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A Survey for Plant-Parasitic Nematodes Associated with Strawberry (*Fragaria ananassa* Duch.) Crop in Korea

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A survey was conducted during February- March 2003 to determine the occurrence and population density of plant-parasitic nematodes in strawberry (*Fragaria ananassa*) fields, cultivated under plastic houses in major strawberry growing regions of Gyeongbuk and Chonbuk provinces, Korea. The survey revealed presence of eleven species of plant-parasitic nematodes *viz.*, *Aphelenchoides fragariae, Criconemoides morgensis, Ditylenchus dipsaci, Helicotylenchus dihystera, Hirschmanniella imamuri, Meloidogyne arenaria, M. incognita, Pratylenchus penetrans, Psilenchus hilarulus, Tylenchorhynchus claytoni* and *Xiphinema* sp. Frequency and density of each species were highly variable from field to field and within the field. Plant growth was not uniform in the surveyed fields under plastic houses; stunted growth, chlorotic leaves, small curled or crinkled leaves, deformed buds and flowers and wilted plants with fewer fruits were observed in patches.

Keywords : *Fragaria ananassa*, korea, plant-parasitic nematodes, survey

Strawberry (*Fragaria ananassa*) is an important agricultural commodity in Korea; its cultivation covers 7,800 hectares with average yield of 2.7-tons/hectare (Ministry of Agriculture and Forestry, Korea, 2002). During recent years interest has increased in strawberry cultivation as an alternative cash crop for small family farms in Korea. However, due to limited arable lands in Korea, the same fields have been continuously used to cultivate strawberry for several years. In such an intensive and continuous cultivation system, soil-borne diseases and nematodes become an important constraint in strawberry production. Plant-parasitic nematodes are known to be pests of fruit and vegetable crops. Nematode parasitism may result in secondary infection by soil-borne fungal and bacterial pathogens (Sikora and Carter, 1987) or transmission of plant viruses (Brown et al., 1995).

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Chemical pesticides and crop rotation with rice and amendment of mountain soil are widely used by the farmers to control soil-borne diseases, including plant-parasitic nematodes in Korea. Use of nematicides provides instant and effective control of nematodes, but several nematicides have been withdrawn from market because of health and environmental problems associated with their production and use (Thomason, 1987). As a result of this, and the increasing public concern over the use of pesticides in food production has increased interest in the development of other effective, sustainable and environmentally friendly methods of nematode control such as the use of natural enemies and host plant resistance. To better understand this it is important to acquire information on the occurrence of nematode species, their host range, initial population density in fields, and pathogenic potentials. Although, recent reports in Korea have been published on association, distribution and density of plant parasitic nematodes on various crops (Cho et al., 2000; Choi and Park, 1991; Park et al., 1995, 1998a, 1998b, 1999a, 1999b, 2002), there are no data available on strawberry, which is needed to form a base line for management and future research. Therefore, the objective of this study was to conduct a survey to determine and document the occurrence, distribution, density and prevalence of plant-parasitic nematodes in strawberry fields cultivated under plastic houses in Korea.

Materials and Methods

A survey was conducted in the major strawberry growing regions of Gyeongbuk and Chonbuk provinces of Korea. Sampling was conducted during February-March 2003, when the crop was in harvesting stage. The following localities were included in the survey: Andong, Chilgok, Geochang and Koryung in Gyeongbuk province and Namwon in Chonbuk province. Soil, root, and foliage (leaves, stem and flower-buds) samples were collected randomly from each locality. Each soil sample was composite of 8-10 soil cores from same field, collected randomly to a depth of 20-cm with a hand shovel. Samples were placed in plastic bags, sealed and brought back to the

laboratory and stored at 5°C until processed for nematode extraction. Roots were washed free of soil and examined for galling and root-knot infection. Mature females of root-knot nematodes were dissected out from the infected roots and perineal patterns were prepared as described by Taylor and Netschler (1974). Each soil sample was thoroughly mixed by shaking the plastic bags and nematodes extracted from 300-cm^3 soil subsamples by centrifugation-flotation (Jenkins, 1964). Strawberry foliage samples were randomly chosen from each locality. Within 24 h of arrival at our laboratory, all the stems, buds and leaves in each sample were cut into small pieces (0.5 cm) placed in bags and mixed. A 15-g subsample from each sample was used for nematode extraction using Baermann funnel (Agrios, 1997) for 3 days. Isolated nematodes were killed at 70°C and fixed in 4% formalin and placed in viols. Prior to counting, solution containing nematodes were agitated thoroughly and 3 ml poured to counting dish. Nematodes were counted at 60 × magnifications using an inverted microscope. Counting of root-knot nematodes based on second stage juveniles (J2) only.

Selected specimens for each of the recorded species were processed for dehydration by Seinhorst's (1959) rapid glycerin method and mounted on plastic slides in anhydrous glycerin. Nematodes were measured at 1000 × magnification with the help of an ocular micrometer. *Meloidogyne* species were identified on the basis of female perineal patterns and morphological characters of males and second stage juveniles according to Eisenback (1985). Identification of other species of plant parasitic nematodes was based on the morphology and measurements of adults (Esser, 1973; Handoo, 2000; Choi, 2001; Handoo and Golden, 1989).

Results

Eleven species of plant-parasitic nematodes were commonly detected in association with strawberry cultivated under plastic houses in the different localities of Gyeongbuk and Chonbuk provinces of Korea (Table 1, 2). The frequency and density of all recorded species were highly variable from field to field and within the field under plastic houses. Foliar nematode, *Aphelenchoides fragariae* (Ritzema Bos) Christie was recovered from above-ground plant parts collected from all surveyed localities (Table 2). However, its occurrence frequency and density were highly variable, with the highest frequency and density was recorded in Koryung and the lowest was in Namwon of Gyeongbuk and Chonbuk provinces, respectively (Table 2). It was also detected in 15% of soil samples collected from Koryung of

Table 1. Occurrence frequency and density of plant-parasitic nematodes in strawberry fields (in 300 cm^3 soil)

Localities → Nematode species	Andong (50)[a]		Chilgok (40)		Geochang (50)		Koryung (60)		Namwon (40)	
	RF[b]	MD	RF	MD	RF	MD	RF	MD	RF	MD
Aphelenchoides fragariae	–	–	–	–	–	–	15	64 ± 16.1	–	–
Criconemoides morgensis	–	–	22.5	73 ± 14.6	38	97 ± 19.5	40	152 ± 33.6	–	–
Ditylenchus dipsaci	42	69 ± 16.1	32.5	48 ± 10.4	36	53 ± 13.1	45	75 ± 15.7	17.5	49 ± 10.2
Helicotylenchus dihystera	–	–	12.5	125 ± 36.8	46	87 ± 19.8	40	88 ± 20.6	20.0	130 ± 23.5
Hirschmanniella imamuri	–	–	–	–	–		–	–	22.5	47 ± 10.8
Meloidogyne arenaria (J2)	36	180 ± 35.4	37.5	301 ± 56.0	46	216 ± 48.3	45	291 ± 55.4	37.5	232 ± 47.8
Meloidogyne incognita (J2)	24	224 ± 55.2	22.5	173 ± 40.3	28	272 ± 51.4	25	243 ± 44.3	30.0	253 ± 47.5
Pratylenchus penetrans	–	–	–	–	18	38 ± 9.2	15	46 ± 11.3	17.5	49 ± 12.2
Psilenchus hilarulus	–	–	–	–	24	43 ± 11.9	20	51 ± 16.6	15.0	25 ± 8.6
Tylenchorhynchus claytoni	–	–	–	–	22	75 ± 18.4	20	97 ± 21.8	22.5	81 ± 17.8
Xiphinema sp.	–	–	7.5	16 ± 3.8	–	–	10	24 ± 7.9	–	–

[a] number of soil samples collected.
[b] RF = Relative frequency of occurrence (percentage of samples in which species was found); MD = Mean density ± standard deviation of nematodes in 300 cm^3 soil.

Table 2. Occurrence frequency and population density of *Aphelenchoides fragariae* in strawberry plant tissues

Locality	Andong (15)[a]	Chilgok (16)	Geochang (22)	Koryung (30)	Namwon (16)
Occurrence frequency [b]	53.3	56.3	63.6	76.7	43.8
Nematodes density [c]	152 ± 11.6	205 ± 19.5	214 ± 24.4	296 ± 43.8	108 ± 12.6

[a] number of greenhouse sampled.
[b] Percentage of samples in which nematode was found.
[c] Mean ± standard deviation of nematodes per 15 g fresh tissue of strawberry plant.

Gyeongbuk province. Among the root parasitic nematodes, *Meloidogyne arenaria* (Neal) Chitwood and *M. incognita* (Kofoid and White) Chitwood were the predominant species in all surveyed localities followed by *Ditylenchus dipsaci* (Kühn) Filipjev. *Helicotylenchus dihystera* (Cobb) Sher also recovered from all localities except Andong. *Criconemoides morgensis* (Hofmänner) Taylor was found in 22.5, 38.0 and 40.0% soil samples from Chilgok, Geochang and Koryung of Gyeongbuk province, respectively. *Pratylenchus penetrans* (Cobb) Filipjev and Schuurmans, *Psilenchus hilarulus* De Man and *Tylenchorhynchus claytoni* Steiner were observed in 15-24% soil samples from Geochang, Koryung and Namwon. *Xiphinema* sp. was found in very low frequency, 7.5 and 10% samples from Chilgok and Koryung, respectively. *Hirschmanniella imamuri* Sher was observed only in Namwon, Chonbuk province. These nematodes were encountered either in mixed or single populations.

Discussion

During survey it was observed that strawberry growth was highly variable in most of the surveyed fields under plastic houses. There were some areas where plant growth appeared normal, and in others plants were severely stunted, chlorotic, with small curled or crinkled leaves (crimp) and deformed buds and flowers with fewer fruits, indicating symptoms associated with nematode problems in strawberry fields. Root galls and reddish brown lesions were also seen on severely stunted, off-colored and poorly grown plants.

This survey provides information on occurrence and density of plant-parasitic nematodes associated with strawberry crops cultivated under plastic houses in Korea. Some nematodes identified in this survey are of economic importance and are considered serious pests of strawberries. These nematodes include *Aphelenchoides fragariae, Meloidogyne arenaria, M. incognita* and *Pratylenchus penetrans*. *A. fragariae* also known as foliar nematode is a parasite of above-ground plant part and may be endo- or ectoparasitic, produce small curled or crinkled leaves (crimp), deformed buds and flowers. *A. fragariae* was found in soils from Koryung only; they might have disseminated through the infected buds or leaves which may have fallen a few days before sampling. *Meloidogyne* spp. are found in the soil or as a sedentary endoparasites in roots and induce root galls. *Pratylenchus penetrans* is a migratory endoparasite of roots, and its infection makes fine reddish-brown lesions on rootlets. It is also known to enhance the severity of *Gnomonia comari* (fungus) (Kurppa and Vrain, 1989) and *Rhizoctonia fragariae* (LaMondia and Martin, 1989) on strawberry roots. Presence of these nematodes in strawberry fields indicates a risk of damage, and recommended management strategies should be taken by growers to prevent them from increasing and spreading. It is reported that *A. fragariae* and *Meloidogyne* spp. have been most frequently associated with strawberry damage in California, USA (Anonymous, 1991). Strawberries are also host of *P. penetrans, D. dipsaci,* and *Xiphinema* sp. including *X. americanum*. All of these nematodes are potential pathogens to strawberry and their identification in strawberry plantings or in land to be planted to strawberries should be cause of concern (Anonymous, 1991).

Other nematodes species identified in this survey are ectoparasitic to root and have not been documented as dangerous pests of strawberry to date. They include *H. dihystera, T. claytoni* and *C. morgensis*. The species of *Criconemoides, Helicotylenchus, Tylenchorhynchus* and *Xiphinema* have also been commonly found in samples from strawberry plantation in New Brunswick, NJ, USA; however, their impact on yield, if any, is unknown (Anonymous, 1991). Species of *Xiphinema* in addition to the direct root damage caused by their feeding also are known to transmit viral diseases (Brown et al., 1995). As virus vectors they can be damaging at very low population levels. The pathogenic status of *Hirschmanniella imamuri* and *Psilenchus hilarulus* on strawberry is currently unknown.

Goochen and Braun (1956) have reported that soil and root samples from wild strawberry plants (*Fragaria virginiana*) in a wooded area in Maryland, USA contained *Helicotylenchus dihystera*, *Pratylenchus penetrans*, *Xiphinema* sp., *Meloidogyne hapla*, *Tylenchorhynchus* sp., *Hoplolaimus* sp. and *Paratylenchus* sp. These genera are also frequently found in commercial strawberry plantings in Maryland. Such findings suggest the possibility that nematodes found in strawberry plantings are indigenous to that region. The variation in occurrence frequency and density of each species of plant-parasitic nematodes in surveyed fields of strawberry seem to be influenced by cropping pattern. It is reported that plant-parasitic nematodes in cultivated soil may be affected by the planting of cover crops, the use of alternate crop sequences, and fallow (Brodie and Murphy, 1975; Brodie et al., 1970a, 1970b).

The results of this study indicate that plant-parasitic nematodes are widely distributed in strawberry fields of Korea. Specific information on current nematode occurrence in strawberry fields in Korea will be helpful for growers who will consider the risk of nematode problems both currently and in future according to the characteristic of each species of plant-parasitic nematode. Presences of many economically important plant-parasitic nematodes in strawberry fields of Korea deserve serious attention by researchers and extension workers. Further research is needed to determine the significance of these nematodes on

strawberry and to determine their possible interaction with other soil pathogens and the environment. This survey provides important background information for planning and administering nematode management strategies in strawberry fields of Korea.

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