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GROWTH AND YIELD RESPONSES OF FIFTEEN CUCUMBER CULTIVARS TO ROOT-KNOT NEMATODE (*Meloidogyne incognita*)

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ABSTRACT

Root-knot nematodes have become a grave menace to the lucrative production of cucumber throughout the world. These nematodes are mainly controlled by applying nematicides, but their use is often associated with hazards. Alternatively, the use of nematode resistant cultivars is considered to be innocuous and economically feasible. For their fitness as nematode-suppressive crops, the reduction in growth and yield parameters of these cultivars must be assessed. As there is little documented data about the effects of *Meloidogyne incognita* on the damage of cucumber, therefore, in the present study, the effects of *M. incognita* were evaluated on growth and yield parameters of fifteen cucumber cultivars. *M. incognita* significantly negatively affected the growth and yield parameters of all the cucumber cultivars. Shoot and root lengths and shoot weights of all the cultivars were significantly reduced as a result of nematode infection. Maximum reductions in these parameters were recorded in highly susceptible cultivars followed by susceptible ones, while the reductions were minimal in resistant followed by moderately resistant cultivars. On the contrary, the infection by *M. incognita* resulted in an increase in root weights of all the cultivars. The increase was found to be the maximum in highly susceptible cultivars followed by susceptible and moderately susceptible cultivars. Likewise, the minimum increase was observed in the resistant cultivars followed by moderately resistant cultivars. Similarly, significant variations in yield parameters among fifteen cucumber cultivars were also recorded as a result of *M. incognita* infection. In the case of highly susceptible cultivars, the reductions in yield parameters were maximum, whereas the reductions in resistant and moderately resistant cultivars were found to be minimum. As cultivars Long Green, Marketmore, Pioneer-II, Dynasty and Summer Green experienced no significant damage compared to susceptible cucumber cultivars and therefore, they are approved for cultivation in nematode infested soils.

Key words: *Cucumis sativus*, root-knot nematodes, growth variables, resistance, susceptibility

INTRODUCTION

Root-knot nematodes have posed a grave menace to the lucrative production of cucumber throughout the globe, including Pakistan in addition to other biotic factors [Ashfaq et al. 2017, Javed et al. 2017a, b, Iftikhar et al. 2018, Kassi et al. 2018, Nabeel et al. 2018]. They have wide geographic distribution, large host range and high destructive potential. Root-knot nematodes are one of the five most important phytopathogens and are on the top of the list of ten most important plant pathogenic nematodes of the world [Kayani and Mukhtar 2018, Mukhtar et al. 2018]. A large number of crops and vegetables are attacked by these nematodes, which drastically retards the growth of plants as a result of typical gall formation on roots.

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They have been reported to be implicated with other plant pathogens like *Ralstonia solanacearum* and results in disease complexes and aggravation of wilt diseases [Shahbaz et al. 2015, Aslam et al. 2017a, b, 2019, Fateh et al. 2017]. The overall yield losses of 50 to 80% have been reported to be caused by these nematodes in vegetables, while cucumber specifically suffers from a loss of about 33% in yield by root-knot nematodes [Sasser 1979].

Among different root-knot nematode species, southern root-knot nematode (*Meloidogyne incognita*) is one of the most important nematodes associated with low production of cucumber [Kayani et al. 2017, 2018, Tariq-Khan et al. 2017]. In Pakistan, *M. incognita* has been found one of the most dominant root-knot species and rampant in cucumber-producing areas of Pakistan, which considerably reduces the growth and yield [Kayani et al. 2013]. The worldwide distribution of this nematode species is 47%. In Pakistan, its overall occurrence is 52% and on cucumber, the incidence of *M. incognita* has been reported above 78% [Kayani et al. 2013]. The yield losses by root-knot nematodes are mainly caused by the buildup of inoculum of the nematode due to repeated cultivation of the same cultivars in the same land every year [Hussain et al. 2016, Mukhtar et al. 2017a].

Root-knot nematodes are mainly controlled by the application of nematicides and resistant cultivars. Although nematicides can effectively manage nematodes, but their use is often associated with hazards in underdeveloped countries like Pakistan and hence becoming unattractive for farmers. On the other hand, the use of nematode resistant cultivars is considered to be innocuous and economically feasible [Mukhtar et al. 2017b]. These cultivars can also be integrated with other management practices in integrated nematode management [Shahzaman et al. 2015, Khan et al. 2017, Rahoo et al. 2017, 2018a, b, Mukhtar 2018]. Cultivars of various crops and vegetables are basically assessed for resistance to root-knot nematodes using root galling index as the only standard of damage to plants, which is unreliable. This necessitates that other parameters like nematode reproduction on cultivars and reduction in growth and yield parameters should also be considered, while assessing the resistance or susceptibility among crop cultivars to root-knot nematodes [Florini 1997, Afolami 2000]. The key principles for accepting cultivars for their successful deployment in fields are their ability to suppress nematode populations and yield profitably in the presence of nematodes. For their fitness as nematode-suppressive crops, the reduction in growth and yield parameters of these cultivars must be assessed in addition to the reproductive potential of the nematode. As there are little documented data about the effects of *M. incognita* on the damage of cucumber, therefore, in the present study the effects of *M. incognita* were evaluated on growth and yield parameters of fifteen cucumber cultivars with varying levels of resistance and susceptibility, commonly cultivated in Pakistan.

MATERIALS AND METHODS

Nematode culture. An indigenous population of root-knot nematode (*Meloidogyne incognita*) initially isolated from cucumber roots, identified on the basis of perineal pattern and maintained on the highly susceptible cultivar of tomato (Money maker) was used in the assessment. The nematode was massively produced on the highly susceptible cultivar of tomato (Money maker) as described previously [Hussain et al. 2016]. Second stage juveniles were extracted from the infected roots for inoculation of plants as described by Whitehead and Hemming [1965].

Cucumber germplasm. Fifteen cucumber cultivars comprising Long Green (resistant); Marketmore, Pioneer-II, Dynasty, Summer Green (moderately resistant); Green Wonder, Poinsett, Cucumber Cetriolo (moderately susceptible); Falcon-560, Cobra, Babylon (susceptible); and Royal Sluis, Thamin-II, Mehran, Mirage (highly susceptible) [Mukhtar et al. 2013] were evaluated to compare the impact of *M. incognita* on growth and yield parameters of these cultivars belonging to different categories of resistance or susceptibility.

Effect of *M. incognita* on growth and yield variables. Plastic pots of 20 cm diameter were filled with 3 kg of soil (pH 7.2; organic matter, 1.5%; sand, 61%; silt, 21% and clay, 18%) sterilized with formalin [Mukhtar et al. 2013] and 3 seeds of each test cultivar were planted separately in each pot. Two weeks after emergence, one healthy seedling of each cucumber cultivar was kept in each pot and was inoculated individually with approximately 3000 freshly hatched juveniles of *M. incognita* contained in 5 ml of water.

The non-inoculated plants of each cultivar were kept as controls. There were five replicates for each cultivar. The pots were arranged in completely randomized design in the glasshouse at 25 ±2°C for sixty days. After stipulated period, the plants were uprooted; their roots were severed from the shoots and cleaned with tap water. Data on root and shoot lengths and weights were recorded. Fruits from each cultivar were picked thrice a week from 30th day after inoculation till the termination of the experiment. At each picking, data regarding total number of fruits and their weights were recorded and their means were computed.

Statistical analysis. The trial was repeated once. Before statistical analysis, percent of decreases in yield and growth components were determined over their controls. First, the data of both experiments were analyzed separately using two-way analysis of variance (ANOVA) using GenStat package 2009, (12th edition) version 12.1.0.3278 (www.vsni.co.uk) for significant interaction. As there was no significant interaction between the two experiments, the two sets of data were combined and again statistically analyzed. The means of each parameter were compared for significant differences by Fisher's protected least significant difference test at ($P \leq 0.05$).

RESULTS

Effect of *M. incognita* on growth variables of cucumber cultivars. *M. incognita* significantly negatively affected the growth and yield parameters of all cucumber cultivars. Shoot and root lengths and shoot weights of all the cultivars were reduced significantly as a result of nematode infection. Maximum reductions in these parameters were recorded in highly susceptible cultivars followed by susceptible ones, while the reductions were the minimum in the resistant cultivar followed by moderately resistant cultivars. In highly susceptible cultivars, the reductions in shoot lengths were 23−45%; in root lengths, 16−23% and in shoot weights 16−20%. In the case of susceptible cultivars, 27−34%, 15% and 9−10% reductions were recorded in shoot lengths, root lengths and shoot weights, respectively. As regards to moderately sus-

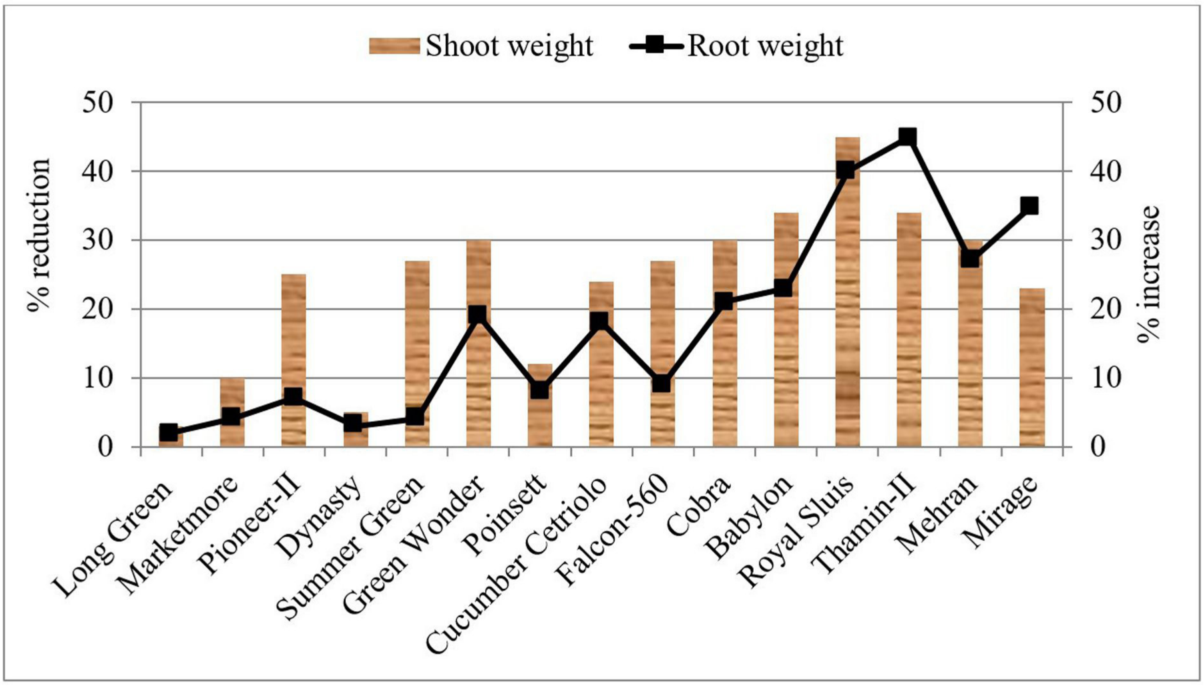

Fig. 1. Effect of *Meloidogyne incognita* on reduction in shoot weight and increase in root weight of fifteen cucumber cultivars

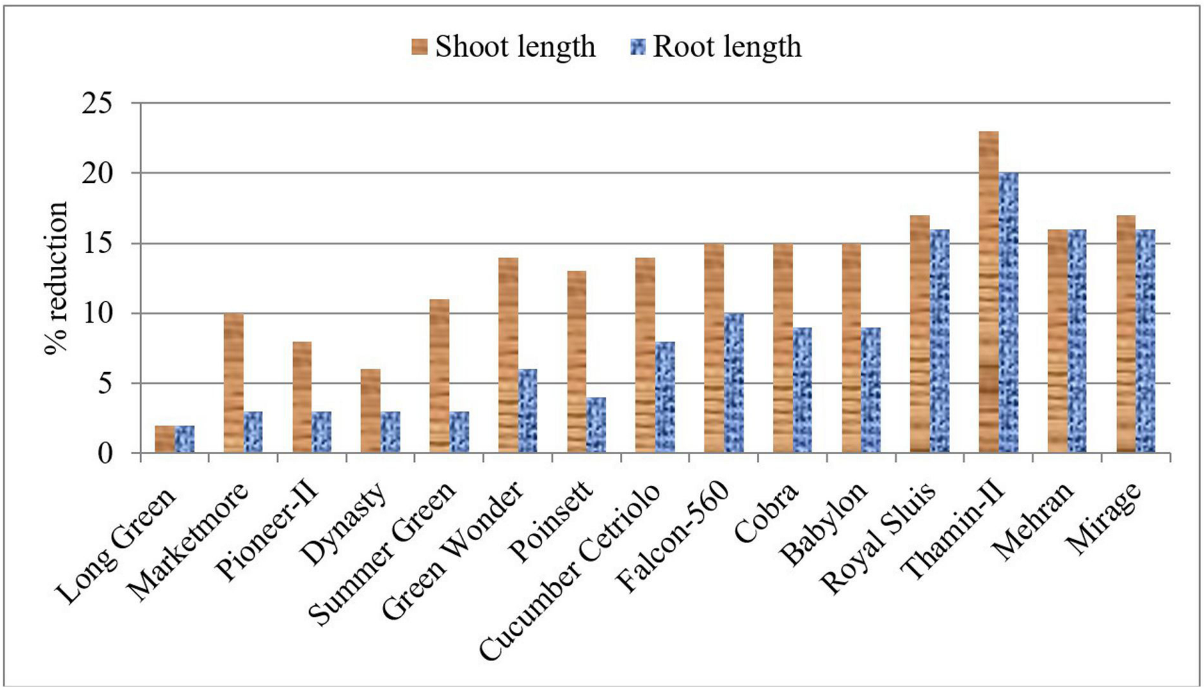

Fig. 2. Effect of *Meloidogyne incognita* on reduction in shoot and root lengths of fifteen cucumber cultivars

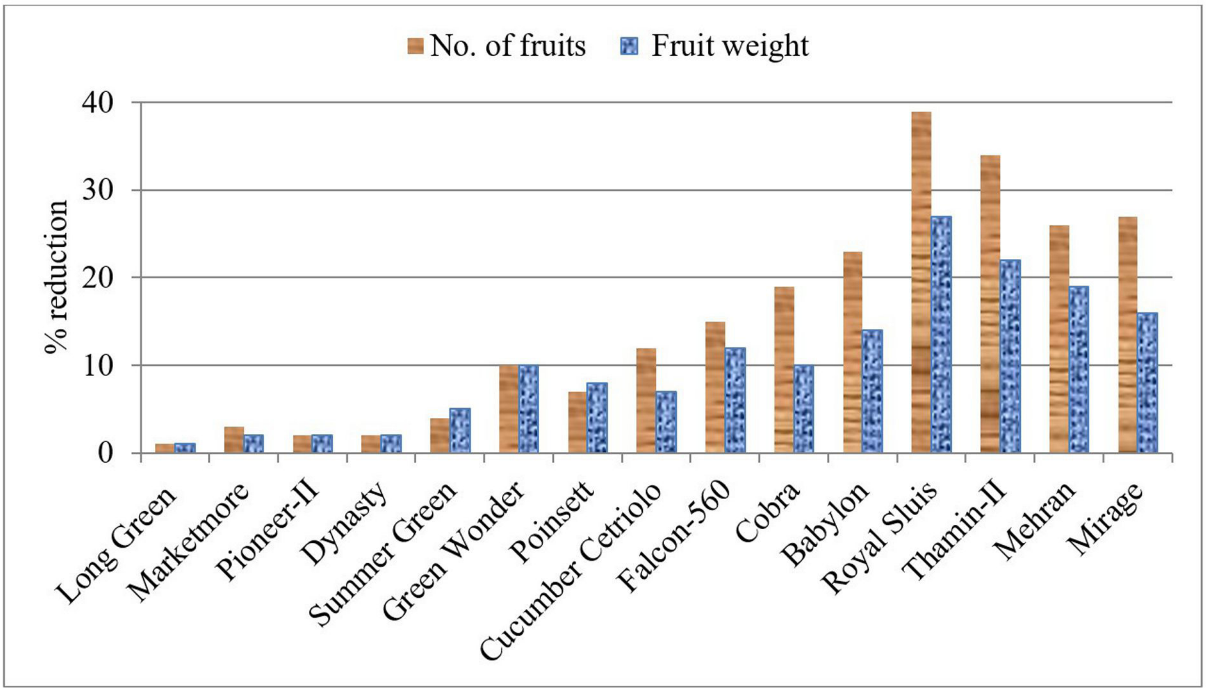

Fig. 3. Effect of *Meloidogyne incognita* on reduction in number and weight of fruits of fifteen cucumber cultivars

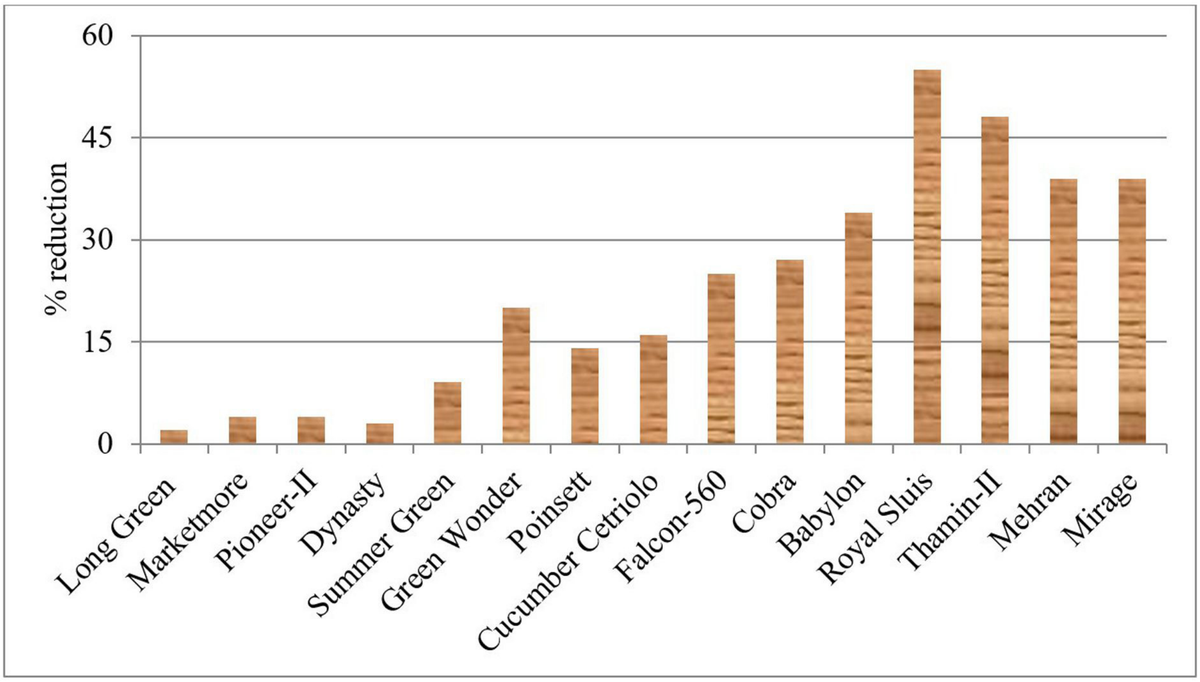

Fig. 4. Effect of *Meloidogyne incognita* on reduction in yield of fifteen cucumber cultivars

ceptible cultivars, the reductions in these parameters correspondingly ranged 12–30%, 13–14% and 4–8%. The only resistant cultivar Long Green suffered from the minimum reductions of up to 3%, whereas resistant cultivars showed reductions in these parameters in the order 5–27%, 6–11% and 3% as shown in Figs. 1 and 2. On the contrary, the infection by *M. incognita* resulted in an increase in root weights of all the cultivars. The increase was found to be the maximum in the highly susceptible cultivars (27–25%) followed by susceptible (9–23%) and moderately susceptible (8–19%) cultivars. Contrarily, the minimum increase of 2% was observed in the resistant cultivar followed by moderately resistant cultivars which showed 3–7% increases in root weights as shown in Figure 1.

Effect of *M. incognita* on yield parameters of cucumber cultivars. Significant variations in yield parameters among fifteen cucumber cultivars were recorded as a result of *M. incognita* infection. In the case of highly susceptible cultivars, the reductions in yield parameters were maximum, whereas the reductions in resistant and moderately resistant cultivars were found to be the minimum. Number and weight of fruits reduced to 26–39% and 16–27% in the highly susceptible cultivars followed by susceptible cultivars which showed 15–23% and 10–14% reductions in these parameters. As far as moderately susceptible cultivars were concerned, the reductions in these parameters were recorded up to 12% and 10%. Similarly, the reductions were found to be the minimum (1–2%) in the only resistant cultivar followed by moderately resistant cultivars showing 2–4% and 2–5% reductions in number and weight of fruits (Fig. 3). Similarly, *M. incognita* also caused reduction in fruit yield. Maximum reduction of 29–55% was observed in highly susceptible cultivars followed by susceptible ones showing 25–34% reductions in fruit yield while in case of moderately susceptible cultivars, 20% reduction was recorded. On the other hand, the only resistant cultivar showed a reduction of 2% followed by moderately resistant cultivars which suffered 3−9% reductions in fruit yield (Fig. 4).

DISCUSSION

In the present study, *M. incognita* caused decreases in growth and yield attributes of fifteen cucumber cultivars belonging to different categories of resistance and susceptibility. Maximum decreases in these variables were recorded in highly susceptible cultivars followed by susceptible ones while the reductions were the minimum in the resistant cultivar followed by moderately resistant cultivars. The maximum decreases in growth and yield variables of susceptible cultivars can be ascribed to severe root damage owing to nematode entry and/or feeding which resulted in impairment and disruption of water absorption by the infected root systems. After entry into roots, the root-knot females induce gall formation and giant cells in the stellar region and cause severe disruption of xylem tissues. Due to extensive disruption of xylem vessels, the upward uptake of water and nutrients is greatly reduced. The root-knot infection also greatly affects permeability of roots to water. Due to the induction of nurse cell systems by females of root-knot nematodes for incessant feeding in infected roots, there is greater translocation of photosynthates towards these infection sites, while the aboveground parts experience acute deficiency of nutrients [Wyss 2002, Di Vito et al. 2004]. As the infected plants face insufficient supply of nutrients, photosynthates, energy, water etc., therefore, development and growth of leaf tissues and their essential constituents particularly chlorophyll pigments, are greatly hampered [Khan and Khan 1997]. The stunted and reduced growth of foliar parts subsequently results in reduced biomass and productivity [Hussain et al. 2016, Kayani et al. 2017].

The successful parasitism by root-knot nematodes in vascular tissues of susceptible plants is characterized by the formation of giant cells. These nurse cells are highly specific and are induced and maintained by females of root-knot nematodes. On the other hand, in case of resistant or moderately resistant cultivars, the juveniles cannot induce the development of giant cells essential for successful parasitism and resultantly the juveniles either die or leave the roots. As a result of unsuccessful parasitism, there is no infection of the host and the yield is not affected. The other major factors that determine the variations in growth and yield variables among cucumber cultivars are the multiplication of nematodes in the hosts and production of egg masses on the roots by females [Hussain et al. 2016]. The variations in reproductive rates might partially be the result of genetic factors which impart resistance or susceptibility to the host or due to genetic variations in nematode populations [Griffin 1982, Jacquet et al. 2005, Castagnone-Sereno 2006]. The variations in the hosts can influence various stages of the life cycle of the nematode. The juveniles either fail to enter the resistant hosts or they are killed after their penetration into the roots. If somehow the juveniles are successful in entering the roots of resistant cultivars, there will be no development and/or reproduction of the nematode.

The variations in reproduction and multiplication of *M. incognita* on cucumber cultivars are owing to variations in their genetic makeup which can be explained in terms of number of egg masses [Mukhtar et al. 2013]. The production of maximum egg masses and eggs on the roots of highly susceptible and susceptible cultivars explains that maximum numbers of juveniles entered the roots and were successful in completing their life cycles in the host. The other way round, in case of resistant and moderately resistant cultivars only few juveniles made their way into the roots and got matured which is obvious by the number of egg masses and their reproductive factors [Hussain et al. 2016]. There are reports that resistant cultivars contain a limited number of developed nematodes as compared to susceptible cultivars [Dropkin and Nelson 1960]. Hindrance in invasion by second stage juveniles of the nematode has been ascribed to failure of maximum numbers of juveniles to develop in the infected roots and/or hypersensitive reactions in the host [Dropkin 1969]. In case of susceptible hosts, the juveniles had the maximum potential to fully develop as evident by their reproductive factors in the highly susceptible and susceptible cultivars [Hussain et al. 2016]. On the other hand, in resistant and moderately resistant cultivars, the development of the juveniles was either curtailed or delayed [Nelson et al. 1990].

CONCLUSIONS

In conclusion, large variations in growth and yield variables of cucumber cultivars were found in response to *M. incognita* infection. As the cultivars Long Green, Marketmore, Pioneer-II, Dynasty and

Summer Green experienced no significant damage compared to susceptible cucumber cultivars, therefore, they are approved for cultivation in nematode infested soils.

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