Review Article

Host Biotic Factors Affecting Virulence of Corn Cyst Nematode, *Heterodera zeae* on Corn in Egypt

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Abstract | Four biotic factors respecting the corn plant affect the virulence of the corn cyst nematode, *Heterodera zeae* such as corn genotype, corn age, corn nutritional status, and cropping sequence regime. For the first factor, when two local corn cultivars, namely, Giza 2 (susceptible) and Kahera 1 (resistant), were subjected to the infection by *H. zeae* to determine the biotic effect of the host susceptibility on development and reproduction of the nematode, the final population and rate of build-up of the nematode were more remarkable on Giza 2 cultivar than on Kahera 1. Due to the high suitability of Giza 2 for nematode reproduction, there was more pronounced damage to plant growth in Giza 2 than in Kahera 1. As for the second factor, the nematode final population and rate of buildup correlated negatively with the host age, which multiplied highly and was more virulent on the youngest seedlings than on the oldest plants. Studies on the effect of N, P and/ or K fertilizers applied to Giza 2 corn on the behaviour of *H. zeae* revealed that the nematode population greatly varied according to the fertilizer type and level. When N, P, or K were used separately, the fertilized plants sustained the lowest nematode final population and rate of build-up as compared with those of the control plants; however, the recommended levels of these fertilizers caused the lower values amongst the applied fertilizers levels and achieved higher increase in the plant growth parameters. As for the N, P, and K used in different combinations, a similar trend was noticed when the recommended levels of the fertilizers were applied to plants. It is worthy of notice that when phosphorus was decreased or nitrogen increased, in combination with the other elements at their recommended levels, the nematode reproduced well and folded several times. Also, population dynamics of juveniles and cysts of *H. zeae* under the stress of a cropping sequence regime revealed that the average number in each stage greatly fluctuated. The density of juveniles or cysts gradually increased with the favorable host (Giza 2 corn) to reach its peak at the crop maturity, while the nematode population dropped sharply when the field became fallow. Likewise, the population densities of the previous stages declined gradually, even in the presence of the non-host crop (Egyptian clover CV. Meskawii).

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Introduction

The successful establishment of a plant parasitic nematode species depends on how much the environmental conditions favors its survival. Such environmental conditions usually involve both biotic and a-biotic factors. The biotic factors in a nematode environment are defined as including all other organisms existing in the habitat. The host plant is one of the most important biotic factors influencing the nematode's behaviour. The corn cyst nematode (CCN), *Heterodera zeae,* has been regarded as one of the most noxious nematodes to corn in several parts of the world. In Egypt, the CCN has been recorded in different localities by Aboul-Eid and Ghorab (1981), Ismail (1985), Abadir (1986), Moussa *et al.* (1988) and Ismail (2009). Some practical applications have been studied to take advantage of this case, which are discussed as follows:

Behaviour of H. zeae under stress of corn genotype in Egypt

The influence of host plants on the population behaviour of the pathogenic nematodes was extensively studied. Host cultivars are also one of the most influential factors affecting nematode infectivity and reproductivity. In the literature concerning cyst forming nematodes, there is ample information concerning the influence of susceptible and resistant hosts on nematode development and reproductivity. Koshy *et al.* (1970) in India found that *Heterodera zeae* cysts hatched and produced more cysts on maize cv. Ranjit than they did on other cultivars. Srivastava and Swarup (1975) reported that with maize cv. Rattan, the number of cysts per plant of the corn cyst nematode, *H. zeae,* ranged from 26 to 100, while with cv. Shakti, it appeared to be the maximum infestation as far as the cyst number was concerned, at almost 1000 cysts per plant. In Egypt, Aboul-Eid and Ghorab (1981) found that maize cv. Amricanibadri gave the highest final population of *H. zeae* cysts,whilemaize cv. Giza 102 produced the lowest final population of cysts. Ismail (1985) found that the highest number of *H. zeae* cysts and the nematode final population were found in corn cv. Giza 2, while the lowest value was obtained by Kahera 1. Hence, when two local corn cultivars, namely, Giza 2 (susceptible) and Kahera 1 (resistant), were subjected to the infection by *H. zeae* to determine the biotic effect of the host susceptibility on the development and reproduction of the nematode, Ismail and Kheir (2014a). They found that the final population and rate of build-up of the nematode were more remarkable on the Giza 2 cultivar than on Kahera 1. Due to the high suitability of Giza 2 for nematode reproduction, there was more pronounced damage to plant growth of Giza 2 than of Kahera 1. The same trend was observed with other species of cyst nematodes by several investigators: (Brown, 1974; Han and Lee, 1975; Phillips *et al.*, 1982; Magnusson, 1984; Elliott *et al.*,1986; Bishnoi, 2009; Toktay *et al.*, 2012).

Influence of the host age on development and virulence of H. zeae in Egypt

The host plant is one of the most important biotic factors influencing the nematode's behaviour. Some investigators had covered this point using other nematode species on different hosts. Fedorko (1962), Jorgenson and Mussenlman (1966), Griffin (1981), and Olthof (1983) found that sugarbeet seedlings became less susceptible to damage by *Heterodera schachtii* as they grew older and larger. Sensitivity of susceptible tomatoes or onions to *Meloidogyne incognita* or *Ditylenchus dipsaci* decreased rapidly with age of the plant (Bergeson,1968; Riedel,1969). Bhatti and Sasser (1972) and Rawsthorne and Hague (1986) used five different host ages and found that the older seedlings were less prone to infestation by *H. lespedezae* or *H. avenae* as compared to the younger and tender seedlings. As for *H. zeae*, Ismail and Kheir (2014b) studied four ages of corn, *Zea mays* L., cultivar Giza 2, to evaluate its influence on the infectivity, development, and virulence of *H. zeae*. They stated that the nematode final population and rate of build-up correlated negatively with the host age. The nematode multiplied highly on the youngest seedlings and was more virulent on the youngest than on the oldest plants.

Behaviour of H. zeae under stress of host nutritional status in Egypt

Host nutritional status is also considered as one of the most influential factors affecting nematode behaviour. The relationship between host nutrition and the development of cyst nematodes has been the subject of much speculation since Ross (1959) stated that fertilization with NH_4 NO_3 prevented much of the damage caused by *H. glycines* to soybean even though the final population density also increased. Lehman (1969) observed that nitrogenous compounds inhibited the emergence of *H. glycines* juveniles from cysts. Ross (1969) showed that in microplot tests,

fewer nematodes developed on a non-nodulating line of soybean fertilized with high rates of $NaNO_3$ as compared to those fertilized at medium to low rates. The application of $NaNO_3$ at 56 to 896 ppm N to the soil reduced *H. glycines* hatch, penetration and cyst development (Barker *et al*., 1971). Juhl (1975) found that maximum multiplication of *H. avenea* on oats and barley was at 46 kg N/ha, and with further increase in nitrogen level, the multiplication rate decreased progressively. In laboratory experiments, Grosse and Decker (1984) reported that 2-day action of 0.03% solutions of calcium ammonium nitrate, ammonium phosphate, ammonium sulphate, or ammonium nitrate on soil infested with *H. avenea* almost completely prevented the hatching of juveniles. Urea caused a strong reduction in larval hatching even at 0.03% concentration for 2-days. As for *H. zeae*, studies on the effect of N, P and / or K fertilizers applied to Giza 2 corn on the behaviour of *H. zeae* by Ismail and Kheir (2014c) revealed that the nematode population greatly varied according to the fertilizer type and level. When N, P or K were used separately, the fertilized plants sustained the lowest nematode final population and rate of build-up as compared with those of the control plants; however, the recommended levels of these fertilizers caused the lower values amongst the applied fertilizers levels and achieved a higher increase in the plant growth parameters.

Population dynamics of H. zeae under stress of a cropping sequence regime

Seasonal variations in populations of the corn cyst nematode or of other nematode species are due to seasonal circumstances and host crops. The population dynamics of *H. rostochiensis* on potatoes were studied by Evans (1969); he found that hatching and invasion occurred early in the season at low temperatures, and most juveniles in the roots were observed in May and June. Gair *et al.* (1969) observed that populations of *H. avenae* decreased under continuous and rotational spring oats and subsequently under spring barley. Chawla and Prasad (1973) and Khan *et al.* (1973) reported that monoculture of some crops resulted in the build-up of nematode populations, but proper crop rotation practices reduced the populations to safe levels incapable of inflicting damage. The effect of the non-host crop cultivars (alfalfa, barley, bean, onion, potato, and wheat) on *H. schachtii* population dynamics was studied by Griffin (1980). He found that the nematode population greatly decreased with onions and bean, more so than with any of the other crops including fallow. Kerry *et al.* (1982) found that spring oats were the cereal most heavily invaded by *H. avenae* and produced the smallest shoots. The juveniles invaded cereal roots in decreasing numbers, as follows: Springoats>autumn oats>spring barley > spring wheat > autumn barley > autumn wheat. Studies by Brown (1984) showed that crop rotations that include periods of fallow or non-host crops reduced population levels of *H. avenae* and improved yields. The results by Srivastava and Sethi (1986) revealed one high peak of *H. zeae* under maize-cowpea-wheat rotation coinciding with maize maturity, indicating host specificity. Ismail (2009) found that *H. zeae* numbers fluctuated greatly according to the cropping system used. In broad bean-corn and Egyptian clover-corn rotations, the population densities were low during the growing season of the winter crops (broad bean and Egyptian clover), then the nematode gradually increased as corn was grown and peaked in September and October for juveniles and cysts, respectively. However, in barley-corn and wheat-corn rotations, the nematode population is relatively high during the winter season, leaving considerable initial populations for the next crop. Subsequently, in the corn crop, the nematode multiplied rapidly, reaching peaks in August and September for juveniles and cysts. Moreover, Ismail and Kheir (2014d) found that the population dynamics of juveniles and cysts of the corn cyst nematode, *H. zeae*, under the stress of a cropping sequence regime greatly fluctuated. The density of juveniles or cysts gradually increased with the favorable host (Giza 2 corn) to reach its peak at crop maturity, while the nematode population dropped sharply when the field became fallow. Likewise, the population densities of the previous stages declined gradually, even in the presence of the non host crop (Egyptian clover CV. Meskawii).

Conclusions and Recommendations

Some host biotic factors, such as host genotype, host age, host nutritional status, and a cropping sequence regime,directly affect the virulence of the corn cyst nematode, *H. zeae*. Some practical applications have been studied to take advantage of this state to manage nematodes.

Novelty Statement

This manuscript deals with the most important host

biotic factors affecting the population density of the corn cyst nematode, *H. zeae*.

Author Contribution

Ahmed El-Sayed Ismail: Suggested the idea, collected the literature necessary for the manuscript, wrote and reviewed the manuscript. Also, the author read and approved the manuscript.

Conflict of interest

The author has declared no conflict of interest.

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