Development of *Meloidogyne arenaria* on Oriental Melon (*Cucumis melo* L.) in Relation to Degree-day Accumulation Under Greenhouse Conditions

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Influence of soil temperature [accumulated degree-day for the base temperature 5°C (DD_5)] on the development of *Meloidogyne arenaria* were studied in a winter grown oriental melon greenhouse in Seongju, Korea. Egg masses were first observed on roots at the accumulation of 565 DD_5 (40 days after transplanting), suggesting that the nematode has completed the first generation in 40 days. Second-stage juveniles (J2) densities were lowest at 863 DD_5 in April, first increased at 1,334 DD_5 in May, peaked at 2,951 DD_5 in July, and declined thereafter. Development of egg masses and J2 density in soil revealed that *M. arenaria* could develop in 7-8 generations in a year in the greenhouse. Degree-day monitoring, therefore, could aid to predict nematode development in soil and can be valuable tool a to develop root-knot nematode control strategies.

Keywords : crop loss, ecology, *Cucumis melo*, *Meloidogyne arenaria*, oriental melon, peanut root-knot nematode.

Oriental melon, *Cucumis melo* L. is a high-value cash crop in Korea. Generally, it is transplanted during the winter period (January-February) and cultivation lasts up to 10 months in a greenhouse. For the last 20 years, oriental melon has been an important crop in Seongju, Korea, and root-knot nematodes, *Meloidogyne* spp., have been recognised as a serious pest (Kwon et al., 1998; Park et al., 1995). Infected plants produce fewer fruits and die early in July unless soil is treated with nematicides or nonhost crops are rotated.

Meloidogyne arenaria and *M. incognita* are two root-knot nematodes species that are the most widely distributed in greenhouses in southern Korea (Kim et al., 2001). They are well adapted to warm soil temperatures of greenhouse conditions (De Guiran and Ritter, 1979; Taylor and Sasser, 1978; Van Gundy, 1985). *Meloidogyne* species overwinter mainly as eggs which hatch when soil temperature increases in spring. Second-stage juveniles (J2) invade roots after planting and nematode development on roots is regulated

by temperature. Embryogenic development occurs between 16.5 and 31.5°C, and is enhanced with temperature increase within the range. Hatching required 53 days at 9°C and 30 days at 33°C (Ferris et al., 1978). Field studies of *M. chitwoodi* on potato demonstrated that degree-day accumulation during the season is more important than the initial soil J2 population in determining crop damage (Pinkerton et al., 1991). Understanding population development of *Meloidogyne* species in greenhouse agroecosystems should aid for the development of management strategies. There are reports concerning the nematode development in relation to temperature (De Guiran and Ritter, 1979; Pinkerton et al., 1991; Tarjan, 1952), but there is no information on that of oriental melon in greenhouse conditions in Korea. The purpose of this study, therefore, was to determine the relationship between degree-day accumulation and development of *M. arenaria* in oriental melon grown in greenhouses.

Materials and Methods

The investigation was conducted at Seongju Fruit Vegetable Experiment Station, Korea. Oriental melon, *Cucumis melo* L. cv. Geumssaragi-euncheon, grafted on Shintozoa (*Cucurbit maxima* x *Cu. moschata*) was planted in February 4, 1999 [avg. outside temperature=-1.0°C (-6.5~5.4°C)] in a 400 m² greenhouse naturally infested with root-knot nematodes. The test site had sandy loam soil with somewhat high P_2O_5 and Ca contents. Grafting is a common practice in oriental melon cultivation to prevent fusarium wilt disease caused by *Fusarium oxysporum* f. sp. *melonis* (Leach et Currence) Snyder et Hansen.

All required cultural practices were applied during cultivation as follows. Fertilizers, 18.7 kg/10a nitrogen, 6.3 kg/10a phosphate, and 10.9 kg/10a potassium, and 3,000 kg/10a compost were broadcast-applied in October of the previous year and disk-incorporated. Soil was ridged to 20 x 180 cm (height x width) rows, and mulched with black plastic film (0.02 mm in thickness). Forty-two day-old oriental melon seedlings were transplanted in the rows with 40 cm spacing. The row was framed using iron wire and covered with clear plastic film (0.02 mm thick) (Fig. 1). During the night, a blanket (thickness=400 gram/m²) covered over plastic film to preserve heat; that was used till the middle of April. The row was drip-irrigated (dripper flow=1.49 l/hr; Netafim Co.) (Fig. 1). Nonsystemic pesticides, such as pyrazophos, dichloflu-

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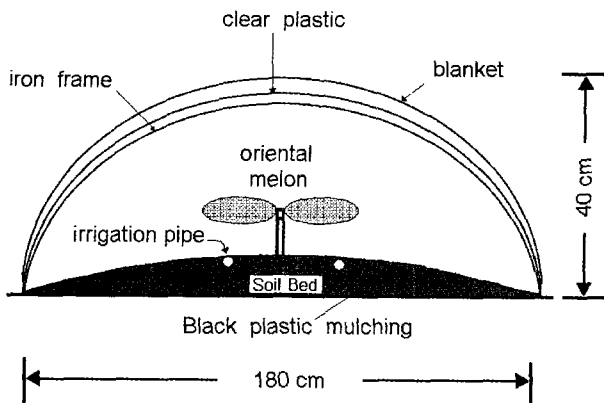Phone) +82-54-931-6789, FAX) +82-54-931-1753
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Fig. 1. Schematic drawing of the oriental melon cultivation system during the winter season in a greenhouse, Seongju, Korea.

Fig. 2. Temperature fluctuation in a typical day in February day at the oriental melon growing area in Seongju, Korea.

anid, and carbosulfan were applied to control insects and fungal pathogens, but no herbicide was used. Harvest started on April 20. **Population dynamics of *Meloidogyne* sp.** Fourteen core samples [2 × 15 (diameter × depth)] were collected from the center row of a plot (2 × 3 m) and six plots were examined at 30-day intervals. Soil was throughly mixed and processed within a day by sieving and centrifugation-flotation method (Southey, 1986) for juvenile extraction. Soil temperature was recorded hourly (Optic Stowaway Temp, Onset Computer Co.) at 10-cm depth during the study period and degree-day accumulation (degree above 5°C, DD_5) was calculated from daily mean temperatures.

Nematode development in relation to root development. To observe oviposition in relation to root development, soil and root samples were destructively collected on 40, 70, and 110 days after planting in separately prepared plots in the same greenhouse. On each sampling date, an 180 × 10 cm (length × width) area posing a plant in the center was sectioned to 10 × 10 × 10 cm block. A block containing soil and roots was about 2,755 g in dry weight. Eighteen soil blocks were taken from each area, and two areas were examined on each sampling date. Samples were processed within a day to estimate root biomass and nematode population densities. All root biomass in each block was picked up and root length and weight were measured except for the fine roots (<0.1 mm in diameter), for which only root weight was measured. Roots were also stained with Phloxin B (15 ml/l) to detect egg masses on the root surface (Taylor and Sasser, 1978). Remaining soil was throughly mixed and processed by the sieving and centrifugation-flotation method (Southey, 1986) for juvenile extraction using 300 cm³ soil for each sample.

Results

Nematodes found in the sampling area were *Meloidogyne arenaria*, *Helicotylenchus* spp., *Criconemoides* spp., and saprozoic nematodes including *Rhabditis* spp. *M. arenaria* was the major plant-parasitic nematode and others were low in number and inconsistent in frequency. Therefore, only *M. arenaria* was counted as important factor to the
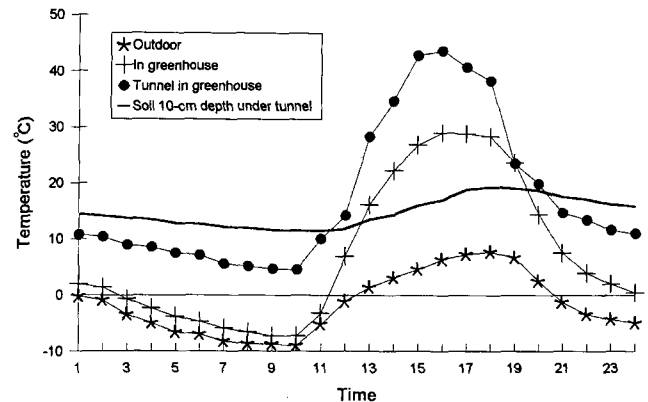
plant growth. This nematode was identified as *M. arenaria* (Neal) Chitwood race 2 based on perineal pattern and host differential test (Hartman and Sasser, 1985).

Temperature changes on a typical day of February in Seongju, Korea are presented in Fig. 2. February is one of the coldest months in Korea and average outside temperature was −1.7°C (−8.2~6.2°C). Temperature inside tunnel fluctuated from 4.5°C at 7:00 to 46.1°C at 14:00 while soil temperature of 10 cm deep ranged 7.2-18°C with the highest at 16:00. Maximum and minimum soil temperatures at 10-cm depth during the test period were 39.8°C and 10.8°C, respectively (Data not presented). Average soil temperature increased steadily from February through June with maximum record on June 13 (33.0°C). Plants showed typical wilt symptoms, which is a problem in the oriental melon production in Korea, and many plants died during July.

Population dynamics of *Meloidogyne* spp. The population changes of *M. arenaria* J2 and accumulated degree-days during the growing season are shown in Fig. 3. The J2 population density was stayed low until April as low as 9 J2/100 cm³ soil, and first increased in May to 1,768 J2/100 cm³, and showed a peak population in July as high as 3,817 J2/100 cm³. Degree-days accumulation was 1,334 DD_5 and 2,951 DD_5 for soil sampling date on May and July, respectively.

Nematode development in relation to root development. In root observations, egg masses were first observed on 40 days (March 16) after transplanting (Fig. 4), revealing the accumulation of 565 DD_5 (Fig. 3). This indicates the nematode completed the first generation in 40 days. Root weight and length appeared the similar growth pattern. Roots reached up to the edge of the row in 70 days, which gave a calculated growth rate of 1.3 cm/day. Few J2 were found in blocks at 40 days after transplanting. At 70 days after transplanting, there was few J2 around the planted center, but the density was relatively high at blocks 70-90 cm away from
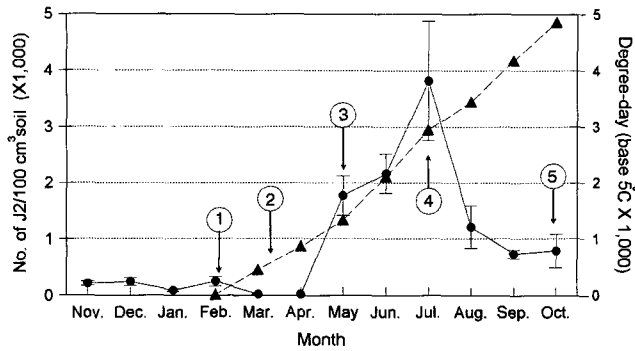
Fig. 3. Relationship between *Meloidogyne arenaria* population (J2s/100 cm^3 soil) development and degree-day accumulation (DD$_5$) on greenhouse-grown oriental melon. Arrows indicate ① : transplanting, ②: first detection of egg masses (565 DD$_5$), and ③: first increase of 2nd-stage juveniles (J2) in soil and beginning of harvest, ④ : highest soil J2 density and oriental melon start dying, and ⑤ end of extended cultivation.

the center. At 110 days after transplanting, a large number of J2 were found around the center and egg masses were found on roots reached edges as far as 90 cm away from the

center.

Discussion

Our studies showed that overwintering populations of *M. arenaria* in the greenhouse penetrated roots shortly after transplanting and produced egg masses in 40 days (565 DD$_5$) (Fig. 3, 4). Development of *Meloidogyne* species for oviposition requires 6,500-8,000 heat units (a heat unit being a degree-hour for 10°C base) (De Guiran and Ritter, 1979), and 565 DD$_5$ was equivalent to 8,635 heat units. *M. chitwoodi* on potato requires approximately 1,000 DD$_5$ to complete the first generation but the subsequent generation requires 500-600 DD$_5$ (Pinkerton et al., 1991), indicating that *M. arenaria* in our study had much lower DD$_5$ for the first generation than *M. chitwoodi*. This must be from the fact that potato roots must be developed from a seed potato, requiring an additional time before the penetration of J2 (Pinkerton et al., 1991). In contrast, oriental melon roots were readily available to J2 because 40 day-old-seedlings were transplanted in soil in our greenhouse study.

The soil J2 population density decreased from February
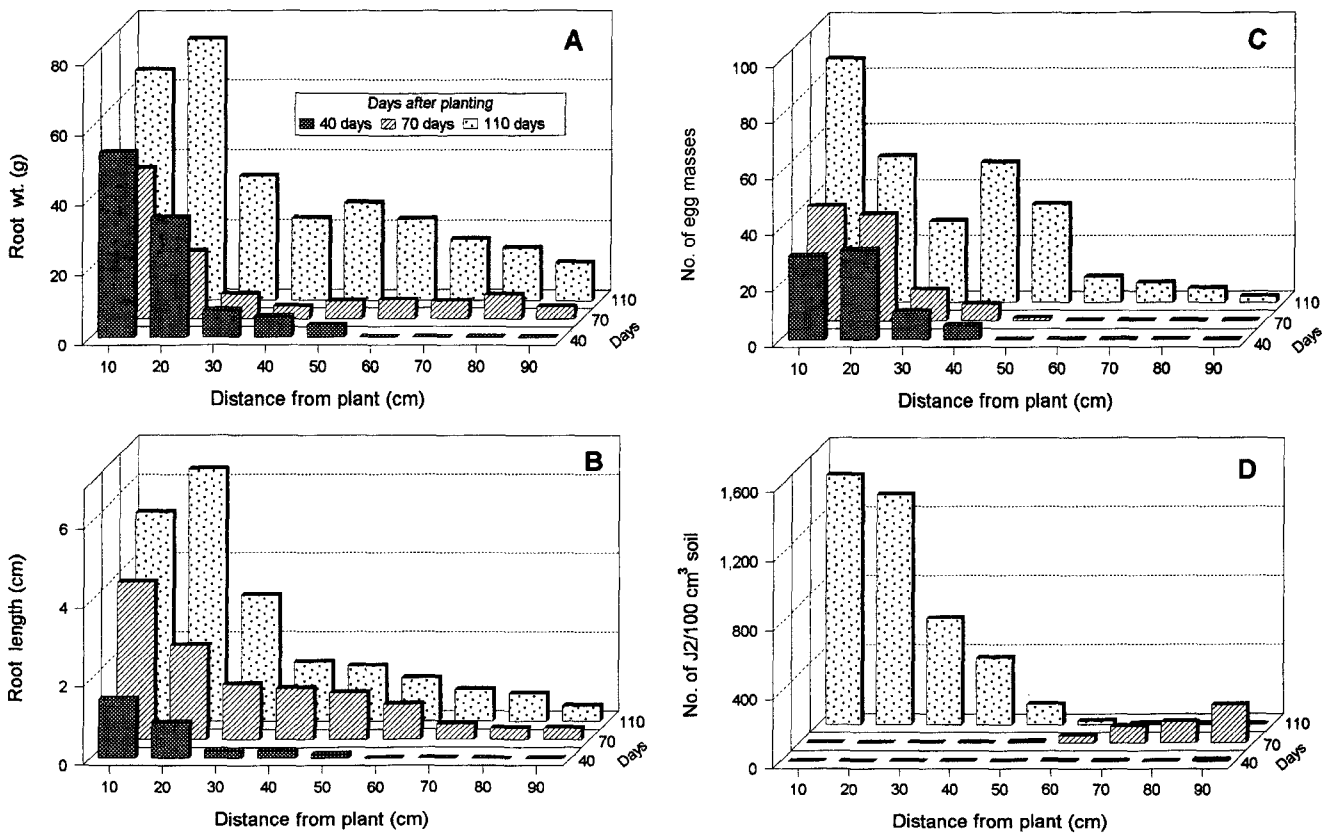
Fig. 4. Relationships between *Meloidogyne arenaria* population development (number of J2 and egg masses) and root development at 40, 70, and 110 days after transplanting. Data were average values from four soil blocks (10 × 10 × 10 cm). **A.** root weight (g), **B.** root length (cm), **C.** number of egg mass in root, **D.** number of J2 per 100 cm^3 soil.

to April, from 240 to 9 J2/100 cm³ soil, and first increased in May to 1,768 J2/100 cm³ soil (1,353 DD₅). Majority of survived eggs from last season may be hatched simultaneously because of root exudates and increased temperature in greenhouse in February as reported in other *Meloidogyne* species (Starr and Jeger, 1985). Hatched J2 will penetrate roots and those unable to penetrate would die, therefore, nematode densities in the soil would decline in March and April as observed in our study.

Meloidogyne arenaria produce eggs in 39 days at 21°C and the eggs hatch almost completely under optimum temperature and moisture conditions and juveniles penetrate the same roots in the following 20-29 days (De Guiran and Ritter, 1979). The small number of J2 found in soil in March and in April may indicate that the majority of hatched J2 from the first generation may have penetrated the same roots, resulting in a low nematode density in soil. Subsequent J2 increase in May at 1,353 DD₅ would be those from the hatching of the second generation egg masses and the rapid increase again in June would correspond to the completion of the third generation. The fact is also supported in root observations. A large number of J2 were found only at 110 days after transplanting around the planted center (Fig. 4D) although egg masses were produced much earlier at 40 days after transplanting (Fig. 4C).

Based on above observations, we could conjecture the relationship between degree-day and development of *M. arenaria* in greenhouse conditions. The third generation would end in 116 days after transplanting at 1,920 DD₅, and the fourth in 148 days at 2,700 DD₅. Approximately 5,000 DD₅ were accumulated in greenhouses in Seongju during the melon growing season Feb. 4-Oct. 8, resulting in 7-8 generations during which the nematode population may built up enough to give severe damage to the plant. This explains the consistent melon damage every year in Seongju greenhouses.

The threshold level for yield reduction in melon is 2-50 root-knot nematode juveniles per 100 cm³ soil (Barker et al., 1985). Such a high potential of damage emphasizes the need to develop control strategies, especially in the early growing season. Several strategies based on degree-day accumulation may be used to mitigate crop loss. Nonfumigant nematicides applied at 500-600 DD₅ (ca. 40 days after transplanting) would prevent penetration of first generation J2 and would restrict the early season population increase. However, the safe period for nematicide treatment in oriental melon has only 30 days before harvest, and only a few nematicides have such short safe period. Field trails have demonstrated that post-plant applications of nematicides can significantly reduce nematode damage on corn (Kaul and Sethi, 1987), cowpea (Meher et al., 1984), peanut (Minton et al., 1981), potato (Griffin, 1989; Ingham et al.,

1991), and Tobacco (Johnson et al., 1992). Monitoring degree-day accumulation and in-season nematicide treatment based on DD₅ may be an efficient and safe control strategy for the root-knot nematode in oriental melon.

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