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Efficacy of Soil Amendment with Medicinal Plant Materials for the Control of Root-knot Nematode (*Meloidogyne incognita*) in Tomato

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Soil amendments with oriental herbal medicines such as fruit of *Anethum graveolens*, flower buds of *Syzygium aromaticum*, rhizome of *Cnidium officinale*, rhizome of *Coptis chinensis*, root bark of *Paeonia suffructicosa*, stem bark of *Phellodendron amurense*, and stem bark of *Cinnamomum cassia* at the rate of 0.2% (weight by volume of soil) significantly reduced *Meloidogyne incognita* infection (root gall formation) of tomato seedlings compared with the control. The most effective treatments were root bark of *P. suffructicosa* and stem bark of *C. cassia* as they gave minimum numbers of galls on tomato roots (4.7% and 8.9%, respectively, relative to control) as compared to other treatments. Another study with root bark of *P. suffructicosa* and *C. cassia* at different application doses also showed consistent results in reducing gall number. The control efficacy decreased as the application doses were lowered, indicating their dose-dependent control activities. These treatments significantly enhanced aboveground plant growths (total masses).

Keywords : *Cinnamomum cassia*, *Meloidogyne incognita*, *Paeonia suffructicosa*, soil amendment

Root diseases caused by root-knot nematodes, *Meloidogyne* spp., are severe in vegetables especially under greenhouse conditions in Korea (Kwon et al., 1998; Lee, 2003; Park et al., 1995). Southern root-knot nematode, *M. incognita*, is known to cause considerable crop production losses, particularly in tomato (Bhatti and Jain, 1977), and is prevalent in greenhouses. Tomato plants affected by root-knot nematodes exhibit slow development and are stunted. The leaves become yellowish green to yellow, tend to droop, and wilting of the plants may occur. The presence of root galls is the most characteristic symptom of root-knot nematode infection.

There are various control measures for root-knot nematodes like pesticides, organic amendments, and cultural practices (Kim, 2001). Repeated application of pesticides causes several unfavorable side effects such as pest resistance, pest resurgence, pesticide residues in food, and soil and water pollution (Ketkar and Ketkar, 1990; Rao and Ramopando, 1993; Sharma, 1994; Shingh, 1990). Hence, there is an urgent need to search for alternative control measures that can be readily available to the farmers.

Nematodes have been managed by using various non-chemical methods. Traditionally, organic amendments (Alam et al., 1978; Khan et al., 1974; Mian and Rodriguez-Kabana, 1986) and recently, biocontrol agents (Davide and Zorilla, 1983; Jatala, 1986; Khan and Hussain, 1988; Khan and Hussain, 1990; Kerry, 1984; Morgan-Jones et al., 1984) have been used for nematode control.

The application of organic soil amendment has some advantages over chemical control because the former is more useful, less hazardous, and pollution free. Among various organic materials, plant materials such as neem cake (Alam et al., 1978) and mustard cake (Gul et al., 1990) have shown significant control of root-knot nematodes. Various plant sources of Chinese herbal medicine were examined on their effects on *Pratylenchus vulnus* and *M. javanica* (Ferris and Zheng, 1999). However, few studies have been done on the use of medicinal materials at practical levels for nematode control.

This study examined the efficacy of soil amendments using some medicinal plant materials on the control of root-knot nematode to develop an environment-friendly and safer measure for nematode control, which can be applied in field conditions.

Materials and Methods

Test plants. Seeds of tomato (*Lycopersicon esculentum*) cv. Phungsaeng were planted in plastic trays containing sandy loam soil. These seedlings were transplanted into plastic pots (1/5,000 a) one month after planting. Each pot contained one plant.

Medicinal plant materials. Dried plant materials were purchased from an oriental medicinal shop and were ground in a blender. These include fruit of *Anethum graveolens*, flower buds of *Syzygium aromaticum*, rhizome of *Cnidium officinale*, rhizome of

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Coptis chinensis, root bark of *Paeonia suffructicosa*, stem bark of *Phellodendron amurense*, and stem bark of *Cinnamomum cassia*.

Soil amendment. Non-sterilized field soil was used to attain soil condition similar to field soil. At the time of transplanting of tomato seedlings, the soil was thoroughly mixed with the ground powder of dried plant materials. For the first experiment, plant materials were incorporated into soil at the rate of 0.2% (weight by volume of soil). For the second experiment, three levels of soil amendment rates (0.05, 0.1, and 0.2%, w/v) were applied using root bark of *P. suffructicosa* and stem bark of *C. cassia* with the same method mentioned above.

Nematode and inoculation. Oriental melon field soil infested with root-knot nematodes (*M. incognita*) was kindly provided by Dr. D. G. Kim of the Kyungbuk Agricultural Institute of Technology. Nematodes were multiplied in the soil using tomato plants. Galls and egg sacs were collected and nematodes were extracted by Baermann's funnel method. After 5 days of transplanting, the plants were inoculated with 2,000 freshly hatched juveniles of *M. incognita* per plant by pouring the nematode solution into rhizosphere. Each treatment was

Table 1. Effect of soil amendment with medicinal plant materials on the gall formation on tomato plants by *Meloidogyne incognita*

Treatment[a]		Korean name	No. of galls/plant[b]	Control efficacy (%)
Plant species	Plant parts used			
Control	–	–	132.2±60.8	–
Anethum graveolens	Fruit	Sariza	53.8±25.4	59.3
Syzygium aromaticum	Flower bud	Jeong-hyang	31.0±15.8	76.6
Cnidium officinale	Rhizome	Cheon-gung	21.0±12.2	84.1
Coptis chinensis	Root	Hwang-ryeon	21.6± 7.7	83.7
Paeonia suffructicosa	Root bark	Mokdan-pi	6.2± 3.4	95.3
Phellodendron amurense	Stem bark	Hwang-baek	36.0±13.9	72.8
Cinnamomum cassia	Stem bark	Gyae-pi	11.8± 4.7	91.1

[a] About 0.2% (w/v) of dried plant materials were incorporated with non-sterilized soil in pots 5 days before inoculation with *Meloidogyne incognita* juveniles. Root gall formation was examined 35 days after inoculation. Control: inoculation only.

[b] Numbers are averages and standard deviations of five replications.

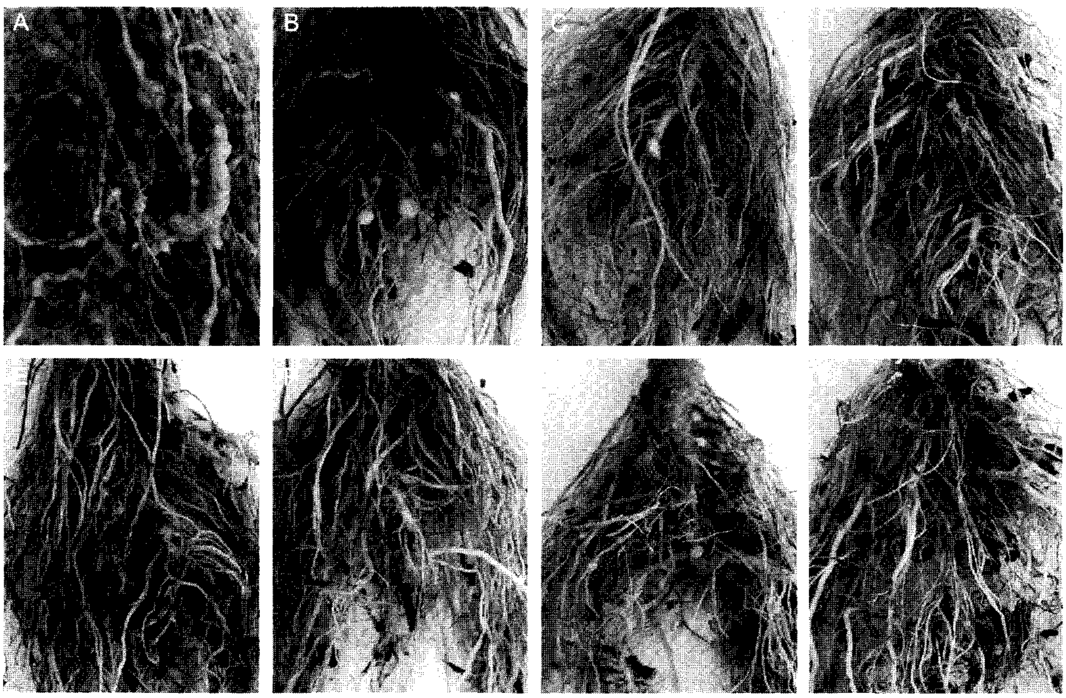

Fig. 1. Effect of soil amendment of seven medicinal plant materials on the formation of galls in tomato plants inoculated with *Meloidogyne incognita* (examined 35 days after nematode inoculation). A maximum number of galls were formed in the control (**A**), while a minimum number of galls were formed in the treatment of root bark of *Paeonia suffructicosa* (**F**). (**B**) Fruit of *Anethum graveolens*; (**C**) Flower bud of *Syzygium aromaticum*; (**D**) Rhizome of *Cnidium officinale*; (**E**) Root of *Coptis chinensis*; (**G**) stem bark of *Phellodendron amurense*; (**H**) stem bark of *Cinnamomum cassia*.

replicated five times. Plants were watered daily. The experiments were conducted in a greenhouse where temperature ranged from 25-30°C.

Examination of gall formation and plant growth. After 35 days of inoculation, the plants were pulled out very carefully from the pots along with their roots. Roots were washed with tap water. The number of galls formed on the whole root system was counted. For the second experiment, plant growths including root weight, total root length, and shoot weight and height were also examined.

Results

Nematode control effect of medicinal plant materials. Root gall formation on tomato plants by the root-knot nematode, *M. incognita*, was reduced by soil amendment with medicinal plant materials, among which, root bark of *P. suffructicosa* was the most effective in reducing gall formation (Table 1, Fig. 1). *P. suffructicosa* gave 95.3% reduction of gall number as compared to the control. Stem bark of *C. cassia* ranked second in controlling root-knot nematode as it gave 91.1% control effect over the inoculated plants. On the other hand, fruit of *A. graveolens* was the least effective as it gave only 59.3% plant disease control.

Results showed that maximum number of galls was formed on the untreated control plants. Due to the root gall formation on the roots and the nematode pathogenic effect, a significant increase in fresh root weight of tomato plants was observed, which was proportional to infection severity (gall number) (data not shown). On the other hand, overall plant vigor including shoot weight and plant height was higher in organic material treatments, with the amendment of root bark of *P. suffructicosa* observed as the most effective, compared with all other plant materials.

Amount of soil amendments and their effect on nematode control and plant growth. Further study on nematode control was conducted using root bark of *P. suffructicosa* and stem bark of *C. cassia*, which were found most effective in reducing root gall formation in tomato plants. Results obtained in reducing the gall number by 0.2% amendment of *P. suffructicosa* root bark (92.7% control efficacy) were consistent with the first inoculation test, but somewhat decreased with the use of *C. cassia* stem bark (Fig. 2). About 85% control of the gall formation was achieved by 0.1% *P. suffructicosa* root bark. Control efficacy was low at the other concentration (0.05%) either in both plant materials.

Control of root gall formation by soil amendments with *P. suffructicosa* root bark and *C. cassia* stem bark also affected plant growth, with increased plant height and shoot weight (Figs. 3A, B), compared with inoculated plants without treatment. Especially, the plant height and shoot weight in 0.2% treatment of *P. suffructicosa* root bark were almost the same as those of non-inoculated healthy plants. Fresh and dry root weights of the plants with root galls were much higher than those of healthy plants (Fig. 3C). Generally, root weight was reduced by the soil amendments.

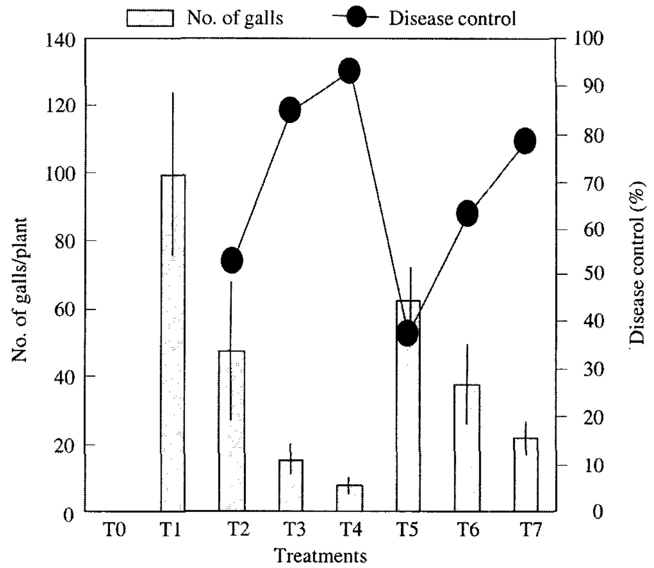

Fig. 2. Effect of soil amendment with medicinal plant materials on the formation of root galls in tomato plants by *Meloidogyne incognita*. Vertical bars and lines are averages and standard deviations of five replications. T0=healthy plant; T1=control (nematode inoculation only); T2=0.05% root bark of *Paeonia suffructicosa*+*M. incognita*; T3=0.1% root bark of *Paeonia suffructicosa*+*M. incognita*; T4=0.2% root bark of *Paeonia suffructicosa*+*M. incognita*; T5=0.05% stem bark of *Cinnamomum cassia*+*M. incognita*; T6=0.1% stem bark of *Cinnamomum cassia*+*M. incognita*; T7=0.2% stem bark of *Cinnamomum cassia*+*M. incognita*.

Discussion

Results of this study showed that root gall formation by *M. incognita* infection was greatly reduced by soil amendment with medicinal plant materials, especially the root bark of *P. suffructicosa* and stem bark of *C. cassia*. Owing to the nematode control, aboveground plant growths were significantly higher than the control plants with nematode inoculation alone. On the other hand, the tomato roots infected with the nematodes weighed much higher than healthy roots, causing imbalanced nutritional distribution in the whole plant system, as well as impaired nutritional uptake and translocation by malfunctioning the root system. This kind of plant damage would be even greater for fruit production because retarded plant growths cumulatively affect on the plants at the reproductive stage.

It is known that root bark of *P. suffructicosa* and stem

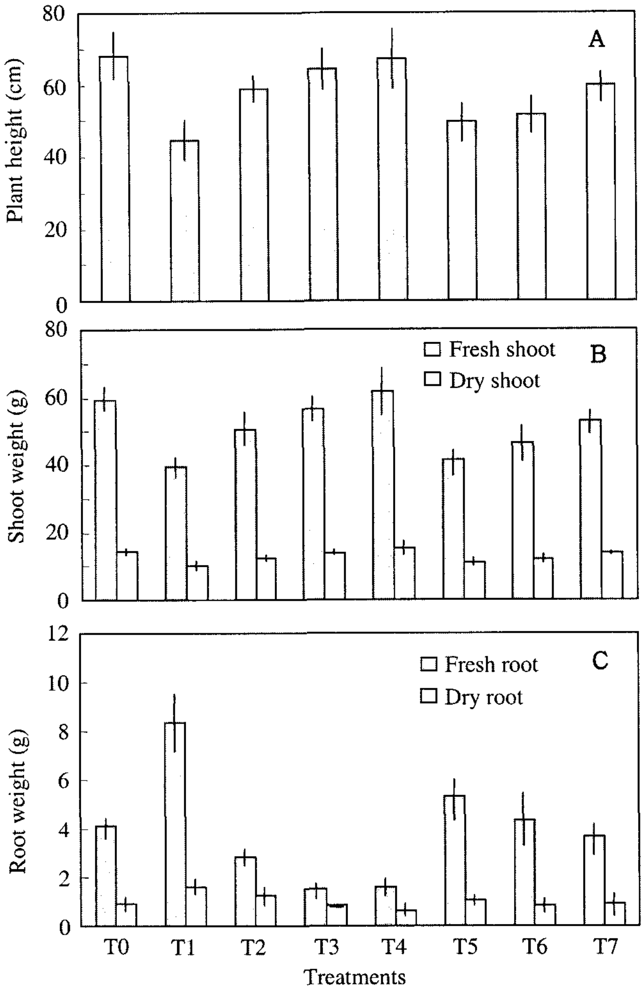

Fig. 3. Effect of soil amendment with medicinal plant materials on the plant growths (plant height <A>, shoot weight <B> and root weight <C>) of tomato plants inoculated with *Meloidogyne incognita*. Vertical bars and lines are averages and standard deviations of five replications. T0=healthy plant; T1=control (nematode inoculation only); T2=0.05% root bark of *Paeonia suffructicosa*+*M. incognita*; T3=0.1% root bark of *Paeonia suffructicosa*+*M. incognita*; T4=0.2% root bark of *Paeonia suffructicosa*+*M. incognita*; T5=0.05% stem bark of *Cinnamomum cassia*+*M. incognita*; T6=0.1% stem bark of *Cinnamomum cassia*+*M. incognita*; T7=0.2% stem bark of *Cinnamomum cassia*+*M. incognita*.

bark of *C. cassia* have antifungal activity against *Alternaria alternata* (Kim et al., 1996), and that the latter inhibits temporarily the activity of *M. javanica* and *Pratylenchus vulnus* (Ferris and Zheng, 1999). These two materials are used as crude drugs in many traditional prescriptions in oriental medicine, and may have some nematicidal or nematostatic components. The major component of stem bark of *C. cassia* is known to be cinnamaldehyde (Kim et al., 1996). Khan et al. (1996) found that mustard cake was most effective in reducing population of root-knot nematodes in soil and gall formations on roots, increasing the yield of tomato. The mode of action may involve the release of volatile nematicidal or nematostatic substances like phenol, formaldehyde or acetone during their decomposition (Alam et al., 1978), or water-soluble fractions that are highly toxic to nematodes (Khan et al., 1974). However, further study is needed to verify the control mechanisms of *Paeonia* root bark and *Cinnamomum* stem bark.

As for the amount of the materials required for the nematode control, 0.2 g of root bark of *P. suffructicosa* exhibited sufficient control in 1 liter of soil, which can be converted to 200 kg/10a for field application. These amounts are 4-10 times higher than that of dazomet (fine granules), of which the application dose is 20-50 kg/10a (Suthey, 1982), and much higher than non-fumigant nematicides like fosthiazite (granule type; 5% a.i.) used at 6 kg/10a for root-knot nematodes in oriental melon under greenhouse conditions (Kim et al., 2001). This suggests that the amount of the plant material may be too high to be used for practical application in the fields. However, row application or use in seedbeds and as potting mixes for valuable crops may require less amount of materials, providing a good feasibility for its practical use. Also, this material can be mixed with nematicides to exert improved nematode control and to decrease the amount of synthetic chemicals used.

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