SSRG International Journal of Agriculture & Environmental Science
ISSN: 2394-2568/ https://doi.org/10.14445/23942568/IJAES-V11I3P103

Volume 11 Issue 3, 19-23, May-Jun 2024

Review Article

Review of Integrated Management of Cereal Cyst Nematode *Heterodera avenae* on Wheat Crop under Centre Pivot Irrigation System

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Received: 10 April 2024 Revised: 14 May 2024 Accepted: 03 June 2024 Published: 19 June 2024

Abstract *- Cereal Cyst Nematode (CCN), Heterodera avenae, was reported on wheat crops grown under center pivot irrigation systems in different parts of Saudi Arabia, including Gassim, Al-Kharj, Hael and Tabuk. The estimation of wheat yield reduction by the CCN in Saudi Arabia ranged from 40 – 92% on sandy soil. An integrated cereal cyst nematode management plan was implemented at TADCO, Saudi Arabia, during the period 2006 – 2011, and it demonstrated a great degree of success as it minimized the expansion of infested areas with CCN and minimized yield reduction to around 4.1%. CCN management plan included monitoring CCN infestations on a yearly basis, and the application of granular systemic nematicide on the infested spots of each pivot. Also, the application of granular NPK 14-38-10 and granular K2SO4 fertilizers, implementation of crop rotation mainly alfalfa by direct drilling using the No-Till method for wheat sowing, use of certified wheat seeds and Machinery Sanitation.*

Keywords *- Cereal Cyst Nematode Management, Crop rotation, Granular nematicides, Nematodes extraction, Wheat crop.*

1. Introduction

The Cereal Cyst Nematode (CCN), *Heterodera avenae* Wollenwebber, causes economic losses on wheat and barley crops worldwide: in North America, Europe and temperate areas in the southern hemisphere. It occurs in Middle East countries with cold winters such as Saudi Arabia, Syria and Turkey (Ibrahim AAM et al. 1999; Imren M et al. 2014).

CCN was detected for the first time in Saudi Arabia in the Gassim area (Youssif GM, 1987), and later on, it was reported to cause economic losses on wheat and barley crops in Al-Kharj and Hail (Al-Hazmi AS,1992).

Heavy infestation with CCN in sandy soil in Saudi Arabia reduced wheat yield by 40 – 92% and 17 – 77% on barley if no control measure was taken (Ibrahim AAM. et al. 1999). CCN was observed at TADCO in one wheat pivot on February 8, 2006, and later on the season, showed the presence of severe infestation of this nematode on small batches of a total of 14 pivots (Naser I et al., 2018).

This article is a review of research work published in May 2018 and research work carried out by the author during the period 2006 - 2011. The purpose of this study is to evaluate the methods utilized for the integrated management of cereal cyst nematode under a center irrigation system.

2. Materials

The nematode juveniles were extracted from a 250 ml soil sample using the modified centrifugal floatation technique (Ayoub SM, 1980). The roots were washed free from soil and stained with 0.5% hot acid lactophenol cotton blue and processed for nematode extraction and counting the number of J2's per root system (Southy JF, 1970). The extracted nematodes were examined under a microscope at 100X magnification. The nematodes of each soil sample were extracted into 50 ml water. The number of 2nd stage juveniles per 1 ml of water was multiplied by 50 and then by 4 to get the number of 2nd stage juveniles per one liter of soil.

3. Methods

To prevent the expected heavy losses on wheat yield, an integrated cereal cyst nematode management plan was implemented and executed into short-term and long-term management plans:

A. The short-term management plan:

- Survey of CCN infestations on wheat pivots; prepare a drawing of damaged areas at each pivot.
- Immediate granular systemic Nematicide treatment such as Nemacur 10G or, Furdan 10G or Vydate 10G on the damaged areas at each pivot at the rate 2 kg / 1000 sq.

meter 35 – 40 days after sowing (3 – 5 leaf stage) to suppress the nematode attack and eliminate damage to the crop.

- Top dressing of all pivots with granular NPK 14-38-10 (150 - 200 kg/Ha.) and granular potassium sulphate (100 Kg/Ha.) after herbicide spray was essential to enhance roots and shoot growth and compensate for the damage caused by the nematode.

B. The long-term management plan:

- Monitoring CCN infestations on the pivots on a yearly basis before sowing to check the suitability of each pivot for wheat planting, as the nematode density should not exceed 10 eggs/gram soil. Also monitoring CCN infestations on wheat pivots during the growing season to treat damaged areas with granular systemic nematicide and direct planting the infested pivots for crop rotation when the infested area was increased.
- Select pivots free from CCN infestations and grasses for the production of certified wheat seeds.
- Crop Rotation: two years of crop rotation of alfalfa or potato was carried out as they are not host to this nematode.
- Sanitation: Since the method of dissemination of this pest is through farm machinery such as harvesters and cultivators, care should be taken to avoid further spread of this pest to new pivots by cleaning the machines after farm operation and before the entry of new pivots.
- Soil Solarization: Land preparation for summer crops can affect cyst viability by direct solar radiation and heat; also, straw decomposition accompanied by the activity of soil microorganisms after pre-irrigation decreases cyst viability.

4. Results & Discussion

Field symptoms showed the presence of yellow batches ofstunted wheat plants (Figures 1.2.5.6), which was far less in their growth and size than normal healthy and green plants. Infested plants were with stunted and pruned root growth (Figures 1 and 2). The damage was more severe in light sandy soil than loamy soil.

Lab inspection of soil samples taken from the infested pivots showed the presence of CCN 2nd stage juveniles (J2) with sharply pointed tails and well-developed median bulb (Figure 3) and the presence of lemon-shaped brown color cysts (Figure 4) with a length of 0.5 - 1 mm with viable eggs inside the cysts confirms the infestation with this nematode (Williams TD and Siddiqi MR, 1972).

In February 2006, new infestations with CCN were discovered on wheat crops at TADCO. To prevent the expected heavy losses on the wheat yield, an integrated cereal cyst nematode management plan was implemented and executed into short-term plans and long-term plans, as mentioned under the materials and methods.

Due to the sub-Mediterranean climate, high water quality, irrigation management and skilled labors, TADCO achieved high quality and high yields of wheat grains during the period 2001 – 2011, and in 2003, average wheat production of an area over 5000 Ha reached 8.73 M.T./Ha (Naser I et al., 2018). To achieve a high yield of wheat, the farmers prefer to sow the seeds in this area during the period Mid December - mid-January every year. Unfortunately, the weather conditions during this period were favorable for cereal cyst nematode infestations.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

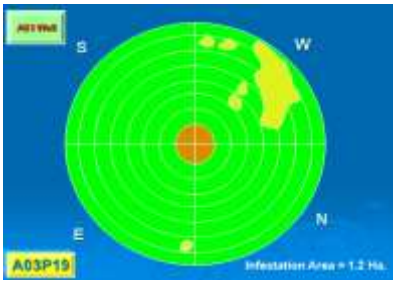

Fig. 5a

Fig. 5b

Fig. 6

Legend: Figure 1. Stunted wheat roots on the right and normal roots on the left; Figure 2. Bunch of stunted wheat roots due to CCN infection; Figure 3. Second Stage juvenile of CCN (J2); Figure 4. Matured Cysts of CCN are Brown in color with lemon shape; Figures 5a and 5b: yellow patches on wheat pivots infested with CCN in the 2007 cropping season; Figure 6. Yellow area of stunted wheat plants.

Table 1. Comparison of CCN infestations at two locations in Saudi Arabia

Analysis	TADCO, Tabuk, Feb 8, 2006(Pivot A3P19)	NADEC, Hael. Jan 12, 2001 (Pivot # 36)
Number of 2nd Stage juveniles/liter of Soil	5920	11849
Number of Cysts per 100 grams of Soil	13	70
Number of Eggs per Cyst	28	43
Number of Eggs/gram of Soil	3.64	30.1
Number of 2nd Stage juveniles/gram Root	476	ND
Number of 2nd Stage juveniles/one Root	31.7	108.3

Table 2. Comparison of wheat yield in three cropping seasons (2006 – 2008)

Comparison Item	Year of Production		
	2006	2007	2008
Number of Infested Pivots	14	15	43
Total Number of Wheat Pivots and Area	151 (7365 Ha.)	142 (7165 Ha.)	139 (6648 Ha.)
Damaged Area (Ha)	3.78	5.039	21.071
Percentage Damaged Area	0.05%	0.07%	0.32%
Wheat Pivots General Yield M.T/Ha.	7.991	8.001	7.647
Damaged Wheat Pivots Yield M.T/Ha.	6.91	6.98	7.47
% Yield Reduction Relative to each year	13.52	12.76	2.31

CCN infestations were prevalent in wheat-growing areas of Saudi Arabia such as Al-kharj, Gassim and Hael, and the estimation on yield reduction ranged from 40 - 92% on heavily infested soil in these areas, especially under the mono-cropping system (Al- Alhazmi AS, 1992). In this study, the number of CCN hatched juveniles in the soil samples taken from the yellow patches of stunted wheat plants at the early stage of seedling growth were utilized as a tool to evaluate the degree of infestation and the expected damage by the CCN on each wheat pivot as the level of damage is affected by the juveniles' numbers (J2) in the soil and the area of infestation. The method of extraction of the juveniles from the soil samples by the sieving and centrifuge method with sugar floatation was a rapid method, accurate and easy to conduct in a short period of time (Ayoub SM, 1980).

Results on the soil and plants of samples collected from two geographic locations in Saudi Arabia showed very high numbers of the different stages of CCN on both samples, and the soil infestation level at NADEC was higher than at TADCO due to the accumulation of infestation with this nematode on NADEC pivot # 36 over many years, see Table 1. Both samples have shown high levels of eggs/gram of soil and 2nd stage juveniles which could cause economic losses to the wheat crop in each season. Although the wheat seedling roots were less than 0.2 grams, they contained high numbers of juveniles per root system, which caused yellowing and stunted growth of plants seen on the damaged patches at each pivot. Both samples have shown a very low level of eggs/cysts. Summary results for the area of wheat crop infested with CCN and the yield in three respective seasons, 2006, 2007, and 2008, are represented in Table 2.

Under the integrated CCN management plan, the total area of infestation was 3.78 Ha in 2006, and it increased slightly to 5.039 Ha in 2007; in 2008, it increased to 21.071 Ha., and these figures correspond to 0.05%, 0.07%, and 0.32% of the total wheat area of each year respectively. Reduction in the yield of infested pivots compared to the mean production in 2006, 2007 and 2008 reached 13.52%, 12.76%, and 2.31%, respectively, as the damaged areas were treated with granular systemic nematicide and top dressing with granular NPK fertilizer 14-38-10 and granular potassium sulphate fertilizer. The damage was more severe in light sandy soil than loamy soil and more damage with continuous cropping. The productivity of infested fields was significantly less than non-infested fields.

Results on the effect of crop rotation and CCN infestations on the yield of wheat crops are shown in Table 3. Two years of crop rotation with alfalfa by direct drilling using the No-Till method was an effective control measure since wheat yield was increased by 2.31%. However, wheat yield was decreased by 12.99% after onion rotation due to grasses infestations. Continuous wheat cropping without following crop rotation led to increased infestations with CCN and grasses, and productivity decreased by 20.97%. Under the integrated CCN management plan over the period 2006 – 2011 with, an average of 7.77 M.T./Ha showed minimum yield reduction, which reached around 4.05% in comparison with the yield of 8.098 M.T./Ha obtained in 2005 when there were no CCN infestations. These results proved a great degree of success of the integrated management plan in minimizing the expansion of the infested area with the CCN and minimizing yield loss.

5. Conclusion

Integrated CCN Management plan at TADCO demonstrated a great degree of success and minimized the expansion of infested areas with CCN and minimized yield reduction to around 4.05% during the period 2006 – 2011 through the application of systemic nematicide on the infested spots of each pivot, the application of granular NPK 14-38-10 and granular potassium sulphate fertilizers and the implementation of two years crop rotation mainly alfalfa by direct drilling using No-Till method for wheat sowing, also the use of certified wheat seeds and machinery sanitation.

Table 3. Effect of crop rotation and CCN infestations on the yield of wheat crop

Type of Rotation	Continuous Wheat	Onion Rotation with CCN	Alfalfa Rotation With CCN	Alfalfa Rotation, No CCN	Potato Rotation No CCN	TADCO Grand Mean	TADCO 2005
Yield	6.14	6.76	7.95	8.68	8.83	7.77	8.098
Area (Ha.)	500	300	250	350	200	6 years	6648
% Change	- 20.97	- 12.99	+ 2.31	+ 11.71	+ 13.64	- 4.05	

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