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Biology and life cycle of maize cyst nematode (*Heterodera zeae)*

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Abstract
The present study on biology and life cycle of maize cyst nematode was carried out under glass house, Department of Plant Pathology, College of Agriculture, Shivamogga to know the biology and time required to complete the life cycle of maize cyst nematode, *Heterodera zeae* on maize (Hytech 5402). The study revealed that, the second stage juveniles of maize cyst nematode, *H. zeae* are the infective stage and penetrated maize roots at 48 h of inoculation. After penetration, the third stage juveniles were observed on the 7th day of inoculation. Fourth stage juvenile at 13th and adult females at 18th day after inoculation were observed, respectively. The mature cyst of *H. zeae* was observed on the 23rd day after inoculation. Thus, the maize cyst nematode, *H. zeae* on maize complete total life cycle of 23 days after inoculation of second stage juvenile.

Keywords: Biology, *Heterodera zeae*, life cycle, maize

1. Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as "Queen of Cereals" because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having a wider diversity of soil, climate, biodiversity and management practices that, contributes 36 per cent (782 m t) in global grain production. The United States of America (USA) is the largest producer of maize contributes nearly 35 per cent of the total production in the world. According to the USDA world agricultural supply and demand estimates report, December 2018 maize production was forecasted 1099.91 million tons in 2018-19. Among the countries United States of America was stood first in maize production with 371.52 million tonnes followed by China (256mt), Brazil (94.50 mt), European Union (59.50mt), Argentina (42.50 mt) and India (26.50 mt) [1]. In India maize occupied second place after rice. It is cultivated over an area of 9.50 million ha and production is about 25.00 million tonnes with an average productivity of 2630 kg/ha. Although, the maize crop is grown in almost all states of the country but major area (about 70%) is covered by Uttar Pradesh, Andra Pradesh, Bihar, Rajasthan, Madhya Pradesh, Karnataka, Gujarat, Maharashtra, Punjab and Haryana [2]. Maize occupy an important place as a source of human food (23%), cattle feed (12%), poultry feed (51%), starch (12%), brewery (1%) and seed (1%). Maize grain contains about 10% protein, 4% oil, 70% carbohydrate, 2.3% crude fiber, 10.4% albuminoides and 11.4% ash. It also possesses vitamin A, nicotinic acid, riboflavin and vitamin E. It is low in calcium but fairly high in phosphorus [3]. Maize production in India and abroad is greatly affected by several biotic factors *i.e.* fungi, bacteria, insect pests and nematodes. Among them, plant parasitic nematodes are responsible to cause 10.2% losses on maize [4]. Plant parasitic nematodes *viz*., cyst nematodes (*Heterodera* spp.), lesion nematodes (*Pratylenchus* spp.), root knot nematodes (*Meloidogyne* spp.), stunt nematode (*Tylenchorhynchus* spp.) and spiral nematode (*Helicotylenchus* spp.) have been found to be associated with maize [5, 6, 7]. Nematodes also interact with other disease-causing agents (pathogens and soil insects) and adversely affect the quantity and quality of maize production. Among nematodes, maize cyst nematode, (*H. zeae*) is considered to be the most important nematode pest of maize in India [8]. It was first reported by Koshy *et al.* (1970) [9] from the Chhapli village of Udaipur district of Rajasthan. It is widely distributed in maize growing areas of Rajasthan, Delhi, Punjab, Haryana, Himachal, U.P., Bihar, M.P., Gujrat, Tamil Nadu, Karnataka, A.P. and Maharashtra [10, 11, 12, 13] reported yield losses of maize to the tune of 17-29

per cent by the maize cyst nematode, *H. zeae* in India at varied inoculum levels and soil conditions.

Recently outbreak of maize cyst nematode was noticed in parts of Shivamogga and Davanagere districts especially in Issuru village of Shikaripura taluk, Shivamogga district and Chikadadkatte village of Honnali taluk, Davanagere district [14]. Since, maize is a major crop in major junk of Karnataka, the maize cyst nematode *H. zeae* is considered as major threat and it has been increasing year after year in all the major maize growing districts of Karnataka. Since, no work has been carried out on maize cyst nematodes. Hence, the study was carried out with the aim to know the biology and life cycle of maize cyst nematode to tackle its infective stage for development of management options.

2. Materials and Methods

The study was conducted during the month of March under glasshouse condition by using seventy-five earthen pots filled with sterilized sandy loam soil and three seeds of maize (Hytech 5402) were sown in each pot. After four days of germination, one hundred freshly hatched second stage juveniles of *H. zeae* were carefully inoculated in rhizosphere of plant. After inoculation, three pots were deported initially at 6 h interval till penetration observed. Thereafter, pots were deported daily till mature cysts were recovered. The roots were carefully washed in running tap water in order to remove the adhering soil particles and stained with 0.1% acid fuchsin lacto-phenol solution. To remove excess stain, the stained roots were washed in running tap water and kept in clear lacto-phenol for at least 24 h before observation. The roots were examined under stereoscopic binocular microscope to observe the different stages of *H. zeae.*

3. Results and Discussion

H. zeae is the unseen enemy of a maize crop it also infects several hosts. It is soil borne and microscopic in nature. The investigation on biology and life cycle of *H. zeae* is presented in the table 1 and plate 1.

The results on biology and life cycle of maize cyst nematode revealed that, the infective second stage J_2 juveniles burrowed into the roots and they entered in to the root system within 48 h of inoculation and start feeding. Penetration was observed in zone of elongation and juveniles were found to penetrate both in the tap as well as in lateral roots. After penetration the juveniles were embedded to root system were seen. The results of the present investigation are in confirmatory with the findings of [15] who observed that, the J_2 of *H. zeae* prefer to penetrate meristematic tissue and the zone of elongation on maize and penetration occurs in 48-72 h. However, [16, 17, 18] reported different time interval for penetration of *H. zeae* on maize. The third stage juveniles J_3 were observed on the 7th day after inoculation and length of J_3 become shorter and wider as compared to J_2 stage. In the later stage, the juveniles developing into females showed the bifurcated development of the genital cells. The evidence of 4th stage juvenile was observed on the 13th day after inoculation. The female juveniles were observed to have thin cuticle and swollen posteriorly whereas, males remain in vermiform. Stylet of female was embedded inside the stellar region of roots and the rest of the body remains outside the maize roots.

Adult females of *H. zeae* were observed on the 18th day after inoculation, which was white in colour and was lemon shaped with reflexes and coiled ovaries. It has well developed neck and vulva with thin wall cuticle. The adult female started turning yellow/brown and change into a mature cyst after 23 days of inoculation. Several times the eggs retained in cysts are easily visible from outside due to thin cuticle of the cyst. The vulval cone was generally prominent and the sub crystalline layer was observed on new cyst. Then, vulval cone was prepared and critically examined under high power of the microscope; ambifenestrations were seen and identified as cyst of *H. zeae.* Thus, from the experiment it is clearly shown that, the life cycle of *H. zeae* from second stage juvenile to the formation of mature cyst was completed in 23 days of inoculation on maize (Hytech 5402).

The results of the present investigation are in confirmatory with the findings of [19] who reported that, *H. zeae* complete its life cycle in 25 days at a temperature range of 28-36ºC. Similarly [20], reported that, *H. sorghi* was able to complete its life cycle from the J_2 to the next generation J_2 in 24 days on maize cv. Deccan-103. However, different workers reported that, different time to complete the life cycle of *H. zeae* on maize [21]. Recorded the life cycle of the cyst nematode, *H. zeae* on maize was completed in 20 days [22]. Reported that, *H. zeae* took 22 days from the date of inoculation of second stage juvenile to the first appearance of newly hatched second stage juvenile [23]. reported that, the life cycle of *H. zeae* from the second stage juvenile (J_2) to (J_2) was completed in 15-18 days at 33ºC, while at 36ºC, 19-18 days were required on maize *cv.* Pioneer 3184 [24]. Reported *H. zeae* are the infective stage and penetrated sweet corn roots at 48 hours of inoculation. After penetration, the third stage larvae were observed on the 6th day of inoculation. Fourth stage larvae and adult females were observed at 13th and 19th day after inoculation, respectively. The mature cyst of *H. zeae* was observed on the 25th day after inoculation. Thus, the life cycle of maize cyst nematode, *H. zeae* on sweet corn took place in 25 days after inoculation of second stage larvae. The differences in time of juvenile's penetration might be due to difference in variety, degree of attractiveness of juveniles by the host roots exudates, temperature, soil moisture, soil type and other factors governing penetration during the course of the investigation.

Table 1: Biology of maize cyst nematode, *H. zeae* on maize (Hytech 5402)

Sl. No.	Developmental Stage	Time after inoculation of second stage larvae
1	Penetration (2nd stage larvae)	48 h
2	3rd stage larvae	7th day
3	4th stage larvae	13th day
4	Adult female	18th day
5	Mature cyst	23rdday

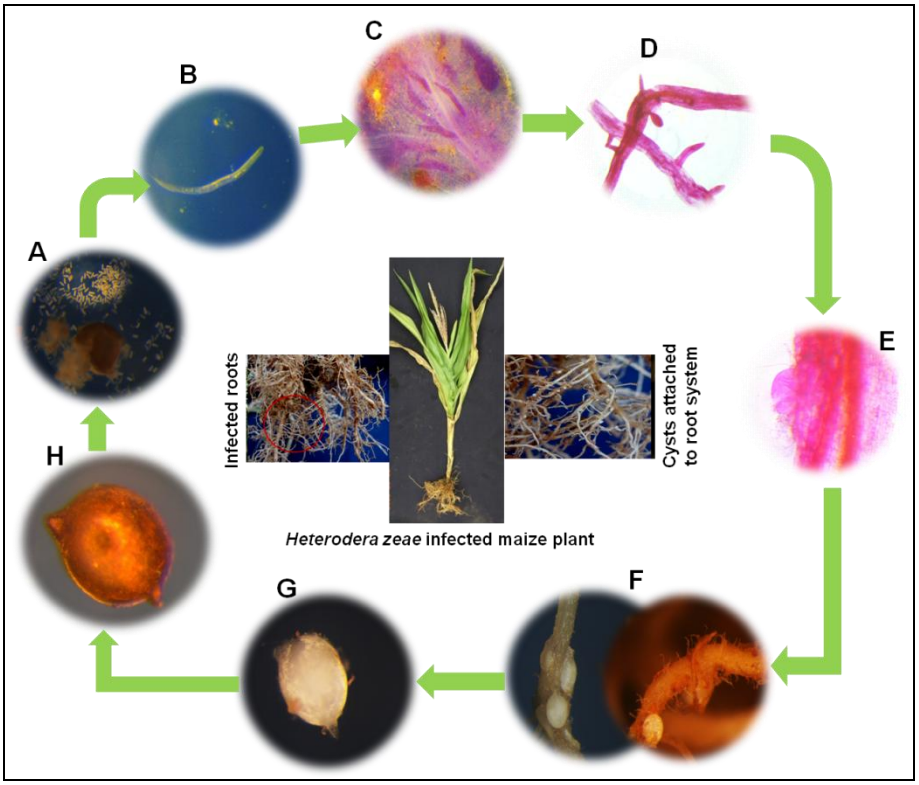

Plate 1: Biology and life cycle of maize cyst nematode (*Heterodera zeae*); A) Eggs, B) Second stage infective juvenile (J_2), C) Third stage juveniles embedded in stained root system, D) Stained roots showing immediately transformed J_2 to J_3 Female stage, E) Stained and fully developed female (J_4) embedded with root system, F) Mature female embedded with roots, G) White cyst, H) Mature Cyst

4. Conclusion

The present study revealed that, the second stage juveniles were attracted to the roots and moved towards the root tip. Infective second stage juveniles (J_2) entered the roots at 48 h of inoculation and they started feeding. After penetration, the third stage juveniles were observed on the 7th day of inoculation. Fourth stage larvae and adult females were observed at 13th and 18th day after inoculation, respectively. The mature cyst of *H. zeae* was observed on the 23rd day after inoculation and total life cycle completes within 23 days after inoculation of second stage juvenile. These differences in time taken by the nematode to complete its life cycle may be attributed to crop variety, soil type, and other physico-chemical properties of soil such as temperature, moisture, relative humidity *etc*.

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