Review Article

Effect of Artificial Mediated Abiotic Components against Plant-Parasitic Nematodes

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Abstract | The artificial mediated abiotic components such as soil temperature, dry heat, irradiation and CO_2 can work for controlling plant-parasitic nematodes. Higher soil temperatures with transparent or black plastic cover reduced citrus nematode, *Tylenchulus semipenetrans* on navel orange and reniform nematode, *Rotylenchulus reniformis* on sunflower. Also, dry heat was used to control rice root nematode, *Hirschmanniella oryzae* on rice soil and root and wheat soil. Several investigators reported that number of galls and egg-masses of root-knot nematode, *Meloidogyne incognita* on roots of several plants were reduced gradually by increasing gamma irradiation doses. When tomato plants infected by root-knot nematode, *Meloidogyne incognita* were exposed to combined elevated atmospheric CO_2 concentration (+100 ppm) and higher temperature (+2°C), tomato shoot dry weight and nematode control were increased compared to prevailing conditions.

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Introduction

Climate change scenarios are now occurring with a 2-3 °C increase in average annual temperatures, shifts in the location and frequency of precipitation and a 200% increase in the amount of carbon dioxide (CO_2) in the atmosphere are expected to occur by the end of the 21st century (Stott *et al*., 2010). High concentrations of CO_2, irradiation and temperature could seriously affect global crop productivity requiring mitigation strategies to adapt to climate change. These factors are affecting on ecosystems and certain harmful microorganisms such as plant-parasitic nematodes or some beneficial microorganisms as root fungi called mycorrhizae colonizing the plant roots (Treseder, 2004) and bacterium called *Pseudomonas fluorescens* living in the rhizospheres of some plants. Sensitivity to some climate changes such as temperature is known for plant parasitic nematodes, when most of their stages exposed to temperatures above 40°C may be killed (Santmeyer, 1955). The numerical fluctuation of some plant parasitic nematodes, among which spiral nematode, *Helicotylenchus* spp., root-knot nematode, *Meloidogyne incognita*, reniform nematode, *Rotylenchulus reniformis* all a year around was correlated negatively or positively with naturally occurring soil temperature (prevailing temperature) (Youssef and El-Nagdi, 2020). Some practical applications have been studied to take advantage of this phenomenon; which are discussed as follows.

Utilization of solarization for reducing numerical density of nematodes

A practical application of climate change is that, in summer months, the temperature of the sun can be used to heat the soil for reducing the population of nematodes in the soil before planting. Soil treatment between three to six weeks where the temperature rises by an average of 3-5°C above the normal air temperature causes the killing of large numbers of nematodes and this method is suitable for protected agriculture under plastic greenhouses and small areas (Ibrahim, 2010). For citrus nematode, *Tylenchulus semipenetrans,* Ismail *et al.* (1997) found that treatment with transparent or black plastic cover for soil planted with navel orange trees infested with citrus nematode resulted in a decrease of nematodes in soil and roots by 9.3-95.8% and improved vegetative growth and production of fruits compared to untreated control. They found that treatment with transparent cover was better than black cover as transparent plastic sheeting provides more heat energy and warmth to the soil than black sheeting through transporting solar radiation to the soil. Pakniyat (2014) found that the percentage of citrus nematode, *T. semipenetrans* survival on sweet orange trees reached or near zero in all treatments of soil solarization. There were no increases in the citrus nematode populations, three months and one year after soil solarization. The vegetative, as well as the reproductive factors of the treated trees were enhanced in the consequent year, which may be due to severe reduction of citrus nematode. After soil solarization, the mean yields in different treatments were increased from 71.6-77.9 and 70.2-77.8% compared to the initial measurement and control, respectively. These results were consistent with the findings of Al-Asad and Abu-Gharbieh (1990) who found improving in growth and yields of tomato and eggplant infested with certain fungi and nematodes in covered treatments. This operation is useful in cold areas or in early plantations where plants are growing at cool times of the year. Also, this method is useful for killing grass weeds and inhibiting them as these grasses are considered as alternative hosts to plant-parasitic nematodes (Thomas *et al.*, 2005; Gharabadiyan *et al.*, 2012). Farahat *et al.*, (1994) showed that the numerical density of reniform nematode, *R. reniformis* on sunflower in microplots was significantly reduced after two weeks of coverage with a transparent plastic cover as the reductions reached 85/ 20 cm^3 density i.e., 75% at 52 and 38°C at depths 5-and 20-cm, respectively. The nematode reduction percentages have increased to 93 and 97% after 30 and 45 days of treatment, respectively.

Utilization of dry heat in reducing nematode density

The burning crop wastes as practical application to reduce the numerical density of the rice root nematode, *Hirschmanniella oryzae* after rice and wheat harvested in contaminated soil was carried out where nematodes survived in soil after migrating from the decayed roots and associated weeds. Bary *et al.* (1992) found that the thermal control of the rice root nematode, *H. oryzae* when rice and wheat stubbles and wastes present after their harvest were set fired, proved to be an effective operation that drastically lowered the rice root nematode population and caused a reduction of 77.8% in rice soil and roots i.e. The host to the rice root nematode and by 74.7% in soil of wheat (Non host). This method is useful for killing grass seeds and inhibiting them as these grasses are considered as alternative hosts to rice root nematode (Abd-Elbary *et al.*, 2012). The reduction of nematodes is due to the fact that the gases released during the burning of the wastes permeate into the soil particles, kill or cause poisoning of the nematodes found in the soil and the roots of plant heels left in the soil after the harvest. Nematode death may be referred to inhibition of enzymes in nematode body when temperature becomes above 50°C at which enzymes become inactive. The optimum temperature of enzyme activity is about 40°C (Santmeyer, 1955). This explanation differed from the old assumptions that nematode death was due to clotting of proteins (Brand, 1960). On the other hand, dry heat was more useful than sterilization because it caused the disposal of grass seeds and germs of some bacteria and fungi (Heald, 1987).

Effect of irradiation on root knot nematode

Irradiation is applied to have few risks when properly employed. Many reports on the effect of gamma irradiation (γ) on plants focused on metabolic alterations, growth and development, and changes in biochemical pathways, especially physiological behavior (Jan *et al.*, 2012) that may be influenced by ionizing irradiation (Rayis and Abdalla, 2014). On the other hand, genetic variability in crop plants induced by gamma irradiation for controlling root-knot nematode on sugar beet has widely been used (Kamel *et al.*, 2011). The results by Abdel-Fattah *et al.* (2008) mentioned that numbers of galls and egg-masses on sugar beet roots were reduced gradually by increasing gamma doses. In breeding grapevine rootstocks using gamma radiation, similar results were obtained. However, increasing of irradiation doses at 20 Gamma rays and upwards, they decreased the rate of survival and shoot growth of *in vitro* derived plants (Lima da silva and Doazan., 1995). Taha *et al.* (2020) proved that irradiated banana plants could control

M. incognita, as they tolerated to its infection when exposed to 10 Gamma rays whereas, plant growth parameters were improved.

Effect of temperature and CO_2 on some antinematode microorganisms as well as on plant growth

Climatic changes including temperature and carbon dioxide (CO_2) have affected control of root-knot nematode, *M. incognita* and two antimicrobial microorganisms. Utobo *et al.* (2016) have shown that nematode infected tomato plants were treated with arbuscular mycorrhizal fungi (AMF) and bacterium, *P. fluorescens*, living in the rhizospheres of most plants, to control root-knot nematode under changing conditions. These changes were done by increasing the prevailing temperature (+2°C) and raising the level of carbon dioxide (+100ppm) compared to prevailing climate conditions of temperature and atmospheric carbon dioxide. The same authors (Utobo *et al.*, 2016). added that the treatment with mycorrhizae and bacterium together was the best in causing nematode reduction, disease index and the control rate under the changing climatic conditions compared to prevailing conditions. As for plant growth, it was found that shoot dry weight of tomato was significantly better in the treatment with root-knot nematode added with AMF either alone or in combination with bacterium (Mycorrhizae+bacterium+root-knot nematode > mycorrhizae+root-knot nematode) than in the control and root-knot nematode only under prevailing temperature. But dry shoot weights were significantly higher under changing climate than under prevailing climate.

Conclusions and Recommendations

Some abiotic factors such as soil temperature, irradiation and changes in CO_2 amount are directly affecting on ecosystems and certain harm microorganisms associated with plants such as plant parasitic nematodes or indirectly through beneficial microorganisms such as root fungi called mycorrhizae and bacterium called *P. fluorescens* living in the rhizospheres of some plants. Some practical applications have been studied to take advantage of this phenomenon to manage nematodes.

Novelty Statement

This manuscript deals with the most important abiotic factors affecting the population density of plant parasitic nematodes.

Author's Contribution

Mahmoud M.A. Youssef: Suggested the idea, and wrote the manuscript.
Wafaa M.A. El-Nagdi: Reviewed the manuscript and collected the literature necessary for the manuscript.
The both authors read and approved the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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