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Root-knot Nematode Populations and Carrot Yield Following Five Forage Legumes and Continuous Carrots

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Abstract. **Root-knot nematode (*Meloidogyne hapla*) juvenile population increased and carrot (*Daucus carota* L.) yield progressively decreased during eight continuous carrot crops grown over 37 months. When 'Haifa' and common white clovers (*Trifolium repens* L.) were cropped for 29 months and plowed down, two succeeding carrot crops suffered severe yield and quality losses and the juvenile nematode population in the soil increased greatly. However, there were significantly fewer juveniles in the soil and significantly higher yield and better quality of carrots when nematode-resistant 'Nevada Synthetic XX' and 'Nevada Synthetic YY' alfalfas (*Medicago sativa* L.) and continuous cultivation preceeded the carrots.**

Fallow cultivation and crop rotation with resistant crops are recommended non-chemical methods for controlling root-knot nematodes. Forage legumes are generally considered to be especially desirable in rotations or for use as a green manure crop. However, root-knot nematode levels in the soil have been shown to increase when alfalfa and white clover were grown (2, 4, 6). Several alfalfa cultivars and germplasm sources that resist increases in root-knot nematode population have been developed (5, 8).

The objectives of this study were: 1) to compare root-knot nematode juvenile populations in the soil when fallow cultivation and continuous cropping with a susceptible crop and resistant and sensitive legumes were grown for 29 months; and 2) to determine the effects of such cropping systems on yields of carrots, a nematode-susceptible crop (3, 9), when it succeeded the legume cropping experiment.

Experiments were conducted on a well-drained volcanic ash Waimea silt loam soil (medial, isothermic Typic Eutrandepts) at an 800-m elevation on the island of Hawaii. Mean monthly air maxima ranged from 20° to 24°C and mean monthly minima from 11° to 15°. Average monthly rainfall was 47 mm; some rain fell each month and only 3 months had more than 100 mm of rainfall. Crops were sprinkler-irrigated during dry periods. Plant materials consisted of alfalfa, white clover, and carrots. 'Nevada Synthetic XX Alfalfa' (8) and 'Nevada Synthetic YY Alfalfa' (5) were root-knot nematode-resistant; 'Washoe', a nematode-susceptible alfalfa (7), common white clover, 'Haifa' white clover, a continuously cultivated fallow check, and eight continuous crops of 'Goldinhart' carrots were the other treatments. From May 1982 through June 1984, the forages were harvested 18 times, after which the legumes were plowed under. Following the plowdown of the forages, carrots were planted and two consecutive mature carrot crops were harvested from all of the legume and cultivated fallow plots during Aug. 1984 and Apr. 1985. The continuous carrot plots were maintained from Mar. 1982 through Apr. 1985. Alfalfa seeds were inoculated with *Rhizobium meliloti* and the clover seeds with *Rhizobium trifolium*. They were planted during Feb. 1982 in rows 0.15 m apart at the rate of 17 kg seed/ha. Plots were 1.5 × 6 m and were arranged in a randomized complete block design with six replications. Weeds were controlled by hoeing.

Root-knot nematode juveniles extracted from soil samples 0 to 0.2 m deep by a sugar flotation technique (1) were identified as *Meloidogyne hapla*. Root-knot nematode juvenile populational levels remained low in all alfalfa plots while alfalfa was growing,

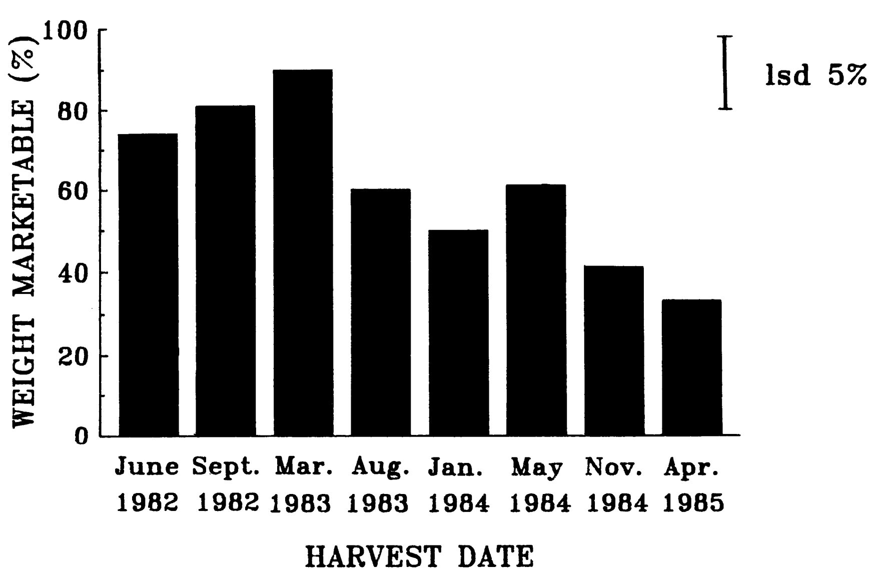

Fig. 1. Percentage (by weight) of marketable 'Goldinhart' carrots during eight cropping periods in the continuous carrot plots.

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Table 1. Number of *Meloidogyne hapla* juveniles per liter of soil at five sampling dates.

Treatment	Sampling date: Feb. 1982	Nov. 1982	May 1983	Apr. 1984	Apr. 1985[z]	LSD[y]
	Juveniles/liter of soil[x]					
Nev. Syn XX alfalfa[v]	10 a	3 b	13 c	16 b	236 c	205
Nev. Syn YY alfalfa[v]	23 a	0 b	33 c	4 b	510 c	284
Washoe alfalfa[v]	16 a	10 b	207 c	50 b	2,700 b	1200
Haifa white clover[v]	10 a	163 ab	3900 a	9,800 a	16,200 a	5700
Common white clover[v]	16 a	267 a	3000 ab	14,200 a	16,600 a	6200
Continuous cultivation	13 a	0 b	16 c	6 b	76 c	40
Continuous carrots[u]	31 a	107 ab	1100 bc	220 b	1,800 b	1200

[z]Carrots were harvested in Nov. 1984 and Apr. 1985.
[y]Mean separation within row by LSD $\alpha = 0.05$.
[x]Mean separation within columns by Duncan's multiple range test, 5% probability level.
[v]Seeded Feb. 1982; plowed under June 1984.
[u]Six crops of carrots were raised from May 1982 to May 1984.

Table 2. Effects of five legume crops grown for 29 months, continuous cultivation, and continuous carrot cropping on the marketable fresh weight and percentage of total harvest weight of carrots harvested in Nov. 1984 and Apr. 1985.

	Marketable yield			
	$kg \cdot m^{-1}$ of row		% of total harvest	
Treatment	Nov. 1984	Apr. 1985	Nov. 1984	Apr. 1985
Nev. Syn XX alfalfa	2.5 a[z]	2.2 a	64 abc	63 a
Nev. Syn YY alfalfa	2.8 a	2.3 a	75 a	63 a
Washoe alfalfa	2.2 ab	1.6 b	65 abc	48 b
Haifa white clover	0.3 c	1.0 c	18 d	39 bc
Common white clover	1.0 bc	0.4 c	37 cd	19 d
Continuous cultivation	2.2 ab	2.2 a	70 ab	64 a
Continuous carrots	1.0 bc	0.7 c	4 bcd	33 c

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

but increased to about 10,000 and 14,000 juveniles/liter of soil in 'Haifa' and common white clover plots, respectively, by 27 months after planting (Table 1). Root-knot nematode populational levels in the continuous carrot plots also were much lower than in the 'Haifa' and common white clover plots after the first six crops of carrots. The lower level of root-knot nematode juveniles in the continuous carrot plots was expected since carrots have a less extensive root mass than clover and there was a fallow period between crops. Continuous cultivation also resulted in low population levels of root-knot nematodes throughout the trial.

After two crops of carrots had been harvested, root-knot nematode juvenile counts in the continuous cultivation plots and plots previously cropped with 'Nev Syn XX' and 'Nev Syn YY' alfalfas had increased, but remained significantly lower than in either of the clover plots or those that were continuously in carrots. Juvenile population levels were higher after the carrot crops following susceptible 'Washoe' alfalfa than after the resistant alfalfas. Juvenile populations in 'Haifa' and common white clover plots were higher after both subsequent carrot crops. Juvenile levels in the continuous carrot plots increased by the final two carrot harvests, but these levels were much lower than those in the 'Haifa' and common white clover treatments.

Symptoms of nematode infection in carrots included gall formation and branching of the main taproot. Harvested carrots were graded as unmarketable when the main taproot had more than one large gall or when it branched. In the continuous carrot treatment, the percentage of marketable carrots was high for the first three crops (Fig. 1) when the nematode count was low (Table 1), and decreased substantively in the final two harvests when the nematode population had increased.

Marketable fresh weight and percentage of marketable carrots were significantly higher in the alfalfa and continuous cultivation plots than in the continuous carrot and either white clover plot, both of which had a high root-knot nematode juvenile population (Table 2). Carrot yield and quality was significantly lower in plots from 'Washoe' alfalfa in 1985 than those from the plots following 'Nev Syn XX' and 'Nev Syn YY' alfalfas. Trends observed from the data suggest that the damage threshold level for carrots lies between about 500 and 1800 juvenile nematodes per liter of soil.

'Nev Syn XX' and 'Nev Syn YY' alfalfa produced 16% to 23% more forage than 'Washoe' alfalfa and yielded about three times as much forage as the white clovers (Table 3).

Table 3. Forage yields of legume hay equivalent material (15% moisture) from 18 harvests during May 1982 to June 1984

Cultivar	Yield of 15% moisture hay ($t \cdot ha^{-1}$)
Nev Syn XX alfalfa	94.6 a[z]
Nev Syn YY alfalfa	88.6 a
Washoe alfalfa	76.6 b
Haifa white clover	31.9 c
Common white clover	29.0 c

[z]Mean separation by Duncan's multiple range test, 5% level.

Continuous vegetable production and subsequent high nematode populations are prevalent in many tropical areas. Social and economic circumstances render prolonged fallow cultivation to be an impractical root-knot nematode control method. Environmental pressures against currently used nematicides are causing concern among vegetable growers; thus, alternative control measures are needed. We believe that high forage-yielding, root-knot nematode-resistant alfalfa germplasm planted in rotation with vegetable crops offers great potential as an alternative root-knot nematode control method for tropical areas.

Literature Cited

1. Ayoub, S.M. 1980. Centrifugal-flotation technique. Plant nematology—an agricultural aid. NemaAid Publications, Sacramento, Calif. p. 114–127.
2. Bookbinder, M.G., K.T. Leath, F.L. Lukezic, and J.R. Bloom. 1979. Assessment of damage to field-grown alfalfa in Pennsylvania

by the root-knot nematode *Meloidogyne hapla*. Plant Dis. Rptr. 63:959–961.
3. Brody, J.K. and C.W. Laughlin. 1977. The effect of vegetable cropping sequences on population development of *Meloidogyne hapla*. Rev. Agr. Brazil 52:13–18.
4. Elgin, J.H., Jr., B.J. Hartman, D.W. Evans, B.D. Thyr, L.R. Faulkner, and O.J. Hunt. 1980. Stem nematode and northern root-knot nematode resistance ratings for alfalfa cultivars and experimental lines. USDA Agr. Res. Results, Northeastern Ser. Lflt. 7.
5. Hartman, B.J., O.J. Hunt, R.N. Peaden, H.J. Jensen, B.D. Thyr, L.R. Faulkner, and G.D. Griffin. 1979. Registration of Nevada Synthetic YY Alfalfa (Reg. No. G.D. 99). Crop Sci. 19:416–417.
6. Healy, W.B., J.P. Widdowson, and G.W. Yeates. 1973. Effect of root nematodes on growth of seedling and established white clover on a yellow-brown loam. New Zealand J. Agr. Res. 16:70–76.
7. Inserra, R.N., J.H. O'Bannon M. Di Vito, and H. Ferris. 1983. Response of two alfalfa cultivars to *Meloidogyne hapla*. J. Nematol. 15:644–646.
8. Peaden, R.N., O.J. Hunt, L.R. Faulkner, G.D. Griffin, H.J. Jensen, and E.H. Stanford. 1976. Registration of a multiple-pest resistant alfalfa germplasm. Crop Sci. 16:125–126.
9. Vrain, T.C. 1982. Relationship between *Meloidogyne hapla* density and damage to carrots in organic soils. J. Nematol. 14:50–57.

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Evapotranspiration Rates of Turf Weeds and Groundcovers

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Abstract. **Small weighing lysimeters were used to determine potential evapotranspiration (ET) (i.e., ET when soil water is not limiting) rates of turf weeds and groundcovers. When ET was monitored during two consecutive summers, white clover (*Trifolium repens* L.) had the highest mean water use rate (7.4 mm·day^{-1}). Dichondra (*Dichondra repens* J.R. Forst. and G. Forst.), a low-growing C_4 dicot, and barnyardgrass [*Echinochloa crusgalli* (L.) Beauv.], a C_4 monocot, used the least water (3.9 and 4.1 mm·day^{-1}, respectively). 'Merion' Kentucky bluegrass (*Poa pratensis* L.), a C_3 species, and yellow foxtail [*Setaria glauca* (L.) Beauv.] and smooth crabgrass [*Digitaria ischaemum* (Schreb.) Muhl.], C_4 species, exhibited intermediate ET rates. Water use rates of these groundcovers should be considered when using them in landscapes. Eradication of some weeds, such as white clover, in well-watered turf areas may be an effective means of reducing ET.**

Irrigation is essential to maintain vigorous turfgrass and other landscape plants in arid and semi-arid regions. Research over the past decade has provided valuable information concerning ET rates of warm- and cool-season turfgrass species (1, 3–5). Little is known, however, about the water use of weeds that encroach into and occupy large portions of turf areas. Furthermore, planting of groundcovers other than turfgrass, such as dichondra and white clover, has sometimes been done without knowledge of their water requirements.

The germination of crabgrass, goosegrass [*Eleusine indica* (L.) Gaertn.], yellow woodsorrel (*Oxalis stricta* L.), and other weeds can be favored by excessive water (2). However, once mature, some weeds, such as goosegrass, often exhibit greater drought resistance than the cultivated grasses with which they compete (2). Consequently, drought, as it often occurs later in the season, can favor growth of undesirable weed species.

Work on water requirements of groundcovers has emphasized clovers (*Trifolium* spp.) (6). In India, Singh et al. (6) found that berseem clover (*T. alexandrium* J.) ET rates declined from 4.08 to 3.60 mm·day^{-1} under wet (0 to −0.025 MPa) and dry (0 to −0.075 MPa) soil moisture regimes, respectively.

The work described in this report was done to compare the ET rates of several groundcovers, frequently planted as desired species, and weeds that often encroach into home lawns. This information may help better assess water requirements of low-quality turf areas inhabited by weeds. Furthermore, knowledge of the ET rates of commonly used groundcovers might justify their use for landscape water conservation.

During the summers of 1985 and 1986 at the Plant Environmental Research Center in Fort Collins, Colo., ET rates for some common weeds and groundcovers were determined in small weighing lysimeters (254 mm in diameter by 154 mm in height) described in detail by Feldhake et al. (3). To simulate a typical Colorado field situation, a sandy clay loam soil (pH = 7.9, organic matter = 3.0%) was used in lysimeters during both years. Soil was added to lysimeters in 5-cm layers, and each layer was packed firmly by hand. Soil was then wetted on repeated occasions to allow settling. Soil used in lysimeters in 1985 was removed and replaced with soil of similar characteristics before seeding in 1986. Lysimeters were placed in the greenhouse and seeded at a rate of 147 kg viable seed/ha on 12 Apr. 1985 and 31 Mar. 1986.

In 1985, NH_4NO_3 (33N–0P–0K) was applied to each lysimeter at 49 kg N/ha on 3 and 25 May. In 1986, 18N–22P–0K was applied at 49 kg N/ha to each lysimeter and lightly incorporated prior to planting. An additional 49 kg N/ha from NH_4NO_3 was applied on 14 Apr. Lysimeters were placed in sleeves in an open field of 'Merion' Kentucky bluegrass on 17 May 1985 and 16 May 1986. Data collection began on 15 June 1985 and 28 June 1986. Studies were terminated on 5 July and 29 Aug. in 1985 and 1986, respectively.

Lysimeters were set so that the top of the weed or groundcover canopy was even with that of the surrounding turf after mowing. Weeds and groundcovers were mowed three times weekly at a 6.4-cm height. 'Merion' Kentucky bluegrass, which surrounded lysimeters in the field, was maintained at a similar height. This was done to provide a uniform microenvironment for the lysimeter-grown plants.

Container capacity weights were determined by removing plugs from the base of lysimeters and watering until drainage occurred. About 24 hr after initial watering, drain plugs were replaced, and lysimeters were weighed. Soil water content at container ca-

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