ABSTRACT

Studies were undertaken to examine the incidence and intensity of root-knot disease and to establish the identity of species and races of root-knot nematodes (Meloidogyne species) associated with vegetable crops in 8 districts in the State of Uttar Pradesh. Aligarh, Bulandshahr, Ghaziabad, Meerut, Muzaffarnagar, Saharanpur, Dehradun and Nainital districts, covering an area of 36,243 km² out of 2,94364 km² (12.31%) of Uttar Pradesh and 1.104% of India, were selected as study area. This area is situated between 27°29' and 29°37N, and 77°29 and 80°5E. January is the coldest and June is the hottest month of the year in the area. Of 8 districts, 6 are located in the plains (altitude range 192 m to 942 m above the sea level) and 2 (Dehradun and Nainital) in the hilly tracts of Himalayas (altitude range 1967.4 m to 3022.5 m above the sea level). Localities with extensive vegetable cultivations in each district were surveyed and root samples of vegetable crops like tomato, eggplant, cucumber, okra, pepper, cabbage and cauliflower were collected. Species and races of root-knot nematodes (Meloidogyne spp.) prevalent in the area were identified and per cent infestation of vegetable fields in each district based on frequency of occurrence of root-knot nematodes in vegetable fields; incidence of root-knot nematodes on each vegetable crop in each district, and incidence of the disease based on infected root sample were calculated. An overall assessment of these aspects was also
made for the entire area. In addition, responses of some cultivars of vegetable crops to M. javanica and to all the 4 races of M. incognita, the two most frequent species of the area were investigated. A comparative assessment of root penetration of juveniles of M. javanica and M. incognita Race 1 in some cultivars of vegetables found susceptible and resistant/immune was also done. The effect of artificially created salinity levels of NaHCO$_3$ and NaCl on hatching, mortality, root penetration and development of M. javanica and M. incognita Race 2 and combined effects of the salinity levels and the root-knot nematodes on plant growth of okra and cucumber were also investigated.

**Incidence and intensity of the disease**

In general, a high percentage of fields grown with vegetables in the area were found infested with root-knot nematodes. Though the incidence of the disease showed a wide range of variations between the localities in each district, more than 50% of the fields grown with vegetables in the districts were infested with root-knot nematodes. The overall incidence of the disease in vegetable fields in the entire area was slightly above 60%. Incidence of the disease was also fairly high on each vegetable crop except cabbage and cauliflower. In each district above 50% fields of each vegetable crop except cabbage and cauliflower were infested. On root sample basis, the incidence of the disease was above 25% in each district. The disease incidence on each vegetable
crop on root sample basis was above 28% except on cauliflower and cabbage, where it was 12.03% and 10.99% respectively. Overall incidence of the disease on root sample basis was above 35%.

Intensity of the disease on the basis of gall index (GI) and eggmass index (EMI) showed a wide range of variations. The GI ranged from 2-5 and EMI 0-5 on Taylor and Sasser scale. The intensity varied from field to field, crop to crop and from sample to sample. The intensity ranged from moderate to severe based on mean GI/EMI. Among the vegetable crops, intensity was highest on eggplant followed by okra, cucumber, tomato, and pepper in decreasing order. On cabbage and cauliflower, the disease intensity was low. Poor root galling and infrequent eggmass production were noticed on these crops.

Identity and frequency of the species

All the four major species of Meloidogyne viz., M. incognita, M. javanica, M. arenaria and M. hapla were found to exist in the area. M. incognita, M. javanica and M. arenaria were encountered in all the districts. But M. hapla was restricted to Dehradun and Nainital districts. Its occurrence was limited to localities situated at the hilly regions of both the districts. In both the localities of Nainital district (Bhawali and Nainital city area), M. hapla was more frequent than other species.

The species of root-knot nematodes were either found in single or mixed populations. Mixed populations of two species
viz., *M. incognita* with *M. javanica*, *M. incognita* with *M. arenaria*, *M. incognita* with *M. hapla*, *M. javanica* with *M. arenaria*, *M. arenaria* with *M. hapla* or *M. incognita* with *M. javanica* and *M. arenaria* were encountered.

*M. incognita* was most frequent species in the area. It was dominant in all the districts except Bulandshahr where *M. javanica* dominated. *M. arenaria* was third in order of dominance. *M. hapla* was least frequent in the area restricted to hilly localities of Nainital and Dehradun districts. Regardless of single or mixed infection in total samples collected from all the districts, 72.26% root samples were infected with *M. incognita*, 44.30% with *M. javanica* and 25.43% with *M. arenaria*. *M. hapla* was found only in 4.71% of the root samples. Single populations of *Meloidogyne* species was encountered more frequently than their mixed populations. Frequency of single and mixed populations was 57.59% and 42.40% respectively. Among the mixed populations of different combinations of species *M. incognita* and *M. javanica* were most frequent, followed by mixed populations of *M. incognita* and *M. arenaria*. The frequency of the former combination was 19.39% and of the latter 9.49%.

**Identity and frequency of the races**

Existence of Race 1, Race 2, Race 3, Race 4 of *M. incognita* and Race 2 of *M. arenaria* was recorded in the area included in the study. Race 1, Race 2 and Race 4 of *M. incognita* were present in all the districts. Race 3 was absent from Dehradun and Nainital districts. It was, however, present in other
districts. Race 2 of *M. arenaria* was found in all the districts. Existence of Race 1 in *M. arenaria* populations in the area was not found. Amongst the races of *M. incognita*, Race 1 was most frequent. Race 2 emerged as the second most common race of *M. incognita*. It was followed by Race 4. Race 3 was least frequent. In the area, per cent occurrence was 34.63, 26.67, 21.01 and 17.69 for Race 1, Race 2, Race 4 and Race 3 respectively. Race 2 was invariably detected in all *M. arenaria* populations. Consequently its frequency was 100%.

With variations in specific localities of the districts, Race 1 of *M. incognita* was most frequent in Aligarh, Bulandshahr, Ghaziabad, Saharanpur but Race 2 was dominant in Muzaffarnagar and Meerut and Race 4 in Dehradun and Nainital. Race 3 was less frequent than Race 1 and Race 2 in all the districts except Bulandshahr and Saharanpur. Its frequency was equal to Race 1 in Bulandshahr and more than Race 2 both in Bulandshahr and Saharanpur. Race 4 was more frequent than Race 3 in Aligarh, Ghaziabad, Meerut, and less frequent in Bulandshahr, Muzaffarnagar and in Saharanpur. *M. arenaria* Race 2 was present in all the districts. Its frequency was highest in Muzaffarnagar followed by Meerut, Nainital, Saharanpur, Aligarh, Ghaziabad, Dehradun and Bulandshahr.

Occurrence of *M. hapla* and Race 1, Race 2, Race 3 of *M. incognita* in the State of Uttar Pradesh is reported for the first time. Records of Race 4 of *M. incognita* and Race 2 of *M. arenaria* are new for India as well as for the State of Uttar Pradesh.
Response of cultivars of vegetables

Thirty six cultivars of tomato, 19 of eggplant, 14 of pepper, 10 of okra, 9 of cucumber, 37 of cauliflower and 23 of cabbage were screened against *M. javanica* and Race 1, Race 2, Race 3 and Race 4 of *M. incognita* in artificial inoculations to evaluate their degree of resistance and host suitability designations (resistance) were assigned to cultivars according to modified Canto-Saenz scheme. Most of the cultivars of the vegetables screened were susceptible. All the cultivars of eggplant and okra screened were susceptible to all the test nematodes. Some of the cultivars of tomato, pepper, cucumber, cauliflower and cabbage, however, showed race-specific resistance to *M. incognita* and to *M. javanica*.

Ten cultivars of tomato viz., Pusa-120, Calmart VFN, Panjab 6.NR-7, EC173898 (72T6), EC173897 (Calmart), EC173896 (Kewalo), CLN363BC1F2-167-1-0, CLN363BC1F2-190-1-0, CLN363BC1F2-344-0-0 and CLN229BC1F2-4-1-4-0 were immune and 2 cultivars namely VFN-Bush and VFN-8 were resistant to all the test nematodes. Pelicon was resistant to Race 1, Race 2 and Race 4 of *M. incognita*; tolerant to Race 3 of *M. incognita* and immune to *M. javanica*. In pepper, two cultivars Jwala and Pusa Jwala showed resistance. Jwala was resistant to all the 4 races but Pusa Jwala was resistant to Race 1 and Race 3 of *M. incognita*. Against *M. javanica*, five cultivars of pepper (Jwala, Bull Nose, Chinese Giant, Chilli N-P.46-A and Suryamukhi) were found immune and five cultivars (Pusa Jwala, Suryamukhi Black, Hungarian Wax, Chilli U-3 and California Wonder) resistant. Rest of the cultivars were susceptible.
In cucumber, except Improved Long Green, all the cultivars were found susceptible to the test nematodes. Improved Long Green exhibited resistance to *M. javanica* and hyper-susceptibility to Race 3 of *M. incognita*. One cultivar of cauliflower (Dania) and one of Cabbage (American Special Ballhead) were immune and resistant to all the test nematodes respectively. A number of cultivars of both the crops were, however, found resistant to one or the other test nematodes.

A marked significant difference in the rate of juvenile penetration in relation to time, total penetration, rate of development and attaining of maturity of females was found, when juvenile penetration and post-penetration development of *M. incognita* Race 1 and *M. javanica* in roots of susceptible and resistant/immune cultivars of some vegetables were assessed. Root penetration by juveniles of both the nematodes in resistant/immune cultivars was significantly poor in comparison to susceptible cultivars of the same vegetable. The development of juveniles of *M. incognita* Race 1 or *M. javanica* in the roots of resistant cultivars of vegetables was delayed and only a few matured into adult females.

**Effect of soil salinity**

Effect of four different concentrations (1.5, 2.5, 3.5 and 5.0 mmhos/cm) of NaCl and NaHCO₃ were tested on juvenile hatching and mortality of *M. javanica* and *M. incognita* Race 2. All the concentrations of both the salts suppressed juvenile hatching of both the nematodes. A direct correlation between juvenile hatching and concentration of the salts was recorded.
Highest juvenile hatch suppression was noticed in 5.0 mmhos/cm. All the salt concentrations induced juvenile mortality of both the species. Highest mortality was found in 5.0 mmhos/cm. Percent mortality increased in all the concentrations with an increase in exposure period.

Effects of 1.5, 2.5, 3.5 and 5.0 mmhos/cm of both the salts was studied on penetration of juveniles (J2) in the roots of cucumber and okra. All the salt concentrations tested adversely affected the juvenile penetration of roots of okra and cucumber. It was true for both the nematodes. A direct correlation existed between the concentration of salt and the number of ingressed juveniles in the roots. Under the influence of salinity, the development of juveniles into adult females and production of eggmasses were delayed. In contrast to control, very few eggmass were produced in all the treatments due to adverse influence of salts.

Soil salinity levels (3.5 and 5.0 mmhos/cm) artificially created by addition of NaCl and NaHCO₃ retarded plant growth of okra and cucumber. The higher salinity level was more inhibitory for plant growth. M. javanica as well as M. incognita Race 2 caused appreciable reduction in plant growth parameters of both the crops. The reduction in growth parameters of both the crops caused by the nematodes was reduced in the presence of soil salinity. Consequently, under the combined influence of soil salinity and root-knot nematodes growth of both crops was better than the plants inoculated with root-knot nematodes alone.