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Distribution and population dynamics of *Meloidogyne arenaria* on oriental melon (*Cucumis melo* L.) under greenhouse conditions in Korea

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Summary. Oriental melon, *Cucumis melo* L., grafted on Shintozoa (*Cucurbit maxima* x *Cu. moschata*) was transplanted in February in a plastic tunnel inside a greenhouse infested with *Meloidogyne arenaria*. Population dynamics of *M. arenaria* juveniles (J2) were monitored at monthly intervals for 12 months, and horizontal and vertical distribution of root systems and number of J2's in soil were examined in July. Soil J2 population dynamics displayed a single peak; nematode density increased slightly after planting but declined to 9/100 cm^3 soil at the 70th day after planting to increase again at the 100th day and this continued until the 154th day to reach 3,817/100 cm^3. Thereafter, the population declined until December. Juveniles were distributed relatively uniformly horizontally over the 180 cm wide row. Maximum root length occurred at 0 to 25 cm depth, and maximum root weight occurred in the top 5 cm of soil around the row center. The highest density of *M. arenaria* J2's was at 0 to 25 cm soil depth, and only a few occurred at 40 to 50 cm. This study of *M. arenaria* on oriental melon under an intensive greenhouse cultivation system in Korea provides information for better understanding of root-knot nematode biology and population dynamics.

Key words: distribution, ecology, oriental melon, peanut root-knot nematode, root biomass.

Oriental melon, *Cucumis melo* L. is a high-value cash crop in Korea. It is transplanted in winter under a tunnel inside a plastic greenhouse, and harvest begins in May. After harvest, stems are trimmed and new shoots develop extending the cultivation period until October. Because of the limited land space in Korea, the same greenhouses have been used continuously for the last 20 years. In such an intensive and continuous cultivation system, soil-borne diseases, especially nematodes, become important yield limiting factors (Park *et al.*, 1995; Kwon *et al.*, 1998). *Meloidogyne* infestations occur in *ca.* 90% of greenhouses in Seongju, Korea (Park *et al.*, 1995; Cho *et al.*, 2000) causing over 30% yield losses.

Nematicides, soil replacement, and rice rotation are widely used by farmers to control root-knot nematodes. Economic and environmental considerations demand development of integrated pest management (IPM) programs. To achieve this, information must be available on nematode distribution in soil and seasonal population dynamics. Whilst there are reports concerning root-knot nematode population dynamics and distribution on various crops (Rich *et al.*, 1986; Barker, 1989; McSorley & Dickson, 1990; Pinkerton *et al.*, 1991; Johnson *et al.*, 2000), there are no similar data on greenhouse grown oriental melon crops in Korea.

MATERIALS AND METHODS

The investigation was conducted in 1998 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 on 4th February 1998 [avg. temp. = -1.0 °C (-6.5 to 5.4 °C)] in a tunnel in a 400 m^2 greenhouse known to be infested with root-knot nematode (Fig. 1). The soil was sandy loam with slightly above average contents of P_2O_5 and Ca. Grafting is a common practice in Korea to prevent fusarium wilt disease caused by *Fusarium oxysporum* f. sp. *melonis* (Leach *et* Currence) Snyder *et* Hansen. All common cultural practices were applied during the

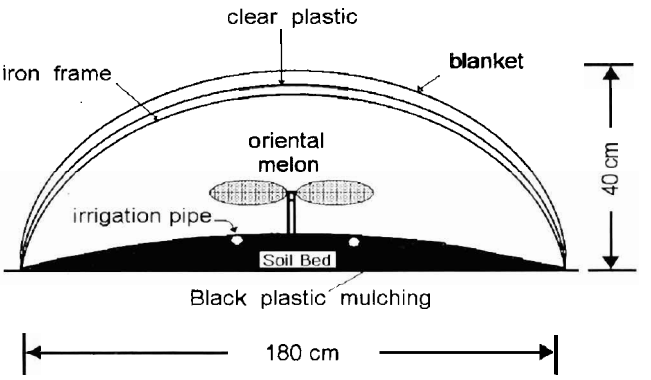

Fig. 1. Schematic drawing of oriental melon cultivation during the winter season in a plastic tunnel inside a greenhouse in Korea.

cultivation period (Anon., 1999).

Population dynamics of *Meloidogyne arenaria*. Six plots were used to monitor population dynamics of *M. arenaria*. Fourteen core samples (single core, 2 cm dia. to a depth of 15 cm) were collected from each side of seven plants in a plot (2 x 3 metre) at monthly intervals from January to December. Holes were sealed after sampling. The soil cores from each plot were mixed, and a 300 cm^3 sub-sample was taken and processed within one day by a sieving and centrifugation-flotation method for juvenile extraction (Southey, 1986).

Horizontal distribution. To study the horizontal and vertical distribution of root biomass and nematode densities, soil samples were taken six months after planting (July) when the plants were fully grown and the nematode population densities were high. A 180 x 80 cm (length x width) area with a plant in the center was sectioned in 10 x 10 x 10 cm samples (soil dry weight, *ca.* 2755 g). A total of 153 soil samples were taken from a plant and three plants were examined. Samples were processed within a day to estimate root biomass and nematode population densities. All root biomass in each sample was harvested and length and root weight were measured; for the fine roots (<0.1mm thick), only the weight was recorded. Remaining soil was thoroughly mixed and a 300 cm^3 sub-sample was processed for nematodes as described. For each section, the percentage of nematodes present at each distance from the row center was calculated by the method described by McSorley & Dickson (1990).

Vertical distribution. A 180 x 10 cm (length x width) area with a plant in the center was sectioned in 10 x 10 x 5 cm samples (length x width x depth). For each section, samples were taken to a depth of 50 cm, at 5 cm interval. A total of 170 soil samples were taken from a transect of a plant and two plants were examined. Root biomass and nematode density at each depth were studied as described.

RESULTS AND DISCUSSION

Nematodes found in the sampling area were *Meloidogyne arenaria*, *Helicotylenchus* spp., *Criconemoides* spp. and *Rhabditis* spp. *Meloidogyne arenaria* was the most important plant-parasitic nematode present with the number of other parasitic nematodes present being small and inconsistent (rarely more than 5 nematodes/100 cm^3 soil in all samples). Counts of other nematodes, mostly *Rhabditis* spp. were recorded as free-living nematodes. *Meloidogyne arenaria* (Neal) Chitwood race 2 was identified by perineal pattern and by host differential test (Hartman & Sasser, 1985).

Soil J2 population dynamics displayed a single peak during the growing season (Fig. 2). Nematode density increased slightly after planting but declined to 9/100 cm^3 soil at the 70th day (April 15th) to increase again in May at the 100th day. This continued until the 154th day (July 8th) after which the population declined until December. Egg masses on oriental melon root were detected at 40 days after transplanting. Thus, the lower J2 number found in soil samples in March and April may indicate that the majority of hatched J2s from the first generation penetrated the same roots. The subsequent increase in nematodes in soil in May would result from the hatch from the second generation egg masses and the rapid increase again in

Table 1. Correlation coefficients between nematode population densities and root biomass measured in greenhouse soil planted with oriental melon.

Root biomass	Soil profile	*Meloidogyne arenaria* J2		Free-living nematodes		No. of observations
		Corr. coef.	Prob.	Corr. coef	Prob.	
Weight	Horizontal	0.19	0.0200	0.24	0.0029	153
	Vertical	0.18	0.0209	0.18	0.0250	170
	Overall	0.26	0.0001	0.45	0.0001	323
Length	Horizontal	0.23	0.0050	0.71	0.0001	153
	Vertical	0.50	0.0001	0.51	0.0001	170
	Overall	0.39	0.0001	0.44	0.0001	323

June would correspond to the completion of the third generation.

The maximum number of soil J2's in our study was 3,817/100 cm^3 at July, which was comparatively less than reported in other studies (Ferris & McKenry, 1974; Pinkerton *et al.*, 1991). Root-knot nematode population densities fluctuate seasonally and can reach high levels e.g. 16,000 *Meloidogyne* spp. J2/100 cm^3 soil under grapevine (Ferris & McKenry, 1974), and 8,000 *M. chitwoodi* J2/100 cm^3 soil under potato (Pinkerton *et al.*, 1991). *Meloidogyne* population density depends on host crop, and melon probably does not support high egg production. In the Seongju greenhouse area, 500 g of galled-root can contain $2x10^4$ eggs and J2's per gram (unpublished results). Large numbers of egg masses and hatched J2's may be inside these galls, and consequently remain undetected by soil examination.

Root biomass is presented as the total length and weight found in each section of soil from each plant (average of three plants for horizontal distribution and two plants for vertical distribution) and population densities of *Meloidogyne arenaria* is expressed as the number of J2's in the soil from each section.

After 180 days, root weight was highest when taken close to the planting center. When measured across 10 cm intervals in a row, about 50% of root weight was found within a 20 cm dia. zone from the center. Root length generally decreased with distance from the planting center. One side of the edge bordered with a path used by the grower had a lower root biomass than the other side (Fig. 3B & D), probably as a result of soil compaction caused by routine cultivation. The greater J2 density was found 40-60 cm away from the center.

The largest root weight occurred in the top 5 cm depth and the greatest root length occurred in the 0 to 25 cm depth (Figs. 3 & 4). Smaller root

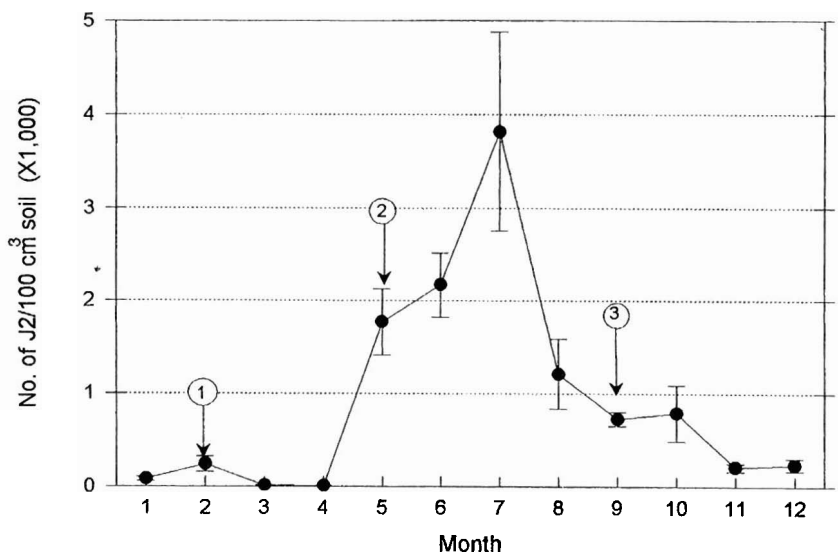

Fig. 2. Seasonal population dynamics of *Meloidogyne arenaria* in oriental melon under greenhouse conditions. Arrows indicate : 1 - transplanting, 2- first harvest, 3 - end of cultivation period.

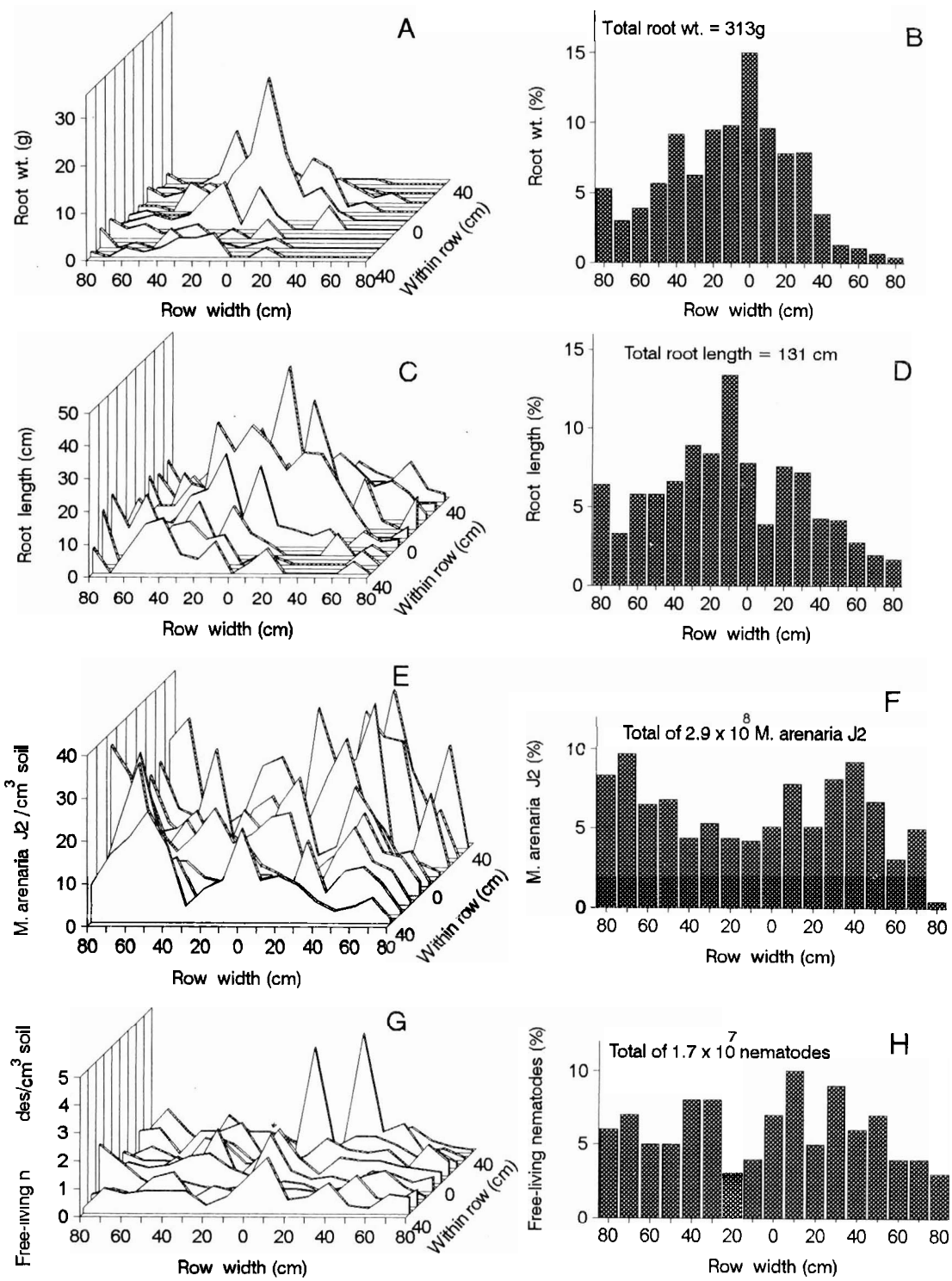

Fig. 3. Horizontal distribution of oriental melon roots and nematodes in greenhouse soil: A & B: Root weight; C & D: Root length; E & F: *Meloidogyne arenaria* J2; G & H: Free-living nematodes.

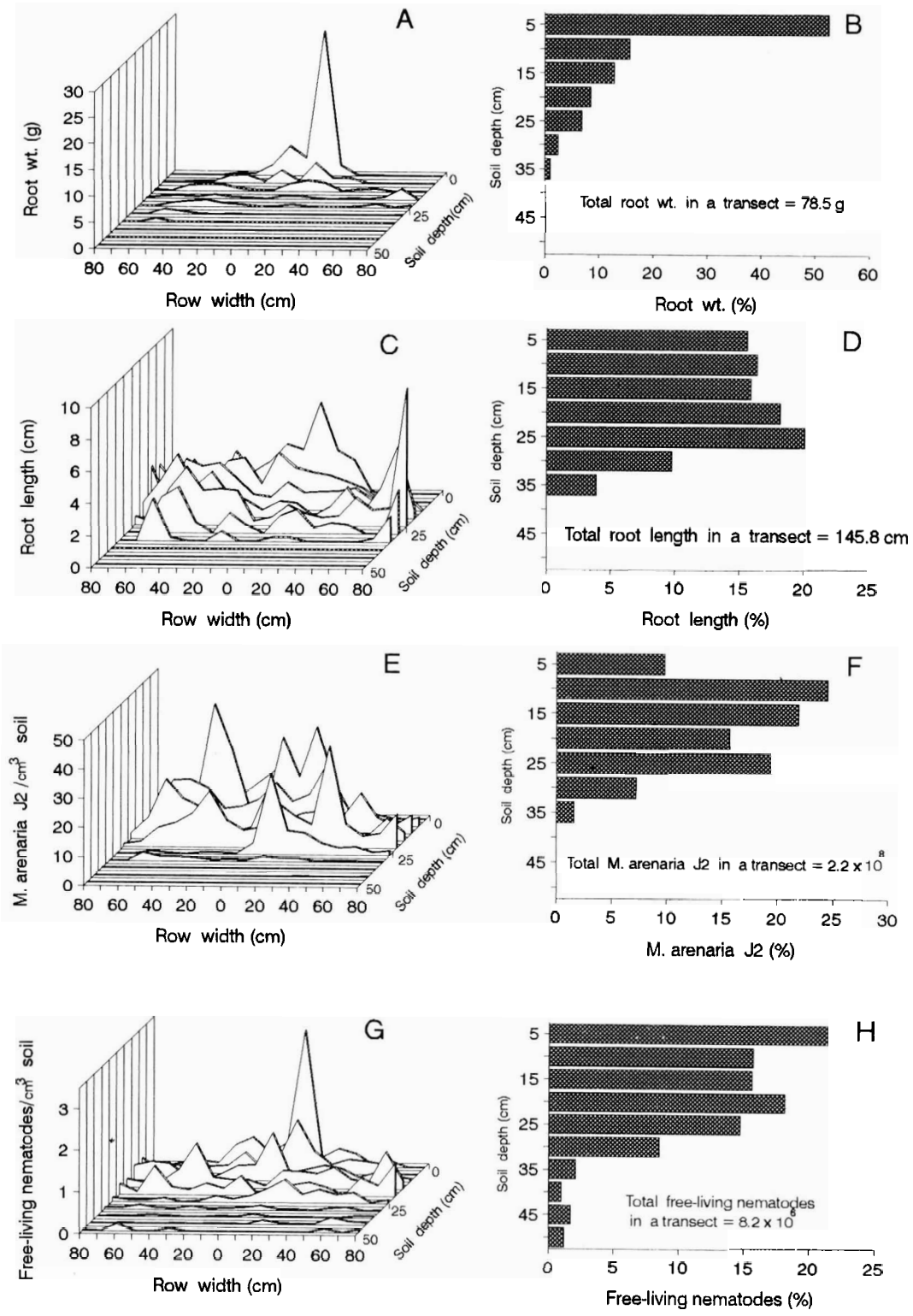

Fig. 4. Vertical distribution of oriental melon roots and nematodes in greenhouse soil: A & B: Root weight; C & D: Root length; E & F: *Meloidogyne arenaria*; G & H: Free-living nematodes.

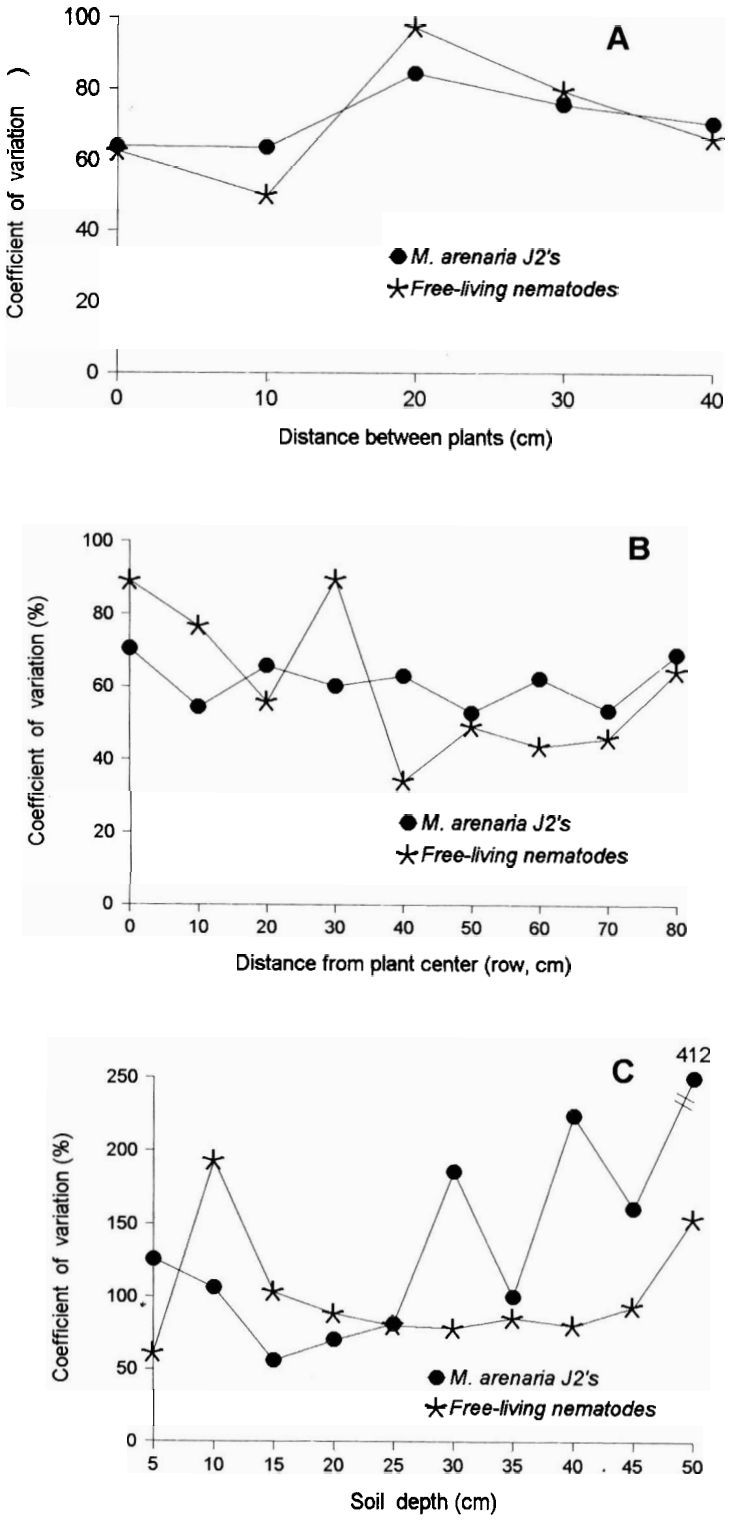

Fig. 5. Coefficients of variation among nematode counts from the oriental melon root zone. Each point represents a mean of 54 groups of samples for A and 30 groups of samples for B and C taken six months after planing.

biomass was found below 35 cm soil depth. The highest population density of *M. arenaria* and free-living nematodes was at the 0 to 25 cm soil depth (Fig. 4), with fewer nematodes occurring at the 40 to 50 cm depth.

Distribution of *M. arenaria* J2's was relatively uniform in the upper 25 cm of soil with higher densities at 40-60 cm away from the row center (Fig. 3E & F). Fifty three percent of the nematode population was present in the upper 15 cm of soil. The results from the greenhouse study differed from other field studies with grapevines or soybean. Population densities of root-knot nematodes are variable under grapevine, but usually rather low and there are few *Meloidogyne* J2's between the rows in the upper 15 cm of soil, particularly beyond 45 cm from the vine (Ferris & McKenry, 1974). Most plant-parasitic nematode population densities are concentrated at soil depths below 15 cm in studies with soybean (McSorley & Dickson, 1990). These differences could be explained by different root system of crops under various cultivation systems and environmental conditions being more variable in the upper soil layer in fields (McSorley & Dickson, 1990). However, in the greenhouses, the soil is covered with black plastic mulch, which should provide relatively constant temperature and a narrow range of moisture fluctuation, which would favour uniform distribution of root-knot nematodes in the upper 15 cm of soil, especially in the top 5 cm layer.

Correlation between root length, root weight, and nematode population densities were positively significant ($P \leq 0.05$) (Table 1). The highest correlation coefficient was between root length and J2 population density, indicating that surface area may be more important than root mass in determining population densities of *M. arenaria*. Vertical distribution patterns were more clear ($r = 0.50$, $p = 0.0001$) than horizontal distribution ($r = 0.23$, $p = 0.005$) (Table 1). Large root galls developed at the upper 5 cm soil layer, around the center of plant growth, these sometimes accounting for more than 50% of the root weight. These probably account for the low correlation coefficients between root weight biomass and J2 population densities.

Distribution patterns of free-living nematodes (Figs. 3G & H; 4G & H) were similar to those of root-knot nematodes. Their distribution appeared to be related to root distribution, although the total number was unexpectedly low, only 4-6% of that of root-knot nematodes (Figs. 3 & 4), and being about ten times fewer than reported for other cropping systems (Mankau, 1968; Griffiths *et al.*, 1994). Plant roots and cultivation systems can substantially affect underground biota (Griffiths *et al.*, 1994). Monoculture of oriental melon in greenhouses appears to have a considerable influence on the density of free-living nematodes.

Barker *et al.* (1985) recommended that to detect field population densities of root-knot nematodes, precise and accurate sampling is necessary because threshold levels for yield reduction in melon is very low (2 to 50 *M. arenaria* J2's per 100 cm^3 soil). A coefficient of variation for nematode distribution was calculated for each position for vertical and horizontal soil sections (Fig. 5). The horizontal root-knot nematode density value was relatively uniform and low, especially close to the planting center where the nematode densities were high and uniform. However, vertically the variation was smallest at 15 cm depth (Fig. 5C). To obtain the best estimate of nematode density around oriental melon roots, samples should be taken close to the plant, preferably between plants in the row center to the depth of 15 cm that represents the region of high nematode density with low variation (Fig. 5).

These data and those of others (Bird *et. al.*, 1974; Hussey, 1977; Minton *et. al,* 1978; Rich *et. al.*, 1986), suggest that the distribution of plant parasitic nematodes in the soil profile is related to the particular crop, nematode species, and soil conditions. Further comparative studies of nematodes such as *M. arenaria* under intensive greenhouse cultivation systems may provide useful information to better understand their biology, ecology and pathogenicity and help to develop improved management strategies.

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Kim D.G. Распределение и динамика популяции *Meloidogyne arenaria* на дынях в теплицах Кореи.
Резюме. Дыни *Cucumis melo* L., привитые на гибрид крупноплодной и мускусной тыкв (*Cucurbita maxima* x *Cucurbita moschata*), пересаживали в феврале в прикрытые полиэтиленом грядки внутри теплиц, пораженных *Meloidogyne arenaria*. Динамику популяции *M. arenaria* прослеживали на протяжении года с интервалом в 1 месяц. Горизонтальное и вертикальное распределение, а также численность личинок *M. arenaria* 2-й стадии в почве определили при обследовании в июле. Динамика популяции *M. arenaria* характеризовалась единственным пиком численности. После посадки отмечали незначительное увеличение численности, после которого наблюдали снижение до 9 личинок на 100 см^3 почвы к 70-му дню. Затем, около 100-го дня начинался рост популяции нематод до 3817 личинок на 100 см^3 почвы. После этого численность нематод неуклонно снижалась вплоть до декабря месяца. Личинки *M. arenaria* были распределены довольно равномерно по всей ширине (180 см) эксперментального рядка. Максимальная длина корней была отмечена на глубине до 25 см, а максимальный вес корней был приурочен к верхним 5 см почвы. Основная часть личинок *M. arenaria* была сосредоточена в верхних 25 см почвы, и лишь отдельные личинки регистрировались на глубине 40-50 см. Исследование развития *M. arenaria* на дыне в условиях практикуемого в Корее интенсивного культивирования в теплицах, дает дополнительные сведения для оценки биологии галловых нематод и динамики их численности.