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QUALITY STATUS OF NUTRIENTS, VITAMINS AND HORMONES UNDER PATHOLOGICAL THREATS IN TOMATO: BASIC SCENARIO

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ABSTRACT

Plants are most attractive biological resources because of their ability to produce a huge variety of chemical compounds, and the familiarity of production in even the most rural settings. Alkaloids, terpenoids, steroids, polyketides, phenylpropanoids and flavonoids are among the economically important compounds derived from plants. By comparison, bacteria and mammals together produce around 3000 economic natural products. Agronomic traits such as herbicide tolerance, insecticides, nematodes resistance, disease-tolerance, and delayed ripening, were initial focus of crop improvement during these days through genetic recombinant DNA technology. Among all the crop quality damaging parasites, nematode infection occupies a most significant position. In this paper, we review the status of neutraceuticals under nematode infection.

Keywords: Rec-DNA technology, Meloidogyne incognita, Improvement, Hormones and Vitamins.

INTRODUCTION

The root-knot nematode, *Meloidogyne incognita* is a root infecting sedentary endoparasite which has evolved very specialized and complex relationship with its hosts. It attacks a wide variety of cultivated plants and causes heavy economic damage world-wide [1]. The epidemiology of root-knot disease is well known. Epidemics are initiated by primary infection from the egg mass that persists in the soil following infection of previous crop and from which second stage juveniles (J2) hatch, migrate and infect nearby root within the root system. Further nematode development depends upon the formation of the giant multinucleated feeding cells. Giant cell is a multinucleate transfer cell in which the multinucleate condition results from multiple mitosis in absence of cytokinesis. Giant cell formation is not accomplished by wall dissolution [2]. Swelling of the cortical cells around the giant cells gives rise to galls on the roots of infected plants that are characteristics of parasitism by root-knot nematode. Female nematode obtain nutrients from the plants via the giant cells and eventually produce egg masses from which a new generation of second J2 hatch and spread to fresh roots, thus initiating the secondary phase of the epidemics [3]. Meloidogyne species are distributed world-wide and are obligate endo-root parasites of thousands of plant species including monocotyledons, dicotyledons, herbaceous and woody plants and also occurs in 23 of 43 crops listed as major important crops ranging from field crops through pasture and grasses to horticultural, ornamental and vegetable crops. The root-knot nematode, Meloidogyne species infect plant roots causing the development of the root-knot galls that drain at the plants photosynthates and

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nutrients. Therefore, their nuclei varied in size and other characteristics like their shape which can be elongate, pyriform or dumb-bell like [4]. The genus Meloidogyne includes more than 60 species with some species having several races. Four Meloidogyne species viz., *Meloidogyne incognita*, *M. arenaria*, *M. javanica* and *M. Hapla* are major pests' world-wide. Females of root-knot lay eggs into gelatinous materials which are produced by six rectal glands and secreted before and during egg formation [5]. The matrix initially forms a canal through the outer layers of the root tissues and later surrounds the eggs, providing barriers to water loss by maintaining a high moisture level. The root-knot nematode, Meloidogyne species due to their world-wide distribution, exceedingly wide host range and interaction with fungi, bacteria and viruses are one of the major plant pathogens. They affect the world's food production and thus are called as "King of Pest". Besides this, Meloidogyne species are important pests of vegetables especially in tropical and subtropical countries. Till now more than 2000 different plant species have been listed in host index of Meloidogyne species [6].

Nutrients

The quality of nutrients which crops take up during growth depends very much on crop species and yield. Both crop yield and nutrient uptake also depend considerably on the choice of crop cultivar, since it has been seen that the new high yielding varieties contain higher nutrient requirements because of their increased yield potential. The mature grains of cereals crops contain about 70 percent of both total nitrogen and phosphorus of the aerial plant parts. Most potassium, however, occurs in the green plant parts and as little as 25 percent of the total potassium of plants. Fertilizers containing nutrients such as super phosphate (P), murate of potash (K) and ammonium nitrate (N) and a mixture of ammonium nitrate with calcium carbonate called "Nitro-Chalk". These fertilizers potentially differ in N, P and K. They are rapidly taken up and required in high quantities by crops. Nitrogen is mainly given in the form of nitrate, ammonium or urea. More specialized fertilizers contain N in a more insoluble form. These forms are slow release N sources. In a small number of phosphate fertilizers, P is present as polyphosphates. An important criterion of phosphorus fertilizers is solubility. Potassium is applied to soils mainly as chloride or sulphate forms. Potassium nitrate and potassium polyphosphate play only a minor role [7].

The extent to which nutrients are transported down to the soil profile varies considerably between soil layers. It depends mainly on the climate; soil type and quantity of the nutrients present in the soil in readily soluble form. Free drained soils are very prone to nutrient removal by leaching. The leaching of plant nutrients not only depends on rate of percolation but also on the quantity of nutrients present in upper soil layers. The rate of leaching of nutrients is highest on light soils and lowers in heavy soils where the rate of percolation is low. Of the major plant nutrients; phosphate is leached at the lowest rate. In inorganic salts, higher rate of phosphate leaching may occur as phosphate is less strongly bund to soil particles [8]. The process of leaching of nutrients in soils is affected by plant cover also. Generally high leaching rates are often found because of absence of a nutrient demand by a growing crop. The differences are particularly marked for nitrogen and potassium which are required and taken up by plant roots at a very high rate. Leaching losses are generally higher in widely spaced crops such as grapes, maize etc.than higher density crops.

Crop Losses

Meloidogyne species attack an array of economically important crop plants affecting them both quantitatively as well as qualitatively. Vegetables, cereals, pulses oilseeds crops and fibres yielding crops fruit trees, plantation crops and ornamentals etc are affected by root-knot nematode on world-wide basis. The infection of young plants may be lethal, while infection of mature plants causes decreased yield [9].

Meloidogyne damage results in poor growth, a decline in quality and yield of the crops and reduced resistance to other stresses like drought and other diseases. A high level of root-knot nematode damage can lead to total crop loss. Nematode damaged roots do not utilize water and fertilizers effectively; leading to additional losses for the growers.The crop loss is defined as the differences between the attainable yield and actual yield [10]. The knowledge of crop losses is an important aspect for establishing research, extension and budget priorities.

Generally vegetables crops grown in warm climates can experience severe losses from root-knot-nematodes and are often routinely treated with chemical nematicides. In case, where the crop losses are not spectacular the control depends upon the population density of the nematodes and other conditions like fertility, moisture and presence of other pathogenic organisms in the soil which may interact with the nematodes.

Estimated crop losses due to Meloidogyne species in major geographical regions of the tropics range from 5 percent to 43 percent. This, however, varies depending upon the crops, the species and the geographical regions. In areas, where management practices for root-knot nematode are not practiced average crop yield losses are estimated to be about 25% with the damage in individual fields ranging as larger as 60 percent [11]. On the world-wide basis, the average annual loss of all the crops has been estimated to be about 10% especially when the indirect effects of nematodes are considered [12].

Host Description

For the effective measurement of the status of nutrients, vitamins and hormones after infection of *Meloidogyne incognita* in a plant, a host upon which the net outcome is measured, is a pre-requisite. For this purpose a seasonal crop tomato *Lycopersicon lycopersicum* L. cv. K-25 (Family Solanaceae) was selected.

Tomato is an unarmed spreading, pubescent seasonal herb with a strong characteristics odour and greenish, green curled, unevenly pinnate leaves found cultivated throughout the world. Fruits are villose when young, glabrous and shining when mature, seeds flat, kidney shaped and hairy. Tomato is a more cultigen than a natural species. The cultivation of tomato on a commercial scale in India began towards the close of the last century. It has now become a popular vegetable and is cultivated extensively, particularly in the vicinity of large towns and cities [13].

Generally plant is propagated by seeds sown in nursery beds and seedlings are transplanted in the fields. Seeds may also be sown directly in the field. The plants are quite sensitive to frost and did not normally set fruit when night temperatures fall below 18 °C. In host wet weather and in good soils, the tomato grows vigorously but wet weather in the tropics with low sunshine and high temperature results in excessive growth. In temperate areas tomatoes are often grown in glass houses. However, glass houses tomato production is a big industry in northern Europe. The stage of maturity at which tomatoes are picked depends on the purpose for which they are grown [14].

Economic Value

It is one of the major vegetable plants. Fruits contain 1.6-6.4 (8%) sugars, vitamins-C (14-94% mg/100gm), fibres, citric acid and maleic acid, carotene, salts of iron, potassium, and phosphorus. Fresh tomatoes are processed by the canning industry in juice, puree, sauce, salted and pickled vegetables. It is a valuable dietary product. Chafed fruits gave a strong bacterial action. Compared with oranges, tomatoes contain nearly twenty times as much vitamin-A, the same amount of Vitamin B1, slightly more vitamin B2, and over two thirds of Vitamin-C [15].

It is now familiar ingredient of salads, being valued for its colour, distinctive flavour and pleasing acidic taste in the fresh, canned or preserved state. Fresh ripe fruits are refreshing and appetizing. A large proportion of the crop is used in the preparation of tomatoes soups, pickles (green tomatoes) and other products. The seeds contain about 24% semi-drying oil which is used as a salad oil and also in the manufacture of margarine and soap. The residual mass or press cake is employed as a feed and fertilizers.

In the early 19^{th} century, researchers, governmental and non-governmental agencies noticed that phyto-nematodes were causing huge losses to agriculture. Thus, to prevent these huge losses, scientific studies and observations should be undertaken seriously throughout the globe. Therefore, the current study was carried under in vitro as well as under glass house conditions, in order to observe the nemato-toxicity of various inorganic compounds against the root-knot infestation caused by *Meloidogyne incognita*.

Review of Literature

Vegetables constitute one of the most important groups of the cultivated plants in India and provide a good source of income to growers and constitute an important part of human nutrition. Therefore, they are considered as protective supplementary food and contain large quantities of carbohydrates, minerals, vitamins and essential amino acids of human metabolic processes. Vegetables are quick growing and yield immediately momentary returns. There cultivation as such occupiesan important place in agricultural developments and economy of each country. In India about 2-5 percent of the total cropped areas are under vegetables cultivation. This area is, however, inadequate to meet the recommended requirement of 280 g of vegetables per day for human consumption. At present the total intake of vegetables per capita is only 58 g [16].
Tomato is one of the most important vegetables crops in India. *Meloidogyne incognita* causes galls on the roots and is often associated with social sickness problems in India. Tomato is supposed to be a good host for root-knot nematode, *Meloidogyne incognita* [17]. Root-knot nematodes, Meloidogyne species are cosmopolitan nematodes infecting a wide range of economically important plants. It has been well established that plant-parasitic nematodes are limiting factors in the crop-production. In United States alone estimates of losses range from $500,000 to $1590326 annually [18].

The development of diseases caused by plant-parasitic nematodes is related to many variables including the nematode populations, presence of other microorganisms, susceptibility of host plants and various environmental factors like temperature, duration of growing season and availability of nutrient etc. Deficiencies of certain elements affect the susceptibility of plants, while deficiencies of other essential nutrients have no apparent effect. Nematodes itself influenced the nutrient uptake and the nutritional balance of the plants, consequently causing deficiency symptoms in the above ground parts of the infected plants. Excess of N in general has been considered to favour the development of the disease [19]. Excess of P and K on other hand, produces resistance to the plants against diseases. There excess reduces the damage chance from many diseases [20].

There are ample evidences that inorganic fertilizers neither suppress the population of nematodes nor promote their reproduction. Even the application of ultra-optimal doses has failed to mitigate the severity of the infection [21]. It is at the same time that severe infection by nematode caused deficiency symptoms e.g., potassium. The earlier work deals either with the effect of mineral elements on the host in relation to nematodes when supplied with the different levels of nutrient. Bird [21] pointed out that low level of inoculum of *Meloidogyne incognita* caused no significant change in the nutrient status of tomato plants. However, high inoculum density of nematodes resulted in an increased accumulation of N, P and K in the infected roots.

Heald and Jenkins [23] found significantly higher amount of calcium and potassium in the leaves of Ilex rotunda and N in the leaves of *Berberis juliance* when inoculated with 10,000 specimens of *Pratylenchus penetrans* but in roots, more of N and less of calcium. Application of N marked by increased in N percentage in both healthy and infected plants.

Peris and Jehle (1983) found that lima bean heavily infected with root-knot were deficient in P despite the fact that the sufficient P was present in the soil. Bird [21]studied the rate of the growth of *Meloidogyne javanica* at different populations level in tomato grown on either full nutrient or in absence of N and found that at low inoculum level, there was an accumulation in the growth of nematodes in N deficient plants than higher inoculums level. This rate was declined and significantly less in plants grown on full nutrients. At highest inoculum level, the rate of growth of nematodes in both the treatments was considerably reduced.

McClure and Viglierchio [25] observed that the rate of development of *Meloidogyne incognita* was decreased at low concentration of sucrose and Fe chelate decreasing the concentration of vitamins and macro nutrient salts were much larger and less compact than those on plants grown in complete nutrition. David and Triantaphyllou [25] reported that the development rate of Meloidogyne incognita was retarded in tomato plants subjected to deficiency treatments of N-P-K, N-P-N, K-P-K and P-N-P. In tomato plants infected with Meloidogyne incognita and *M. javanica*, the absorption of P^{32} as well as dry weight of the plants was adversely affected. In healthy plants on the other hand, the absorption of N, P, K and Mg was higher as compared to the diseased plants. Thus, they concluded that root-knot infection adversely affected the absorption translocation capacity of the plants.

In the roots of Okra plants infected with *Meloidogyne incognita*, there was greater accumulation of N, P and K as compared to the roots of healthy plants. Moreover, the aerial parts of the infected plants contained less N, P and K as compared to unaffected parts and thus showed deficiency symptoms [26]. Bergesson [27] reported that sensitivity of tomato seedlings to Meloidogyne incognita infection was correlated with the age of the seedlings and seedlings reduced in growth had normal levels of major and minor elements. He concluded that root-knot could cause extreme growth reduction even when plants had sufficient nutrition, possibly due to imbalance in growth regulators.

Hunter [28] while studying the nutrient absorption and translocation of P in plant infected with *Meloidogyne incognita*, found that dry weight of tops of infected tomato plants was significantly greater than that of infected plants except those at the lowest nutrient level. He then concludes that the detrimental effect of the root-knot nematode on the growth of tomato plant can be not being attributed to interference with the absorption/translocation of mineral elements.

Marks and Sayre [29] found retarded development of Meloidogyne incognita in the roots of *Cucumis sativus* L. var. Burpee receiving low levels of K, whereas at higher levels not only rate of development was accelerated but greater number of nematodes reached maturity. They concluded that root-knot development caused by *Meloidogyne incognita* depends upon the host metabolism and is indirectly influenced by K level on the host. However, no such correlation with *Meloidogyne hapla* or *M. javanica* was found.

The root-knot nematode population in the soil was affected by high concentration of ammonia, N, P and K. Further light soil proved conducive to their multiplication, while heavy soils inhibited their growth. Dickson and Mitchell [30] were able to increase the yields of nematodes infected sugar beets from 1000 to 12000 kg per hectare by applying K fertilizers. They further reported that *Heterodera schachtii* infection did not disturb the absorptive ability of the roots of the sugar beets but markedly influenced the uptake of nutrients especially that of K consequently the infected beets existed K deficiency symptoms.

Fayad and Sweelam [31] reported application of single super phosphate as a source of P, reduced population of *Meloidogyne javanica* on tomato and thus increased nutrient uptake and tomato growth. Wood [32] studied the effect of two species of root-knot nematode namely *Meloidogyne javanica* and *M incognita* on growth and nutrient status of resistant and susceptible plant seedlings. They found that when these seedlings were inoculated with different inoculum densities of Meloidogyne *javanica* the weight of roots and tops increased with moderate inoculum level but decreased considerably with highest inoculumdensities. In resistant variety, the Mg and Fe contents increased with the increase in inoculum. However, when they inoculated the seedlings with both the species of the nematode, the variety which was resistant to both the species was found to have increased amount of Mg, K and Ca in the leaves. The variety which was resistant to *Meloidogyne incognita* but not to *Meloidogyne javanica* has increased amount of K and variety which was susceptible to both the species of Meloidogyne was found to have more K whereas Mg and Ca tended to increase with the increase in inoculum of both the nematode species.

Von Monde and Bloodows [33] observed that inoculation of chilli plants with Meloidogyne incognita and *Pratylenchus penetrans* and only reduced the fresh and dry weight of tops but resulted in greater accumulation of N, P, K and Ca in the roots of infected plants. Nematode reproduction rate was increased by fertilizer but at the same time the plants become more tolerant to attack. An increase of potassium either alone or with other fertilizers increased the reproduction rate of nematode as well as the tolerance of plants to attack.

Badra [34] reported that roots of the boxwood infected with *Pratylenchus* species contained higher level of N and Na while roots of uninoculated plants contained higher levels of P and K. Sugar beet infected with *Hetrodera schachtii* were characterized by low calcium P, Mg, N and low K and therefore, concluded that the plants were deprived of these elements as a result of nematode infection (Mishra and Bajaj, 1999).

Lingaraju [35] observed that the population of the Pratylenchus species increased with increase of P content of leaves of sour cherries. The highest population of *Xiphinema* americanum and *P. penetrans* occurred at low K concentration whereas, those of *Helicotylenchus dihystera* at high K concentration. The application of high K fertilizers and K chloride both reduced the cysts of *Heterodera schachtii*on the beets. However, in the former there was an increase in the size of the roots, where in the later neither the yield nor the sugar content were affected. Further there was no relationship between the potassium contents of the roots and the infestation level [36].

Total dry weight of tops of tomato plants infected with *Meloidogyne incognita acrita* was significantly reduced and the leaves showed chlorosis indication malnutrition. However, there was no indication that a deficiency existed because of the nematode infection. On the contrary, where significant differences in the nutrient contents occurred in the higher content in infected plants. Verma and Jain [37] while studying the effect of host nutrition on the development of the cabbage yellow on the susceptible moderately resistant variety of cabbage found that in the absence of the K, the rate of disease development increase in the susceptible variety when N and P.

Borah and Phukan [38] found that Lima-beans heavily infected with root-knot were deficient in the P despite the fact that sufficient P was present in the soil. They studied uptake of P^{32} in the healthy and galled tomato roots and observed that the P content of nematodes present in the roots remained uniform as if they did not take the P from the roots during the course of their development and the galled roots absorbed this element at a slower rate as compared to healthy roots. The presence of nematode did not prevent the translocation of P. Seed inoculation with efficient strain of *Rhizobium* is pre-requisite for harvesting maximum symbiotic N and yield of legume crops. One of the important desired characters of the efficient strain is the ability to recycle N which enhance N fixation. But some pathogen like *Meloidogyne incognita* caused significant reduction in the N fixation and yield. However, when pathogen infected the roots simultaneously, the damage is extensive [39].

Influence of some commonly used in-organic fertilizers on rice root-knot nematode, *Hirschmanniella oryzae* under field conditions and fund that therate of N at 60 kg N/ha was useful for managing the nematode and increasing grain yield. Rajendran and Saritha [40] observed that among all the nutrients tested in tomato plant against *M. incognita*, silica recoded higher shoot length over control while the plants grown from the K sulphate recorded lower percent in increase over control and also observed that among the nutrients, silica was found superior to other treatments in reducing the nematode population.

Perveen et al [41] observed a positive relationship between the initial inoculum levels of *Meloidogyne incognita* and reduction in shoot, root/sucker fresh and dry weights, oil yield, total chlorophyll, total phenol and total sugar content of fresh leaves. Reduction in different growth parameters (length and weight of plant, number of pods), chlorophyll content of leaf and water absorption of roots caused by *Meloidogyne incognita* and *Rotylenchus reniformis* were statistically significant [42-44]. Kodandra and Rao [45] concluded that luxuriant plant growth due to the exogenous application of WSF of rice polish and pyridoxine may help the plant to escape nematode attack or have a key role in the defence mechanisms of the plants to pathogens directly.

Melillo [46] showed that plant treated with ascorbic acid, nicotinic acid and riboflavin were found effective in reducing reproduction of Meloidogyne incognita on tomato plants. Dev and Gupta [47] studied the effect of N, P and K application against *Heterodera* cajani on cowpea by taking N, P and K in the form of urea, single super phosphate (SSP) and murate of potash respectively and mixed them with the soil in the various combinations viz., NPK, NPPK, KN N, P, K and observed that plant length (root and shoot) and weight, root nodulation and total number of cysts (per pot and per g root). The total cyst population was significantly reduced with all fertilizers treatments compared to control (no fertilizers). Significant reduction in cyst population was recoded with K treatment alone/or in various combination with P or N. Significant increase in plant growth parameters viz., shoot length, shoot weight, root length and root weight was found in all fertilizer treatments as compared to control. Among the treatments, K treated pots were found to have significantly higher plant growth. The plant growth increased in nutrients receiving higher doses of fertilizers compared to lower does. Reduced in nematode reproduction at 150 kg/ha may be attributed to highest total phenol content which confers resistance to plant against *Meloidogyne incognita*.

The efficiency of certain AM fungi on plant growth, in presence of nematode, could be due to their host preference or the high inflow rate of P as evidenced by a higher percent root colonization and P uptake [47]. Plant growth parameters decreased by *Meloidogyne incognita* inoculation compared to uninoculated control at all P levels. The maximum growth parameters were recorded in the treatment where recommended levels of SSP were applied alone. Among the combined inoculations of VAM and root-knot nematode along with different levels of SSP, the half of recommended level of SSP recorded higher plant growth parameters of green gram. Kaushal and Madvi [42] estimate the size and aperture as well as number of trichomes of leaves was also smaller in tomato plants inoculated with *M.incognita*. The treatments having simultaneous inoculation of fungus and nematode responding synergistic effect on plant growth parameters exhibited poor system with chlorosis and wilting due to which the absorption of water and mineral content was also affected and the plants showed least chlorophyll content.

It is clear from the above review that most of the studies deal with the effect of nutrients on the development of nematode diseases and N-P-K status of plants, however, no work has been carried out on the effect of nutrient on development of nematodes in the host. Moreover, nothing has yet come out whether this deficiency of element is due to the fact that root system becomes ineffective in absorbing these elements or infestation brings about an adverse effect in translocation of these elements.

DISCUSSION

In our country, plant-parasitic nematodes are serious threat to crop productivity and they cause severe damage to the cultivated crops [48]. The economic condition of our farmers is control of nematodes because the chemicals are, by and large, costly and not easily available in the market. The chemical as fertilizers are every difficult to handle and pose pollution threat to the environment. Therefore, there has been a growing interest in the biological control of plant-parasitic nematodes [49]. Hence, the present investigations were undertaken to carry out the efficiency of chemicals (inorganic salts) against the root-knot nematodes, *Meloidogyne incognita*-a greatly influence the development of diseases. Concentration of these elements predisposes the plants to the attack of nematode presumably due to importance of absorption and translocation as a result of nematode infection. Moreover, application of lower doses of these elements has been found to mitigate the diseases [50].

In 1970, a programme for an extensive use of inorganic fertilizers has been embarked upon; therefore, there is an urgent need to determine the effect of inorganic fertilizers on the development of root-knot nematode number in India. Initially the experiments were designed to investigate the effect of the different levels of N, P and K on the root knot nematode, *Meloidogyne incognita.*

N is one of the most unpredictable element and its higher demand coupled with various losses in the cropping system made this nutrient a highly significant one in the soil under dry land condition. An excess of N level brings about a corresponding increase in the dry weight of roots, stems and leaves of both inoculated and uninoculated plants. Excess of N in general has long been considered to favour the development of certain diseases and predisposes the plants to the attack of a variety of pathogens [51]. As a result of gradual increase in the supply of N, there is a corresponding increase in the N content of roots, stems and leaves and a decrease in P and K content up to 1N level. However, at excess level of N i.e., 2N even P and K content increase slightly. It is only the roots of the inoculated plants that have high N content. The increase in K content of the roots of infected plants in each of the treatment has been significantly higher than that of uninoculated plants [52]. An increase in the level of P brings about a corresponding increase in the length and dry weight which occurs only up to the normal level of P. However, at 2P, this increase in the length and dry weight fails to manifest itself. Presumably because of this ultra-optimal level of P, Fe, present in the nutrient solution, precipitates as insoluble non-phosphate. Consequently, there is relatively poor growth as the plants in amount of P up to 1P increases the N and K content of the roots, however, the excessive P causes a slight decrease and similar results have been obtained for the stem and leaves.

An increase in the supply of potassium up to the normal level (1K) results in an increase in the growth of both inoculated and uninoculated plants as evidenced by an increase in shoot length as well as dry weight of roots, stems and leaves. An increase in the potassium level results in a corresponding increase in the N content of the roots only up to 1K. On other hand, the P content responds invariably to an increase in the K supply. K affects the mechanical composition of the cell-wall by promoting thickening of the cell wall and formation of firm tissue structures [53]. Consequently excess K is supposed to increase resistance of the plants to the penetration of some of the pathogens [54].

Inoculation of plants with low levels of inoculum densities (0, 10,100, 500 and 1000) has been beneficial to plants growth, though statistically significant increase has been observed in the plants inoculated with 1000 larvae. Although tomato plants with 1000 larvae exhibit reduction in their root and shoot length at 2K as compared to the uninoculated plants, yet a significant increase occurs in relation to the dry weight of roots, stem and leaves.These results are in conformity with the findings of Peter and Bergesson [55].

The increase in the growth of the plants may partly explained by the fact that a moderate infection of the nematodes induces excessive proliferation of external roots to combat the damage likely to be posed by the nematode, thereby increasing the surface of absorption and consequently the plant growth is ameliorated. The inoculation o the plants with 1000 larvae produces deficiency symptoms at the deficient K level which are slightly more severe as compared to control plants at the corresponding K level intomato plants studied.

From the foregoing study it is clear that high doses of P increase the susceptibility of the host plant as evidenced by root-knot index (RKI). At the same time, it does not impair the absorptive capability of the roots to absorb N, P and K even in the high population of the nematodes. This is borne out by the fact that total N-P-K content in both the infected and healthy plants as such does not materially differ through the N-P-K content in the diseased plant roots for more exceeds than the healthy roots [56]. In healthy plants, on the other hand, the N-P-K content of stem and leaves is much higher than diseases plants. This may be probably due to the fact that the metabolic activities are higher in the galled roots than in healthy roots. Consequently, there is a greater accumulation of these elements in addition to free amino acids, amide, protein etc [57].

These results clearly go to show that infection caused by root-knot nematodes results in an accumulation of N, P and K in the roots of the infected plants and consequently they decline in stems and leaves. These results also clearly show that root-knot development is markedly influenced by K and less so by N and P. During in vitro studies, it was observed that chemical treatments viz., KNO_3, NaH_2PO_4 and $Ca(NO_3)_2$Anhyd were highly deleterious to the root-knot nematode, *Meloidogyne incognita* however to varying extent. It cannot be ruled out that the nematode toxicity can be due to the treatment of some inorganic chemicals (fertilizers) which are already formed in the leaf, fruit flowers and other parts of test plant (*Lycopersicon lycopersicum* L.). On other basis of the toxicity of these chemical against the plant-parasite nematodes, these test chemicals can be arranged as KNO_3, $NaHPO_4$ and Ca $(NO_3)_2$Anhyd. The toxicity and suitability of N-P-K to *Meloidogyne incognita* are well known (Adegbite et al., 2011).

Generally high concentration of N in plant increases penetration rate of Meloidogyne incognita larvae (J2) to root of the host plants, and penetration increases with the corresponding increase in the concentration of N [58]. All treatments reduced the root-knot development caused by *Meloidogyne incognita*, highest being in those treated with KNO_3 followed by NaH_2PO_4 and $Ca(NO_3)_2$.Anhyd respectively. There was also an increase in plant growth of tomato cv. K-25. This may be partially due to the reduction in the root-knot development and partially due to the fact that these inorganic chemicals also served as manures. The toxicity of decomposing products or an increase in predacious or parasitic activity of the soil biota [59] changes in physical or chemical properties of soil caused by inorganic fertilizers (N-P-K) may be inimical to nematode or they may be responsible for increasing host resistance [60]. Thus, it can be concluded that the chemicals used in present study could be of great use of control the plant-parasitic nematodes. This could be an additional utilization of these inorganic chemicals.

The plant growth characters were significantly improved with the application of these treatments. KNO_3 treatments show highest plant length and plant weight at all doses followed by the same dose of NaH_2PO_4 and $Ca(NO_3)_2$Anhyd respectively. The results obtained were in composition to those obtained by Despande and Patil [61] who reported that the N-P-K and their potentialised concentration (S, S/2, S/10 and S/100) can be effectively used against root-knot nematode, *Meloidogyne incognita* on tomato. The fact that the plant growth characters were improved may be partially because of the fact that these inorganic chemicals also served as fertilizers.

SUMMARY & CONCLUSION

The solutions of the different concentrations of the three different chemicals (inorganic salts viz., KNO_3, $NaHPO_4$ and $Ca(NO_3)_2$.Anhyd.) were found highly deleterious to the root-knot nematode, *Meloidogyne incognita*. All types of the concentrations significantly inhibited the larval hatching of the nematode. There was a direct relationship between the mortality of the test nematode and concentrations of these chemicals. The nematode mortality increased with an increase in the concentrations of these chemicals and the different exposure periods. The treatments with different concentrations of these chemicals (inorganic salts) were found to be highly satisfactory in reducing the root-knot development caused by *Meloidogyne incognita* on tomato (*Lycopersicon lycopersicum* L.cv.K-25). The plants treated with these chemicals with different concentrations (S, S/2, S/10 and S/100) were found highly effective in increasing the plant growth and reducing the root-knot development. Therefore, above potentialised concentrations of these chemicals effectively improved the plant growth characters partially because of the fact that these inorganic chemicals served as manures. On the basis of their efficacy these inorganic chemicals can be arranged as $KNO_3 > NaHPO_4 > Ca(NO_3)_2$.Anhyd.

Root dip treatment in the solutions of the different concentrations of KNO_3, $NaHPO_4$ and $Ca(NO_3)_2$.Anhyd were found highly inhibitory to the root-knot nematode, *Meloidogyne incognita*. These treatments decreased the penetration of the root-knot juveniles inside the roots of tomato cv.K-25. The penetration also brought about significant improvement in plant growth.The penetration of the root-knot juveniles were significantly decreased with an increase in the dip duration.

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