Effects of Potassium Fertilization and Pratylenchus penetrans on Yield and Potassium Content of Red Clover and Alfalfa[1]

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Abstract: Red clover and alfalfa were inoculated with *Pratylenchus penetrans* and grown in an Alberry sandy loam soil to which potassium (K^+) was added at seeding at 0, 41.5, 83, and 166 $\mu g/g$. In one experiment with alfalfa, additional K^+ was added after each forage cut to replace that which was removed. Nematode populations were not consistently affected by K^+ fertilization. Nematode infection stunted red clover and alfalfa and resulted in lower yields at all K^+ levels, except for alfalfa at the lowest K^+ level. Nematode infection had no effect on taproot yields. However, it resulted in lower rootlet yields from red clover at all K^+ levels, lower rootlet yields from alfalfa only at the highest K^+ level in one experiment, and lower rootlet yields at all but the lowest K^+ level in a second experiment. Potassium fertilization enhanced yield of red clover and alfalfa. Yield increases were smaller from increased K^+ fertilization in nematode-infested soil than in noninfested soil. *Pratylenchus penetrans* had little effect on the K^+ content of red clover or alfalfa. The stunting of plants from nematode infection resulted in less K^+ being removed from the soil. *Key Words:* potassium nutrition, *Medicago sativa,* root-lesion nematode, *Pratylenchus penetrans, Trifolium pratense.*

Host nutrition and plant-parasitic nematodes often affect forage legume crops markedly. Potassium (K^+) nutrition is important in productivity of alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) (7, 8) and survival of alfalfa (13). Root-lesion nematodes (*Pratylenchus* spp.) reduce productivity of alfalfa and red clover (2, 12, 14) and survival of alfalfa (11).

Host nutrition is known to affect the development and reproduction of plant-parasitic nematodes, including root-lesion nematodes, on annual and perennial crops. Collins et al. (3) reported that a K^+ deficiency did not affect *Pratylenchus scribneri* Steiner. Oteifa and Diab (9) showed that an increase in K^+ fertilization allowed for the highest rate of reproduction of *Tylenchorhynchus* and *Pratylenchus* spp., and Dolliver (4) found that treatments which inhibited root development and plant growth suppressed reproduction of *Pratylenchus penetrans* (Cobb) Filipj. and Schuur.-Stekh. Kirkpatrick et al. (6) showed that high population levels of *P. penetrans* were associated with low-to-deficient K^+ nutrition. Parasitism by root-lesion nematodes increased the concentration of K^+ in pepper (6) and decreased the concentration in cherry (10).

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The effects of nutrition of alfalfa and red clover on reproduction of root-lesion nematodes and the effects of nematode infection on mineral content have not been investigated previously. The objectives of this study, therefore, were to determine the effects of K^+ fertilization and root-lesion nematodes on yields of alfalfa and red clover, and K^+ levels in plant tissue and in soil. The influence of K^+ on nematode reproduction also was studied.

MATERIALS AND METHODS

Alberry fine sandy loam, pH 6.5 and 86 μg exchangeable K^+/g, was fumigated with methyl bromide at the rate of 0.9 g/kg soil to eliminate nematodes. Prior to placing 4,200 g (oven dry equivalent) of soil in 5-liter plastic pots, 25μg N/g as NH_4NO_3, 75 μg P/g as $CaH_4(PO_4)_2 \cdot H_2O$, and 1.25 μg B/g as $Na_2B_4O_7 \cdot 10H_2O$ were thoroughly mixed into the soil. Potassium treatments and nematode inoculation were effected also prior to potting. The K^+ treatments for experiments with red clover and alfalfa were the same at the beginning of the experiments and were 0, 41.5, 83, and 166 μg K^+/g applied as KCl. No additional K^+ was added in the first experiments. In a second experiment with alfalfa, K^+ was added to each pot after cuts 1 to 5. The amounts added (Table 1) were calculated to replace approximately that which was removed by the foliage in addition to that which remained in the roots and stubble in the noninfested treatments. The root-lesion nematodes, *P.*

penetrans, were obtained from roots by mist extraction from greenhouse stock cultures maintained on alfalfa. Sufficient water suspension of the nematodes was mixed with the soil to give approximately 9,700 nematodes/pot.

A split-plot experimental design with four replications was used for each of the experiments. Main-plot treatments were infested with *P. penetrans* and noninfested controls. Subplots were K^+ fertilization levels. 'Lakeland' red clover and 'Vernal' alfalfa seeds were germinated 36 h on moist filter paper. Fifteen seeds were planted in each pot and thinned to 10 plants per pot after 4 weeks. Commercial strains of *Rhizobium* for red clover and alfalfa (The Nitragin Company, Milwaukee, Wisconsin 53209) were added to the germinated seeds just prior to planting.

Pots were maintained in a greenhouse at 22 ± 2 C during the day and 14 ± 2 C at night. Supplementary light from fluorescent and incandescent sources (approximately 10,000 lx) was provided to give a 14-h photoperiod. All pots were watered initially by weight to 21% soil moisture content, and watered again only when the soil moisture content of any pot reached 15%. Plants were cut back to a height of 4 cm when a minimum of 10% of the plants had reached the flowering stage. Forage was harvested seven times (six cuts for the second experiment with alfalfa); yields were based on oven-dry (80 C for 24 h) weight of the forage.

Exchangeable K^+ in the soil was determined at the beginning and end of each experiment, total K^+ in forage for each cut, and total K^+ in taproots and rootlets at the end of each experiment. Following neutral ammonium acetate extraction (1), exchangeable K^+ in the soil was determined by flame photometry; and following ammonium-EDTA extraction (5), total K^+ in the forage, taproots, and rootlets was determined by flame photometry.

Roots were removed carefully from the soil at the termination of the experiments and, after washing, 10 g of rootlets that had been trimmed from the taproots were placed in a mistifier for 1 week. Taproot and rootlet (a portion after mist extraction) yields were based on oven-dry weights (80 C for 24 h). Soil samples were passed through a 2-mm screen and nematodes were extracted for 1 week (by the modified Baermann pan method) from a 50-g subsample. Nematode populations were expressed as numbers per pot (soil + rootlets). General observations of intact root systems indicated no visual effects of K^+ fertilization or *P. penetrans* infection on nodule numbers or size. Therefore, no nodule counts or measurements were taken.

RESULTS

Red clover: Levels of K^+ fertilization had no effect on the numbers of *P. penetrans* present 200 days after the beginning of the experiment (Table 2). No further increase in forage yield of red clover in the noninfested pots was obtained from the addition of more than 83 μg K^+/g; whereas in the nematode-infested pots, no further increase was obtained above 41.5 μg K^+/g. Nematode infection suppressed forage yield at all K^+ levels, with a 64% greater loss at the highest than at the lowest K^+ level. Taproot yield was not affected by either K^+ level or *P. penetrans.* Rootlet yield increased with increasing K^+ level and was suppressed by nematode infection at all K^+ levels. Potassium in the forage generally increased with increasing K^+ level, decreased with successive cuts, and was higher in the nematode-infested forage only at the 166

TABLE 1. Potassium (K^+) additions—second experiment with alfalfa.

K^+ added preseeding ($\mu g/g$)	μg K^+/g added after cuts				
	1	2	3	4	5
0	22.8	12.5	0.0	0.0	0.0
41.5	35.3	18.7	10.4	20.8	10.8
83	39.4	24.9	20.8	31.1	31.1
166	41.5	31.1	31.1	41.5	41.5

TABLE 2. Effects of potassium and *Pratylenchus penetrans* on yield and potassium content of Lakeland red clover.

K^+ added preseeding (μg/g)	No. of *P. penetrans*/pot (in 1000's)		Yield (g/pot)			K^+ content					
						Forage					
	Initial	Final[a,b]	Forage[c]	Tap-roots[a]	Root-lets[a]	Cut 1 (%)	Cut 4 (%)	Cut 7 (%)	Tap-roots[a] (%)	Root-lets[a] (%)	Soil[a] (μg/g)
0 (86)[d]	0	0	31.6	1.0	3.1	2.36	0.96	0.32	0.15	0.24	28
	9.7	645.0	24.9	1.1	1.7	2.36	1.03	0.23	0.22	0.31	34
41.5 (126)	0	0	37.3	1.1	3.8	3.38	1.27	0.42	0.13	0.23	25
	9.7	719.8	31.6	1.6	2.8	3.35	1.34	0.23	0.23	0.20	30
83 (149)	0	0	42.3	1.3	4.6	3.57	1.58	0.40	0.19	0.20	25
	9.7	608.9	32.8	1.4	3.4	3.66	1.80	0.53	0.34	0.30	35
166 (239)	0	0	44.9	2.0	5.5	3.80	2.55	0.75	0.32	0.32	26
	9.7	781.2	33.9	2.1	3.4	3.88	2.70	0.96	0.67	0.49	56
LSD[e] (P = 0.05)		NS	4.3	NS	1.0	0.40	0.43	0.16	0.10	0.12	9

[a]At the termination of the 200-day experimental period.
[b]Only data from nematode-infested pots included in statistical analysis.
[c]Total yield from seven cuts.
[d]Figures in brackets are μg exchangeable K^+/g in the soil determined after a 4-week incubation period with no plants present.
[e]LSD's are for K^+ level x *P. penetrans* interaction.

μg K^+/g level at cut 7. No distinct K^+ deficiency symptoms were observed on the leaves. In noninfested soil, K^+ content of taproots and rootlets was higher at the termination of the experiment only at the 166 μg K^+/g level. Nematode infection resulted in higher K^+ in the taproots at 83 μg K^+/g and 166 μg K^+/g, and in the rootlets at 166 μg K^+/g than at lower K^+ levels. Exchangeable K^+ in the soil at the termination of the experiment was the same at all K^+ levels in the noninfested treatments, but was higher at 166 μg K^+/g in the nematode-infested treatments. At 83 and 166 μg K^+/g, the exchangeable K^+ in the soil was greater in infested than in noninfested treatments.

Alfalfa: In the first experiment with alfalfa, the number of *P. penetrans* present 200 days after inoculation was higher when no K^+ was added at the beginning of the experiment than when K^+ was added (Table 3). The lowest numbers of nematodes were observed at the highest level of K^+ added. The addition of 41.5 μg K^+/g increased alfalfa forage yield over the 0 μg K^+/g level in both noninfested and nematode-infested treatments. There were no further significant yield increases except at the 166 μg K^+/g level in the noninfested treatment. Nematode infection suppressed forage yield at all K^+ levels except the 0 μg K^+/g level. Taproot yield generally increased with increased K^+ but was not affected by *P. penetrans*. Rootlet yield was suppressed by nematode infection only at 166 μg K^+/g, the only K^+ level which increased rootlet yield in the noninfested treatments. Potassium content of alfalfa forage, taproots, and rootlets was higher with an increased level of K^+; and no distinct K^+ deficiency symptoms were observed on the leaves even at the 0 μg K^+/g level. Potassium content of the forage at cut 7 was lower with *P. penetrans* at 0 and 41.5 μg K^+/g, and of rootlets at 166 μg K^+/g, but was higher in rootlets at 83 μg K^+/g. Exchangeable K^+ in the soil at the termination of the experiment was the same at all K^+ levels in the noninfested treatments but was higher at 166 μg K^+/g in the nematode-infested treatments. The exchangeable K^+ was higher in the nematode-infested than the noninfested treatment at 166 μg K^+/g.

In a second experiment with alfalfa, level of K^+ fertilization had no effect on the reproduction of *P. penetrans* (Table 3). Alfalfa forage yield in noninfested treatments was increased at all levels of added K^+ compared to the check. Only 83 μg K^+/g increased forage yield in the nematode-

TABLE 3. Effects of potassium and *Pratylenchus penetrans* on yield and potassium content of Vernal alfalfa.

K^+ added preseeding (µg/g)	No. of *P. penetrans*/pot (in 1000's)		Yield (g/pot)			K^+ content					
						Forage					
	Initial	Final[a,b]	Forage[c]	Tap-roots[a]	Root-lets[a]	Cut 1 (%)	Cut 4 (%)	Cut 7[d] (%)	Tap-roots[a] (%)	Root-lets[a] (%)	Soil[a] (µg/g)
Experiment 1											
0 (86)[e]	0	0	28.2	4.2	3.1	1.69	0.87	0.50	0.25	0.18	23
	9.7	1,088.8	24.5	4.7	2.0	1.72	0.86	0.30	0.25	0.17	28
41.5 (126)	0	0	34.5	6.5	3.6	2.38	1.14	0.52	0.28	0.17	24
	9.7	554.4	29.6	6.2	3.1	2.42	1.24	0.34	0.28	0.18	28
83 (149)	0	0	38.0	7.5	3.7	2.52	1.57	0.59	0.33	0.21	26
	9.7	776.1	29.0	7.1	3.0	2.72	1.74	0.61	0.38	0.26	35
166 (239)	0	0	38.8	10.2	5.2	2.94	2.37	1.10	0.40	0.44	23
	9.7	421.1	32.1	8.8	2.9	3.04	2.37	1.03	0.43	0.39	57
LSD[f] (P = 0.05)		238.0	4.1	2.0	1.3	0.33	0.24	0.11	0.09	0.05	10
Experiment 2[g]											
0 (86)	0	0	22.6	3.8	2.6	2.53	1.68	0.80	0.25	0.16	29
	9.7	284.3	20.6	4.2	2.2	2.64	1.80	0.58	0.25	0.23	33
41.5 (126)	0	0	28.9	4.4	3.6	2.89	2.71	2.19	0.59	0.40	30
	9.7	263.9	20.4	5.1	1.9	2.96	2.78	1.87	0.58	0.55	76
83 (149)	0	0	32.7	7.3	3.9	3.03	3.16	2.48	0.67	0.71	51
	9.7	307.7	25.4	6.4	2.5	3.16	3.11	2.18	0.84	0.58	94
166 (239)	0	0	29.1	7.1	3.2	3.17	3.47	3.16	0.85	1.44	118
	9.7	282.6	20.9	5.2	1.8	3.39	3.45	2.45	1.00	1.06	204
LSD[f] (P = 0.05)		NS	4.9	2.6	1.3	0.34	0.42	0.44	0.20	0.23	26

[a]At the termination of the 200-day experimental period.
[b]Only data from nematode-infested pots included in statistical analysis.
[c]Total yield from seven cuts in Experiment 1, six cuts in Experiment 2.
[d]Cut six in Experiment 2.
[e]Figures in brackets are µg exchangeable K^+/g in the soil determined after a 4-week incubation period with no plants present.
[f]LSD's are for K^+ level x *P. penetrans* interaction.
[g]For further K^+ additions, see Table 1.

infested treatments. Nematode infection suppressed forage yield at all K^+ levels; however, the difference at the 0 µg K^+/g level was not significant. The 83 and 166 µg K^+/g treatments increased taproot yield in the noninfested but not in the nematode-infested treatments. Nematode infection had no effect on taproot yield. Potassium fertilization had little effect on rootlet yield in either noninfested or infested treatments; rootlet yield, however, was reduced significantly by nematode infection at all but the 0 µg K^+/g level. Potassium content in the alfalfa forage was higher, although not always significantly, with increased K^+ fertilization at all cuts in both noninfested and nematode-infested treatments. Nematode inoculation had no effect on K^+ in the forage except in cut 6 where the K^+ content was lower at all K^+ fertilization levels but significant only at the highest K^+ level. Potassium content of the taproots increased with increased K^+ fertilization but was not affected by *P. penetrans*. Rootlet K^+ content increased with increased K^+ fertilization but was lower with nematode infection at the highest level of K^+ fertilization only. The exchangeable K^+ remaining in the soil at the termination of the experiment increased with increased K^+ fertilization levels in both noninfested and nematode-infested treatments. The exchangeable K^+ remaining in the soil, however, was significantly higher in the nematode-infested than in the noninfested treatments except at the 0 µg K^+/g level.

DISCUSSION

The effects of K^+ fertilization on *P. penetrans* populations, as determined at the termination of these experiments, were inconsistent. In the experiment with red clover, nematode reproduction was not influenced by K^+ levels. With alfalfa, nematode reproduction was influenced by K^+ levels which were different at the beginning of the experiment, but nematode reproduction was not influenced in another experiment in which supplemental K^+ was provided. Other workers have also reported results of K^+ nutrition on root-lesion nematode reproductions to vary from no effect (3), to reduced reproduction with low K^+ (4), and to increased reproduction at low K^+ (6).

Since no supplemental K^+ was added to red clover and alfalfa (first experiment), the availability of K^+ to the plants decreased as the experiments progressed (evidenced by the lower K^+ content in the forage at cuts 4 and 7, and in the soil at the termination of the experiments). At the termination of the experiments, the amount of exchangeable K^+ in the soil was the same for all noninfested soil treatments; and although somewhat higher in the high K^+ level nematode-infested treatments, it was below the level which would support optimum growth (7, 8). The fact that all red clover and alfalfa plants in the first experiments were growing in soil deficient in K^+ at the termination of the experiments would indicate that K^+ nutrition was not responsible for the different results with red clover and alfalfa. The difference could be the expression of different host-parasite relations between the nematode and the two plant hosts.

The different effect on final nematode populations in the second experiment with alfalfa (in which K^+ was supplemented to maintain differential levels) indicates that K^+ nutrition does not affect the host-parasite relations between alfalfa and *P. penetrans*. Among the nematode treatments within the two experiments with alfalfa, nematode numbers were negatively related to forage yield. The 31% higher yield at the highest K^+ level, compared to the lowest level in the first experiment with alfalfa, was associated with a significantly lower nematode population; whereas in the second experiment, there was no difference in either forage yield or nematode population between the lowest and highest K^+ fertilization levels.

Pratylenchus penetrans stunted both red clover and alfalfa, as reported earlier (2, 12, 14). Yield losses of both alfalfa forage and rootlets from nematode infection were greater at higher levels of K^+ fertilization even though nematode numbers were the same or lower. Oteifa and Diab (9) suggested that higher K^+ fertility increased the tolerance of the plant to the detrimental effects of nematodes. Under the conditions of the experiments reported here, however, higher forage yield potentials of red clover and alfalfa were obtained at lower K^+ levels with *P. penetrans* than in noninfested treatments. Even though the experimental period for both experiments with alfalfa was 200 days, forage yields were lower in the second experiment in which supplementary K^+ was added. The lower yields are probably a reflection of the season when the experiments were conducted. The first experiment was conducted from November to June and resulted in seven forage cuts, while the second experiment was conducted from June to January and resulted in only six forage cuts.

The K^+ contents of red clover and alfalfa forages in these experiments are within the ranges of those reported earlier (7, 8), and indicate K^+ deficiency at the time of cut 4 (except at the highest K^+ levels) and at the time of cut 7 in the experiments in which K^+ was not added after the experiments were initiated. Potassium was deficient in the alfalfa forage only at the lowest K^+ level at cut 6 in the second experiment with alfalfa. The higher K^+ content of red clover forage and root treatments harvested from some of the nematode-infested treatments appeared to be a direct result of more K^+ being available; however, the reason for lower K^+ levels in the nematode-infected alfalfa forage at cut 6 in the second alfalfa experiment is not understood. In contrast to the lower K^+ content of forage of alfalfa plants infested with *P. penetrans*, Shafiee and Jenkins (10) reported that K^+ accumulated in the leaves of pepper plants infested with this nematode.

With the significant loss in forage yield due to *P. penetrans*, less K^+ was removed from the soil than was removed from the soil of noninfested controls. This lower uptake of K^+ was reflected by significantly higher K^+ levels remaining in the soil of the nematode-infested treatments at the termination of the experiments, particularly the second alfalfa experiment.

It is well known that any functional disturbance of root systems may have an effect on plant yield. Nematode infection damages root systems and often results in low yields. Increased availability of nutrients to root systems may compensate for damage to roots with the resulting inefficiency in nutrient uptake. Evidence was obtained in this study that red clover and alfalfa plants infected with *P. penetrans* utilized added K^+ fertilizer less effectively than noninfected plants. The problem of maintaining a proper nutritional balance in nematode-infested soils is, therefore, of significance and must be considered in soil fertility and plant nutrition.

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