26.24)\* | 18.00  (40.39)\* | 19.40  (33.56)\* | 290.66  (34.39)\* | 279.53  (38.22)\* | 285.09  (36.33)\* |
| **Untreated check (T2)** | 24.20 | 25.86 | 25.03 | 28.20 | 30.20 | 29.20 | 443.06 | 452.53 | 447.79 |
| **Bujhra** | **Fluopyrum 34.48 % SC**  **5ml/kg seed (T1)** | 12.13  (33.35)\* | 9.80  (53.17)\* | 10.96  (43.96)\* | 13.06  (29.51)\* | 10.40  (51.85)\* | 11.73  (41.52)\* | 125.33  (56.73)\* | 115.00  (62.90)\* | 120.16  (59.81)\* |
| **Untreated check (T2)** | 18.20 | 20.93 | 19.56 | 18.53 | 21.60 | 20.06 | 289.66 | 310.00 | 299.83 |
| **T-test** | | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. |

\*Figures in parentheses are percent decrease over untreated check

**Table-1B: Estimation of avoidable losses caused by cereal cyst nematode, *Heterodera avenae* infecting wheat in different agro-ecological conditions (1B)**

\*Figures in parentheses are percent increase over untreated check

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **Treatments** | **Fooder yield (q/ha)** | | | **Grain yield (q/ha)** | | | **Avoidable losses (%)** | | | | | |
| **Fooder yield (q/ha)** | | | **Grain yield (q/ha)** | | |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Madar** | **Fluopyrum 34.48 % SC at 5ml/kg seed (T1)** | 80.13  (29.45)\* | 80.38  (30.38)\* | 80.26  (29.91) \* | 53.42  (29.44)\* | 53.59  (30.38)\* | 53.51  (29.91) \* | 22.75 | 23.30 | 23.02 | 22.74 | 23.30 | 23.02 |
| **Untreated control (T2)** | 61.90 | 61.65 | 61.78 | 41.27 | 41.10 | 41.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nagda** | **Fluopyrum 34.48 % SC at 5ml/kg seed (T1)** | 77.14  (27.60) \* | 77.47  (28.64) \* | 77.31  (28.12) \* | 51.43  (27.61) \* | 51.65  (28.64) \* | 51.54  (28.11) \* | 21.63 | 22.26 | 21.95 | 21.64 | 22.26 | 21.95 |
| **Untreated control (T2)** | 60.45 | 60.22 | 60.34 | 40.30 | 40.15 | 40.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Bujhra** | **Fluopyrum 34.48 % SC at 5ml/kg seed (T1)** | 84.79  (36.47) \* | 85.13  (37.70) \* | 84.96  (37.07) \* | 56.53  (36.47) \* | 56.76  (37.73) \* | 56.65  (37.10) \* | 26.72 | 27.38 | 27.04 | 26.72 | 27.39 | 27.05 |
| **Untreated control (T2)** | 62.13 | 61.82 | 61.98 | 41.42 | 41.21 | 41.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **T-test** | | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | - | - | - | - | - | - |

**Table-2A: Economics of estimation of losses on wheat caused by cereal cyst nematode (A)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **Treatments** | **Yield** | | **Yield increase over untreated control (q/ha)** | | **Additional return**  **(Rs/ha)** | | | **Cost of additional input\*\*\***  **(Rs/ha)** | **Net profit**  **(Rs/ha)** | **Cost benefit ratio** |
| **Fodder yield** | **Grain yield** | **Fodder yield** | **Grain yield** | **Fodder return\*** | **Grain**  **return\*\*** | **Total output**  **(Fodder + Grain)** |
| **Madar** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 80.13 | 53.42 | 18.23 | 12.15 | 3646.00 | 24786.00 | 28432.00 | 5800.00 | 22632.00 | 1:3.90 |
| **Untreated control (T2)** | 61.90 | 41.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nagda** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 77.14 | 51.43 | 16.69 | 11.13 | 3338.00 | 22705.20 | 26043.20 | 5800.00 | 20243.20 | 1:3.49 |
| **Untreated control (T2)** | 60.45 | 40.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Bujhra** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 84.79 | 56.53 | 22.66 | 15.11 | 4532.00 | 30824.40 | 35356.40 | 5800.00 | 29556.40 | 1:5.09 |
| **Untreated control (T2)** | 62.13 | 41.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

\*Cost of fodder yield in 2022-23:- 200 Rs/q

\*\*Cost of grain yield in 2022-23:- 2040 Rs/q

\*\*\* Cost of treatment (Chemical cost + Labour charge)

**Table-2 B: Economics of estimation of losses on wheat caused by cereal cyst nematode (B)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **Treatments** | **Yield** | | **Yield increase over untreated control (q/ha)** | | **Additional return**  **(Rs/ha)** | | | **Cost of additional input\*\*\***  **(Rs/ha)** | **Net profit**  **(Rs/ha)** | **Cost benefit ratio** |
| **Fodder yield** | **Grain yield** | **Fodder yield** | **Grain yield** | **Fodder return\*** | **Grain**  **return\*\*** | **Total output**  **(Fodder + Grain)** |
| **Madar** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 80.38 | 53.59 | 18.73 | 12.49 | 3746.00 | 26541.25 | 30287.25 | 5800 | 24487.25 | 1:4.22 |
| **Untreated control (T2)** | 61.65 | 41.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nagda** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 77.47 | 51.65 | 17.25 | 11.50 | 3450.00 | 24437.50 | 27887.50 | 5800 | 22087.50 | 1:3.80 |
| **Untreated control (T2)** | 60.22 | 40.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Bujhra** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 85.13 | 56.76 | 23.31 | 15.55 | 4662.00 | 33043.75 | 37705.75 | 5800 | 31905.75 | 1:5.50 |
| **Untreated control (T2)** | 61.82 | 41.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

\*Cost of fodder yield in 2023-24:- 200 Rs/q

\*\*Cost of grain yield in 2023-24:- 2125 Rs/q

\*\*\* Cost of treatment (Chemical cost + Labour charge)

**Table-2C: Economics of estimation of losses on wheat caused by cereal cyst nematode (C)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** | **Treatments** | **Yield** | | **Yield increase over untreated control (q/ha)** | | **Additional return**  **(Rs/ha)** | | | **Cost of additional input\*\*\***  **(Rs/ha)** | **Net profit**  **(Rs/ha)** | **Cost benefit ratio** |
| **Fodder yield** | **Grain yield** | **Fodder yield** | **Grain yield** | **Fodder return\*** | **Grain**  **return\*\*** | **Total output**  **(Fodder + Grain)** |
| **Madar** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 80.26 | 53.51 | 18.48 | 12.32 | 3696.00 | 26180.00 | 29876.00 | 5800.00 | 24076.00 | 1:4.15 |
| **Untreated control (T2)** | 61.78 | 41.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Nagda** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 77.31 | 51.54 | 16.97 | 11.31 | 3394.00 | 24033.75 | 27427.75 | 5800.00 | 21627.75 | 1:3.72 |
| **Untreated control (T2)** | 60.34 | 40.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Bujhra** | **Fluopyrum 34.48 % SC 5ml/kg seed (T1)** | 84.96 | 56.65 | 22.98 | 15.33 | 4596.00 | 32576.25 | 37172.25 | 5800.00 | 31372.25 | 1:5.40 |
| **Untreated control (T2)** | 61.98 | 41.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

\*Cost of fodder yield in 2023-24:- 200 Rs/q

\*\*Cost of grain yield in 2023-24:- 2125 Rs/q

\*\*\* Cost of treatment (Chemical cost + Labour charge

Fig -1: Estimation of avoidable yield losses caused by cereal cyst nematode on wheat

**DISCUSSION :-**

Results of investigation are also agreement with the results of earlier workers who esti-mated losses caused by plant parasitic nematodes on numerous crops. Meagher (1982) observed that in South-Eastern Australia, where large areas of cereal crops are grown in a Mediterranean climate, yield loss caused by *Heterodera avenae* is generally more severe than in Northern Europe. This appears to be due to differences in cropping pattern and the stages of crop growth when roots are exposed to larvae. Mathur *et al.* (1986) conducted experiments on the assessment and chemical control of molya disease of wheat caused by *H. avenae*at several infested sites. Losses up to 47.2 percent for wheat variety Kalyan Sona, in the sandy soils of Rajasthan. Hassan *et al*. (2010) found that increasing initial population densities (Pi) of ***Heterodera avenae*** significantly reduced yield components of two wheat cultivars in field trials. At the highest Pi of 40.4 eggs and juveniles per gram of soil, grain yield losses reached 56.6% in durum wheat and 49.6% in bread wheat. Similarly, fodder yield was reduced by 49.5% in durum wheat and 44.6% in bread wheat. In Rajasthan, Baheti and Bhati (2017) also recorded 41.30-45.50%, 37.50-41.52% and 22.45-25.38% avoidable yield losses in light, medium and heavy soil, respectively caused by *M. incognita* on okra. Hamid *et al*., (2021) reported ***H. avenae*** infestations in 80% of 250 samples collected from wheat and rice monoculture fields. In wheat fields, cyst populations ranged from 7 to 38 cysts per 100g of dry soil, with egg and juvenile counts between 142 and 771. The highest nematode incidence in wheat fields was 16.88% in Silanwali while the lowest was 5.5% in Kot-Momin, both within the Sargodha region. Singh *et al*., (2024) estimated yield losses of 26–78% (p < 0.001) by *H. cajani* on black gram. Additionally, there was a corresponding decrease in grain protein content by 9–22% (p < 0.01), subsequently reducing protein productivity by 11–83% (p < 0.001).

**REFERENCES:**

Anonymous, 2022. Agricultural statistics at a glance 2022. Ministry of agriculture and farmers welfare, New Delhi. ( Govt. of India).

Anonymous, 2023-24. Second advance estimates of Area, Production and Yield of crops in respect of Rajasthan state for the year 2023-24.Govt. of Rajasthan.

Baheti, B. L. & Bhati, S. S. 2017. Estimation of losses caused by root-knot nematode, *Meloidogyne incognita* in varied soil conditions on okra (*Abelmoschus esculentus* L.). *Current Nematology*,**28**(2),201-207.

Bhati, S. S. & Baheti, B. L. 2020 a. Population fluctuation of *Meloidogyne incognita* infecting cucumber in polyhouse. *International Journal of Current Microbiology and Applied Science*s, **9**(8),3708-3715.

Bhati, S. S. & Baheti, B. L. 2020 b. Occurrence and population status of root-knot nematode, *Meloidogyne incognita* on cucumber under protected cultivationin Rajasthan. *Journal of Entomology and Zoology Studies*, **8**(4), 1441-1444.

Bhati, S. S. and Baheti, B. L 2021. Estimation of avoidable losses caused by *Meloidogyne incognita* infecting cucumber in poly-house. *Journal of Agriculture and Applied Biology* 2(1):35-40

Hamid, M.I., Ghazanfar, M, U., Khan, M, Q, N., Hasan, Z, U. and Aslam, S. 2021. Incidence of cereal cyst nematode prevailing in wheat-rice growing regions of Punjab Province. *Pakistan. Agricultural Science Digest*, **41**: 439-444.

Hassan, G., Assas –AI, K. and Jamal, M. 2010. Damage potential and reproduction of *Heterodera avenae* on wheat under Syrian field conditions. *Nematology Mediterranean*, **38**: 73-78.

Kumar, V., Khan, M. R. and R. K. Walia, 2021 : Crop Loss Estimations due to Plant-Parasitic Nematodes in Major Crops in India, Natl. Acad. Sci. Lett. 43 : 409-412

Mathur, B.N., Handa, D.K., Swarup, G., Sethi, C.L., Sharma, G.L. and Yadav, B.D. 1986. On the loss estimation and chemical control of ‘Molya’ disease of wheat caused by *Heterodera avenae* in India. *Indian Journal of Nematology*, **16**(2):152-159.

Meagher., J.W. 1982. yield loss caused by *Heterodera avenae* in cereal crops grown in a Mediterranean Climate1, **12**(4): 325-331.

Nicol J. M., Turner S. J., Coyne D. L., Nijs L. D., Hockland S. and Z. T. Maafi, 2011 : Current nematode threats to world agriculture. In: Jones, J., Gheysen, G. Fennol, C. (Eds). Genomics and molecular genetics of plant nematode interactions. Dordrecht, The Netherlands, Springer. pp. 21-43.

Singh, B., Devindrappa, M. and Hazra, K.K. 2024. Pigeonpea cyst nematode (*Heterodera cajani* Koshy) pathogenicity in black gram (*Vigna mungo* L.): Quantitative and qualitative yield losses and bio- organic management. *Crop Protection,* **186**:106916.