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EFFECTS OF SEED COATING ON FORAGE LEGUME ESTABLISHMENT IN MINNESOTA

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INTRODUCTION AND LITERATURE REVIEW

Establishing an adequate stand is essential for economically producing alfalfa (*Medicago sativa* L.). Factors influencing alfalfa stand establishment include the seeding method; the soil moisture, temperature, pH, and fertility; weed control; and disease and insect control (Delwiche et al., 1981). Biological nitrogen fixation (a symbiotic relationship between alfalfa plants and bacteria *Rhizobium* sp.) is also essential for successful stand establishment and long-term yield.

Seed coating is a method of delivering chemical and biological substances (lime, fertilizer, *Rhizobium*, and/or pesticide) with the seed, to benefit seedling survival and establishment in a cost effective manner. Lime coating may also protect *Rhizobium* from injurious environmental conditions (e.g., low soil pH) (Burton, 1972).

Application of additives to the seed surface can be traced back to the pyramids in Egypt (Spiva, 1976). Current methods of seed coating are a refinement of this adhesion process. The seed and seed additives are encapsulated together within biologically stable materials. The first known patent for such a process was issued in 1905 (Porter, 1976). It involved binding a fertilizer to cereal seed with glue. In 1958, there were 35 patents in the United States describing various seed coating methods and seed coating products (Porter, 1976).

Sophistication of seed coating materials varies. Some consist of 10% gum arabic in a peat slurry for delivery of *Rhizobium* in a seed coating. Others are more complex. They consist of a synthetic polyacrylamide gel which may contain a complex of additives including seed protectants (Sparrow and Ham, 1983). It's difficult to generalize regarding the nature of inert materials used in seed coating, however, they generally act to stabilize and adhere additives to the seed coat.

There have been several reports on beneficial effects of seed coating on forage establishment. In one, coating alfalfa seed with a mixture of lime, rhizobia, and other additives (Rhizo-Kote, CelPril Industries, Inc. Manteca, CA) enhanced emergence, plant survival, and yield (Bartkowski and Turk, 1982; Turk and Bartkowski, 1982, 1981A). This response was attributed to neutralization of soil acidity in the immediate vicinity of the germinating seedling and to improved nodulation and biological nitrogen fixation from having *Rhizobium* bacteria in close proximity to the emerging root system (Johnson, 1971; Turk and Bartkowski, 1981A, 1981B).

In Arkansas, coating alfalfa seed with calcium carbonate (lime) increased yield on an acid soil compared to a noncoated control, but coating seed with molybdenum (a micronutrient essential in biological nitrogen fixation) did not improve yield in comparison to a calcium carbonate coating (Thompson and Hsieh, 1972). Kunelius and Gupta (1975) also reported that coating alfalfa seed with lime increased alfalfa yields on acid soils.

Coating alfalfa seed with *Rhizobium meliloti* (Vincent and Smith, 1982), and white clover (Trifolium repens L.) seed with lime and *Rhizobium trifolii* (Lowther and McDonald, 1973) increased nodulation of both species. Lime and fertilizer coating of ryegrass (*Lolium perenne* L.) and orchardgrass (*Dactylis glomerata* L.) seed improved establishment compared to non-coating (Vartha and Clifford, 1973).

Seed coating has not always increased forage establishment or yield. Dowling (1978) reported that coating tall fescue (*Festuca arundinacea* Schreb.) and reed canarygrass (*Phalaris arundinacea* L.) with dolimite lime (calcium magnesium carbonate), superphosphate, and potassium sulfate reduced germination. Lime and *Rhizobium* coating of alfalfa seed did not increase alfalfa stands or yield (Kehr et al., 1983; Heichel et al., 1979; McClellan, 1975), or nodulation (Heichel et al., 1979) during the seeding year on non-acid soils. In New Zealand, grass and legume seed coating improved establishment and yield on low fertility, acid soils but only with soil moisture and temperature favorable for germination and plant development (Dowling, 1978; Scott, 1975; Vartha and Clifford, 1973).

In Michigan, lime coating did not improve alfalfa stands or yield on high pH soils (6.4–6.6) but improved yields in one of three trials on low 5.3 pH soils (Tesar and Huset, 1979). However, the best yields on the low pH soil were only 66% as high as on high pH soils. In Michigan (Powles and Tesar, 1976) and in Minnesota (Barnes, 1978), alfalfa stand establishment and yield were similar for lime-coated inoculated seed and moist *Rhizobium* inoculated seed on non-acid soils.

Birdsfoot trefoil (*Lotus corniculatus* L.) is a relatively new forage legume in Minnesota. It is tolerant of lower soil pH and higher soil moisture levels than alfalfa, is resistant to potato leafhopper, and is not bloat inducing. It's an important crop in northwestern Minnesota (McGraw and Beuselinck, 1983), but stand establishment is a difficult aspect of its production. The bacteria (*Rhizobium loti*) responsible for nodulation and biological nitrogen fixation in birdsfoot trefoil is normally introduced into the rooting environment by seed inoculation. The use of seed coating to supply birdsfoot trefoil inoculate has not been evaluated.

Conflicting responses to seed coating treatments and the uncertain role of the environment made Minnesota research on seed coating necessary. Research on farms and University Experiment Stations determined the effect of *Rhizobium*, lime, fungicide, and insecticide-nematicide seed coatings on the establishment and seedling year yield of alfalfa and birdsfoot trefoil.

Table 1. Soil fertility levels at the start of the seed coating experiments at six Minnesota locations.

LOCATION	SOIL TYPE	pH	Phosphorus	Potassium
			lb/acre	*lb/acre*
Becker	Hubbard loamy sand	7.3	30	179
Grand Rapids	Cowhorn sandy loam	6.5	50	232
Lamberton	Webster silt loam	7.0	63	214
Morris	McIntosh silt loam	6.2	63	196
Rosemount	Waukegan silt loam	6.8	82	232
Staples	Sverupt sandy loam	6.5	37	196

Table 2. Deviation from total monthly precipitation and average monthly temperature throughout seed coating studies at six Minnesota location during 1983, 1984 and 1986.

		TEMPERATURE (°F)						PRECIPITATION (inches)					
YEAR	LOCATION	April	May	June	July	Aug.	Sept.	April	May	June	July	Aug.	Sept.
1983	Grand Rapids	0.0	-1.8	+1.8	+5.7	+7.9	+3.4	-1.01	-1.33	+0.27	+1.05	+4.64	-0.12
	Morris	-2.3	-2.3	+1.4	+4.5	+6.2	+3.4	-1.60	-0.78	-0.23	+1.04	+2.06	+0.04
	Rosemount	-2.5	-1.8	+1.8	+5.2	+6.5	+3.1	+1.17	+3.04	-0.62	+0.12	-2.03	+1.13
	Staples[1]	-1.3	-2.7	-0.2	+4.1	+6.5	+2.3	-1.72	-0.12	+7.06	-1.29	-2.73	-0.51
1984	Becker[1]	+1.3	-0.4	+3.1	+2.3	+5.4	-1.4	+1.33	-0.90	+4.60	-1.48	-2.46	-0.04
	Grand Rapids	+5.0	+0.2	+4.3	+2.3	+6.1	-1.0	-0.90	+0.06	+3.59	-2.80	-1.87	-0.95
	Lamberton	+0.2	-1.3	+0.9	+0.6	+3.8	-3.8	+2.26	-0.47	+4.45	-0.98	-0.04	-1.29
	Rosemount	+3.1	+0.4	+3.6	+0.8	+4.9	-0.4	+0.55	-0.62	+0.59	+1.60	-2.46	-0.51
	Staples[1]	+2.0	-0.9	0.0	+0.2	+3.4	-2.7	-0.66	-0.82	+0.90	-2.77	-1.13	-0.04
1986	Grand Rapids	+5.2	+5.9	+3.4	+2.5	-1.6	+0.6	+2.49	-1.09	+2.30	+1.33	-0.55	+1.80
	Rosemount	+8.2	+3.4	+3.4	+1.6	-2.3	+0.6	+2.73	+0.90	+1.76	+0.16	-0.31	+5.50

1. Irrigation applied as needed at these locations.

MATERIALS AND METHODS

Experimental Station Studies

Seed coating studies using alfalfa and birdsfoot trefoil were conducted at several locations in Minnesota (Table 1) in 1983, 1984, and 1986. In 1983 and 1984, alfalfa in coated and non-coated seed treatments was seeded at 15 lb/acre of pure live seed (PLS) in April or May. Birdsfoot trefoil was seeded at 10 lb/acre PLS. In 1986, coated and non-coated alfalfa was seeded at 15 lb/acre. Seeding at equivalent weights and numbers of PLS (as in 1983 and 1984) allowed a direct comparison of treatments on an individual plant basis.

Seeding solely on a weight basis (as in 1986) resulted in varying seeding rates of PLS among treatments because of the weight associated with seed coating. For example, the Rhizo-Kote seed treatment resulted in a decrease from 220,000 to 145,000 seeds/lb. Legumes were seeded into 6 x 20 ft plots at a 0.4 in depth using a nine-row seeder.

Eptam, (s-ethyl dipropylthiocarbamate) a preplant incorporated herbicide, was applied at 2 lb active ingredient (AI)/acre before seeding for annual grass control. Soils had high pH and moderate to high levels of P and K (Table 1). Precipitation and air temperature at each location from April to September are shown in Table 2.

Treatments were arranged in a randomized complete block design with four replicates. The treatments applied to alfalfa and birdsfoot trefoil seed each year are shown in Table 3. Rhizo-Kote

Table 3. Location, planting date, seed treatments, and rhizobia/seed for 1983, 1984, and 1986 seed treatment studies.

YEAR	LOCATIONS	SEEDING DATE	TREATMENT	Rhizobia/seed[1]
1983	Grand Rapids	28 May	*Alfalfa* ('DK 120')	
	Morris	23 May	Untreated seed	NA[2]
	Rosemount	10 May	Rhizo-Kote	2576
	Staples	11 May	Rhizo-Kote + Apron[3] (coated at 0.031 lb AI/cwt[4])	1515
			Preinoculated + Apron (coated at 0.031 lb AI/cwt)	182
			Rhizo-Kote + Furadan[5] (15G), 1 lb AI/acre	2576
			Rhizo-Kote + Furadan (4F), 1 lb AI/acre	2576
			Rhizo-Kote + Furadan (4F), 2 lb AI/acre	2576
			Preinoculated + Advantage[6] (15G), 1 lb AI/acre	182
			Rhizo-Kote + Advantage Liquid, 1 lb AI/acre	2576
			Rhizo-Kote + Advantage Liquid, 2 lb AI/acre	2576
			Rhizo-Kote + Apron + Furadan (15G), 1 lb AI/acre	1515
1984	Becker	20 Apr.	*Alfalfa* ('DK 120')	
	Grand Rapids	16 May	Untreated seed	NA[2]
	Lamberton	22 May	Rhizo-Kote	4545
	Rosemount	19 Apr.	Rhizo-Kote + Apron (coated at 0.031 lb AI/cwt)	2576
	Staples	2 May	Rhizo-Kote + Furadan (coated at 2.9 lb AI/cwt)	8788
			Rhizo-Kote + Furadan (4F), 1 lb AI/acre	4545
			Rhizo-Kote + Apron + Furadan (4F), 1 lb AI/acre	2576
			Birdsfoot Trefoil ('Carroll')	
			Untreated seed	NA[2]
			Preinoculated	NA[2]
			Preinoculated + Apron (coated at 0.031 lb AI/cwt)	NA[2]
			Rhizo-Kote	5
			Rhizo-Kote + Apron (coated at 0.031 lb AI/cwt)	28
1986	Grand Rapids	14 May	*Alfalfa* ('Baker' and 'Oneida')	
	Rosemount	12 May	Untreated seed	NA[2]
			Untreated + Magnum[7] (coated at 0.169 lb AI/cwt)	NA[2]
			Rhizo-Kote	8788
			Rhizo-Kote + Apron (coated at 0.031 lb AI/cwt)	25788
			Rhizo-Kote + Magnum (coated at 0.169 lb AI/cwt)	2576
			Rhizo-Kote + Magnum (coated at 0.169 lb AI/cwt) + Apron (coated at 0.031 lb AI/cwt)	2576

1. Estimated by the Most Probable Number method.
2. Rhizobia estimation not applicable to this treatment.
3. Metalaxyl (N-(2,6-dimethylphenyl)-N-(2-Methoxyacetyl)-DL-alanine).
4. Active ingredient/100 lb of seed.
5. Carbofuran (2,3-Dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate).
6. Carbosulfan (2,3-Dihydro-2,3-dimethyl-7-benzofuranyl [(dibutylamino) thio] methylcarbamate).
7. Dimethyl N,N-[thios-[(methylimino) carbonyloxy]] bis (ethanimimidothiocate).

is a seed coating of lime, *Rhizobium*, and other additives (CelPril Industries Inc.). Apron is a fungicide used for control of soil-borne pathogens which cause root rot (*Phytophthora megasperma* Drechs.) and lower stem rot (*Pythium* spp.) of alfalfa. The insecticides-nematicides, Furadan and Advantage, were incorporated into the soil before seeding (Table 3). Furadan was also applied to alfalfa as a seed coating in 1984. In 1986, the fungicide-nematicide Magnum replaced Furadan as a seed coating.

For all treatments, the number of rhizobia/seed was estimated using the most probable number method (Vincent, 1970) after the seed coating treatments were applied (Table 3). Rhizo-Kote seed had greater numbers of *Rhizobium* per seed than preinoculated seed. Rhizo-Kote and preinoculated alfalfa had greater numbers of *Rhizobium* per seed than similarly treated birdsfoot trefoil.

Spring stand counts were made four weeks after planting at all locations in all years. Stand counts were also made in the fall of the 1983 seeding year at Grand Rapids, and at all locations in 1984 and 1986. Stand counts were conducted on the first date by counting plants in two areas, each 1 ft², from the middle three rows in each plot. On the second date, plants within a 2 ft² area from the middle five rows in each plot were counted following up-rooting with a tractor mounted undercutting device.

Alfalfa and birdsfoot trefoil yield was measured by harvesting twice at full bloom during the seeding year at most locations (Table 3). Yield for each treatment was determined by harvesting a 3 x 15 ft strip from within the plots and drying a subsample at 1400 F to determine dry matter concentration. Weed contamination was visually estimated, and yields were expressed on a weed-free dry matter basis.

Farm Studies

On-farm trials were conducted in eleven, seven, and three Minnesota counties during 1984, 1985 and 1986, respectively, by farm cooperators using farm equipment. The trials involved three treatments of alfalfa and birdsfoot trefoil seed: i) raw seed (check), ii) Rhizo-Kote seed coating, and iii) Rhizo-Kote plus Apron as a seed coating. They were planted in 24 x 300 ft plots, arranged in a randomized complete block design with three replicates on each farm in the study. Equal rates of PLS/acre for each treatment were seeded in August.

Stand counts and yield measurements were conducted by trained personnel in a manner similar to that previously described for the experimental station studies. In 1984, stand counts were made four weeks after planting, and again in the fall of the year following seeding. Stand counts for 1985 and 1986 were made only in the fall of the year following seeding. Dry matter yields in the year following seeding were taken on a harvest schedule used by the farm cooperator. This system generally resulted in three harvests each year.

Data from experimental station and farm studies

Table 4. Effect of seed treatment on alfalfa stand density (Std. Dens.) [plants (plts)/ft²] in the spring and/or fall of the seeding year, and forage dry matter yield (H1=first harvest, H2=second harvest, T=total) at four Minnesota locations in 1983.[1]

	GRAND RAPIDS[2]					MORRIS[3]			ROSEMOUNT	STAPLES
	Std. Dens.		Yield			Std. Dens.	Yield		Std. Dens.	Std. Dens.
TREATMENT[4]	Spring	Fall	H1	H2	T	Spring	H1	H2	Spring	Spring
	plts/ft²		Ton/acre			plts/ft²	Ton/acre		plts/ft²	plts/ft²
Untreated seed	28	24	0.5	1.3	1.8	35	1.8	3.2	33	38
Rhizo-Kote	21	13	0.5	1.2	1.7	36	2.0	3.4	31	44
Rhizo-Kote + Apron	47	34	0.5	1.3	1.8	38	1.9	3.4	30	49
Preinoculated + Apron	40	26	0.7	1.7	2.4	39	1.8	3.4	26	37
Rhizo-Kote + Furadan (15G) 1 lb/acre	50	20	0.8	1.4	2.2	43	1.9	3.3	31	41
Rhizo-Kote + Furadan (4F) 1 lb/acre	45	28	0.7	1.5	2.2	45	2.0	3.5	—	—
Rhizo-Kote + Furadan (4F) 2 lb/acre	44	31	0.7	1.4	2.1	45	1.8	3.5	37	45
Preinoculated + Advan. (15G) 1 lb/acre	44	22	0.7	1.6	2.3	40	2.0	3.6	37	47
Rhizo-Kote + Advan. (4F) 1 lb/acre	54	36	0.8	1.5	2.3	41	1.8	3.3	—	—
Rhizo-Kote + Advan. (4F) 2 lb/acre	41	24	0.7	1.4	2.1	38	1.8	3.3	29	43
Rhizo-Kote + Apron + Furadan (15G)	64	39	0.8	1.5	2.3	43	1.9	3.4	34	61
LSD (0.05)[5]	18	10	0.2	NS	NS	NS	NS	NS	NS	NS

1. Stand density determined four weeks after seeding (spring) at all locations and at Grand Rapids in the fall (19 weeks after seeding). Yield not measured at Rosemount or Staples.
2. Two harvests in the seeding year at Grand Rapids.
3. One harvest in the seeding year (H1) and a residual harvest (H2) in 1984 at Morris.
4. Apron applied as a seed coating, Furadan and Advantage (Advan) applied to the soil preplant.
5. For comparison of two treatment means; NS=no statistically significant differences.

were analyzed by SAS (statistical analysis system) using an appropriate model for the randomized complete block design. Means were separated using the LSD (least significant difference) method at 0.05 level of significance.

RESULTS

Experimental Station Studies

Alfalfa. The effect of seed coating and soil treatments on alfalfa establishment and yield were inconsistent over years and locations (Tables 4 to 7). The inconsistent responses were not related to climatological conditions present during the studies (Table 2).

The Rhizo-Kote seed treatment (without additional amendments) increased spring stand density compared to the untreated seed at Staples, Lamberton, and Grand Rapids in 1984 (Table 5). However, this same treatment effect on stand density was observed only at Becker in the fall. Stand density was similar for Rhizo-Kote and untreated seed at all locations in 1983 and 1986.

Apron as a coating on preinoculated or Rhizo-Kote seed improved spring stand densities compared to Rhizo-Kote without Apron at Grand Rapids in 1983 (Table 4) and at Rosemount and Staples in 1984 (Table 5). Apron application increased fall stand counts compared to treatments without Apron at Lamberton, Rosemount, and Staples in 1984. Furadan or Magnum, which were applied on Rhizo-Kote seed in 1984 and 1986, respectively, did not improve stand density at any location compared to Rhizo-Kote alone (Tables 5 and 7).

Preplant soil application of the insecticides-nematicides Furadan or Advantage increased alfalfa stand density in the spring of 1983 at Grand Rapids compared to untreated and Rhizo-Kote seed (Table 4), but had no consistent effect on stand density at other locations in 1983 or 1984. Soil applied Furadan, combined with Rhizo-Kote plus Apron seed coating, produced greater stand densities than all other treatments at Grand Rapids and Staples in 1983 (Table 4) and greater densities than all other treatments except the Rhizo-Kote and Apron treatment at all locations in 1984 (Table 5). Sheaffer et al., (1982) also reported an increase in alfalfa stand density at Grand Rapids with Furadan and Apron applications to the soil. They concluded that a nematode-fungus disease complex was responsible for poor legume seedling establishment and yield.

Planting untreated and Rhizo-Kote seed at similar weights regardless of number of PLS/lb in 1986 resulted in similar seeding year stand densities for the two treatments. However, with the Rhizo-Kote treatment 25 fewer seeds/ft^2 were planted.

Although seed treatments increased stand density at several locations, alfalfa forage yield was not generally increased. Rhizo-Kote seed increased forage yields compared to untreated seed only in 1984 at Becker (Table 6). Seed applied Apron and seed or soil applied Furadan increased alfalfa yields compared to untreated and Rhizo-Kote seed

Table 5. **Effect of seed treatment on legume stand density (plants/ft^2) in the spring and fall of the seeding year at five Minnesota locations in 1984.[1]**

TREATMENT	ROSEMOUNT Spring	ROSEMOUNT Fall	BECKER Spring	BECKER Fall	STAPLES Spring	STAPLES Fall	LAMBERTON Spring	LAMBERTON Fall	GRAND RAPIDS Spring	GRAND RAPIDS Fall
	Plants/ft^2									
ALFALFA										
Untreated seed	46	32	45	33	35	38	21	21	38	27
Rhizo-Kote	51	33	47	44	42	42	35	24	46	31
Rhizo-Kote + Apron[2]	63	40	49	46	47	48	39	29	42	34
Rhizo-Kote + Furadan[2,3]	—	—	—	—	30	37	25	20	43	25
Rhizo-Kote + Furadan (4F)[4]	51	37	39	34	32	33	26	28	46	27
Rhizo-Kote + Apron + Furadan (4F)[4]	59	38	44	41	46	48	33	26	51	34
LSD (0.05)[5]	6	4	3	5	3	4	4	4	6	5
BIRDSFOOT TREFOIL										
Untreated seed	20	20	27	19	25	23	34	21	27	16
Preinoculated	27	24	34	18	31	22	31	25	36	18
Preinoculated + Apron[2]	23	22	31	16	36	21	27	21	32	14
Rhizo-Kote	22	26	34	28	32	31	38	25	34	14
Rhizo-Kote + Apron[2]	29	25	35	26	43	34	27	28	34	19
LSD (0.05)[5]	3	3	4	6	4	3	4	4	5	5

1. Spring and fall stand density determined 4 weeks and 19 weeks after seeding.
2. Apron and Furadan applied as a seed coating.
3. Treatment not included at the Rosemount and Becker locations.
4. Furadan (4F) soil applied at 1 lb AI/acre.
5. For comparison of two treatment means within species.

for the first harvest at Grand Rapids 1983 (Table 4) and at Rosemount in 1984 (Table 6).

Birdsfoot Trefoil. Rhizobium seed treatment (preinoculation or Rhizo-Kote) increased spring birdsfoot trefoil stand density at four of five locations compared to untreated seed (Table 5). Adding Apron to preinoculated or Rhizo-Kote seed increased spring birdsfoot trefoil stand density at Becker and Rosemount locations compared to the treatments alone (Table 5).

Rhizo-Kote seed increased forage yields compared to untreated or preinoculated seed without Rhizo-Kote. Apron application with Rhizo-Kote did not enhance yields compared to Rhizo-Kote preinoculation alone (Table 6). Dry matter yields were similar for the untreated, preinoculated, and preinoculated plus Apron birdsfoot trefoil seed treatments (Table 6).

Farm Studies

Alfalfa. Alfalfa stand densities and yields did not differ among treatments in any of the three years of the on-farm study (Table 8).

Birdsfoot Trefoil. Rhizo-Kote seed increased birdsfoot trefoil stand densities and forage yield in 1985 (Table 8). Apron plus Rhizo-Kote seed did not improve stand density or yields compared to the Rhizo-Kote seed.

Table 6. Effect of seed treatment on legume seedling year forage dry matter yield (H1=first harvest, H2=second harvest, T=total) at five Minnesota locations in 1984.[1]

	ROSEMOUNT			BECKER			STAPLES			LAMBERTON			GRAND RAPIDS		
TREATMENT	H1	H2	T	H1	H2	T	H1	H2	T	H1	H2	T	H1	H2	T
							Ton/acre								
ALFALFA															
Untreated seed	1.0	1.2	2.2	0.8	1.8	2.6	1.1	1.4	2.5	0.2	1.5	1.7	1.9	0.6	2.5
Rhizo-Kote	1.1	1.2	2.3	0.9	2.1	3.0	1.1	1.5	2.6	0.3	1.4	1.7	2.0	0.6	2.6
Rhizo-Kote + Apron[2]	1.2	1.2	2.4	0.9	2.0	2.9	0.8	1.4	2.2	0.3	1.3	2.6	2.0	0.7	2.6
Rhizo-Kote + Furadan (seed)[2,3]	—	—	—	—	—	—	1.0	1.4	2.4	0.2	1.3	1.5	2.1	0.7	2.8
Rhizo-Kote + Furadan (4F)[4]	1.0	1.0	2.0	0.8	2.0	2.8	1.2	1.5	2.7	0.3	1.4	1.7	1.9	0.6	2.5
Rhizo-Kote + Apron + Furadan (4F)[4]	1.4	1.0	2.4	0.8	2.2	3.0	1.3	1.5	2.8	0.4	1.4	1.8	1.9	0.7	2.6
LSD (0.05)[5]	0.2	0.1	0.2	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	NS	0.1
BIRDSFOOT TREFOIL															
Untreated seed	0.3	0.7	1.0	0.1	1.0	1.1	0.6	1.2	1.8	0.1	1.6	1.7	1.5	—	1.5
Preinoculated	0.2	1.0	1.2	0.1	0.9	1.0	0.4	1.0	1.4	0.1	1.5	1.6	1.6	—	1.6
Preinoculated + Apron[2]	0.4	0.9	1.3	0.1	0.4	0.5	0.4	1.1	1.5	0.1	1.3	1.4	1.4	—	1.4
Rhizo-Kote	0.7	1.1	1.8	0.3	1.7	2.0	1.0	1.7	2.7	0.1	1.7	1.8	1.3	—	1.3
Rhizo-Kote + Apron[2]	0.7	1.3	2.0	0.3	1.6	1.9	1.1	1.5	2.6	0.1	1.6	1.7	1.6	—	1.6
LSD (0.05)[5]	0.1	0.1	0.2	0.1	0.3	0.4	0.2	0.2	0.3	0.1	0.1	0.3	0.2	—	0.2

1. Harvested when alfalfa and birdsfoot trefoil reached full bloom.
2. Apron and Furadan applied as a seed coating.
3. Treatment not included at Rosemount and Becker locations.
4. Furadan (4F) soil applied at 1 lb AI/acre.
5. For comparison of two treatment means within species.

Table 7. Effect of seed treatment on alfalfa stand density (plants (plts)/ft^2) in the spring and fall of the seeding year, and forage dry matter yield (H1=first harvest, H2=second harvest, T=total) at two Minnesota locations in 1986.[1]

	GRAND RAPIDS					ROSEMOUNT				
	Stand density		Yield			Stand density		Yield		
TREATMENT[2]	Spring	Fall	H1	H2	T	Spring	Fall	H1	H2	T
	plts/ft^2		Ton/acre			plts/ft^2		Ton/acre		
Untreated seed	22	13	0.9	0.9	1.8	26	22	1.2	0.6	1.8
Untreated + Magnum	24	16	1.1	0.9	2.0	27	26	1.3	0.6	1.9
Rhizo-Kote	18	10	1.0	1.0	2.0	23	15	1.1	0.6	1.7
Rhizo-Kote + Apron	18	11	1.0	0.9	1.9	23	17	1.1	0.6	1.7
Rhizo-Kote + Magnum	18	13	1.0	0.9	1.9	24	15	1.1	0.6	1.7
Rhizo-Kote + Magnum + Apron	21	14	1.0	0.9	1.9	26	17	1.1	0.6	1.7
LSD (0.05)[3]	NS	5	NS	NS	NS	NS	7	NS	NS	NS

1. Spring and fall stand density determined at 4 and 19 weeks after seeding, respectively. Harvested at full bloom.
2. All treatments seeded at equivalent weight without regard to seed/lb. Apron and Magnum applied as a seed coating.
3. For comparison of two treatment means; NS=no statistically significant difference.

The lack of treatment differences in farm studies may in part be attributed to large variation in the data. This can be attributed to variation in field soil characteristics, seeding techniques, and harvesting procedures. This illustrates the difficulty of large scale research on farms.

SUMMARY

Alfalfa

1. At three of ten locations, Rhizo-Kote increased alfalfa stand density four weeks after seeding, compared to the untreated seed. However, by fall of the seeding year, stand density for Rhizo-Kote was greater than for untreated seed at only one location. Rhizo-Kote increased seeding year dry matter yield, compared to untreated seed, at one of 9 locations.

2. Rhizo-Kote plus Apron improved stand density, compared to untreated seed, at five of nine locations four weeks after seeding, and at five of nine locations in the fall after seeding.

3. Rhizo-Kote plus Apron improved alfalfa stand density, compared to Rhizo-Kote without Apron, at two of seven locations four weeks after seeding, and at three of seven locations in the fall following seeding. Rhizo-Kote plus Apron improved total seeding year dry matter yield, compared to Rhizo-Kote without Apron, at one of seven locations.

4. Rhizo-Kote plus an insecticide-nematicide (Furadan, Advantage, or Magnum) applied either on the seed or to the soil increased alfalfa stand density, compared to Rhizo-Kote alone, at one of eleven locations four weeks after seeding and at one of eight locations in the fall following seeding. Total seeding year dry matter yield of this treatment was greater than Rhizo-Kote alone at two of nine locations.

5. Rhizo-Kote plus Apron increased alfalfa stand density four weeks after seeding, compared to Rhizo-Kote plus an insecticide-nematicide (Furadan, Advantage, or Magnum) applied on the seed or to the soil, at four of eleven locations and at four of eight locations in the fall following seeding. Total seeding year dry matter yield of Rhizo-Kote

Table 8. Effect of seed treatment on summer seeded alfalfa and birdsfoot trefoil stand density [plants (plts)/ft²] four weeks after planting and/or in the fall of the year following planting, and on forage dry matter yield. On-farm studies in Minnesota during 1984, 1985, and 1986.[1,2]

YEAR	SPECIES	TREATMENT	Stand density 4 Weeks	Stand density Fall	Yield
			plts/ft²		Ton/acre
1984	Alfalfa	Untreated seed	21	25	—[4]
		Rhizo-Kote	24	24	—
		Rhizo-Kote + Apron	24	24	—
		LSD (0.05)[5]	NS	NS	—
1985	Alfalfa	Untreated seed	—	20	1.3
		Rhizo-Kote	—	20	1.3
		Rhizo-Kote + Apron	—	19	1.2
		LSD (0.05)[5]	—	NS	NS
1985	Birdsfoot Trefoil	Untreated seed	—	16	1.0
		Rhizo-kote	—	19	1.4
		Rhizo-Kote + Apron	—	19	1.2
		LSD (0.05)[5]	—	2	0.2
1986	Alfalfa	Untreated seed	—	14	1.5
		Rhizo-Kote	—	14	1.4
		Rhizo-Kote + Apron	—	14	1.4
		LSD (0.05)[5]	—	NS	NS
1986	Birdsfoot Trefoil	Untreated seed	—	17	—
		Rhizo-Kote	—	18	—
		Rhizo-Kote + Apron	—	20	—
		LSD (0.05)[5]	—	NS	—

1. 1984 study conducted at 11 locations. 1985 study conducted at seven locations. 1986 study conducted at three locations.
2. Values are averaged over all locations each year.
3. Apron applied as a seed coating in all treatments.
4. No data collected.
5. For comparison of two treatment means within years and species; NS=no statistically significant differences.

plus Apron was greater than for Rhizo-Kote plus an insecticide-nematicide at two of nine locations.

6. Rhizo-Kote plus Apron in combination with soil applied Furadan or Magnum increased alfalfa stand density at four weeks after seeding, compared to Rhizo-Kote in combination with Furadan or Magnum applied on the seed or to the soil, at six of eleven locations and at five of eight locations in the fall following seeding. Total seeding year dry matter yield of Rhizo-Kote plus Apron in combination with Furadan or Magnum was greater than the Rhizo-Kote plus Furadan or Magnum at three of nine locations.

Birdsfoot Trefoil

1. Preinoculated birdsfoot trefoil seed increased stand density at four weeks after seeding, compared to untreated seed, at four of five locations, but only at one of five locations in the fall of the seeding year. Total seeding year dry matter yield of the preinoculated and untreated seed was similar at all locations.

2. Rhizo-Kote increased birdsfoot trefoil stand density at four weeks after seeding, compared to preinoculated seed, at one of five locations and at two of five locations in the fall of the seeding year. Total dry matter yield of Rhizo-Kote was greater than for preinoculated seed at three of five locations.

3. Rhizo-Kote plus Apron increased birdsfoot trefoil stand density at four weeks after seeding, compared to Rhizo-Kote alone, at two of five locations, but stand densities were similar for the treatments at all locations in the fall of the seeding year. Total dry matter yield of Rhizo-Kote was greater than for preinoculated seed at one of five locations.

DISCUSSION AND CONCLUSIONS

In our studies alfalfa was established on non-acid soils which had been previously cropped to alfalfa (within five years). Under these conditions, application of *Rhizobium* through preinoculation or Rhizo-Kote seed coating did not consistently increase alfalfa stand densities or yield.

For alfalfa establishment on acid soils or on land which has not been planted to alfalfa within five years, *Rhizobium* application has often been beneficial (Tesar and Hurst, 1979). However, these soil conditions were not evaluated in our studies.

Preinoculated and Rhizo-Kote seed increased birdsfoot trefoil stand establishment and yield, more consistently than for alfalfa. This may have been related to a lack of effective *Rhizobium* in the soil which are specific for birdsfoot trefoil. We therefore made a general recommendation to inoculate birdsfoot trefoil seed before seeding on all soils. Rhizo-Kote seed was generally more effective at increasing birdsfoot trefoil stand densities and yields than preinoculated seed.

In all studies except the 1986 experiment station trial at Grand Rapids and Rosemount (Table 7), alfalfa was seeded at 15 lb/A pure live seed which resulted in initial stand densities of 20 to 60 plants/ft^2 depending on the seed treatment. Although seed treatments sometimes increased seeding year alfalfa populations, differences in stand density due to treatment were not consistently associated with differences in alfalfa yields.

In a new stand, yield is often not affected by stand density because as stand density decreases, plants develop larger crowns and produce more stems (Bolger and Meyer, 1983; Volenec et al., 1987). This compensation by individual plants results in similar yields per acre despite large differences in stand density (Bolger and Meyer, 1983). McCellan (1975), and Sund and Barrington (1973) report that increasing alfalfa seeding rates from 4 to 32 lb/acre PLS increases stand density initially. They also note that total seeding year dry matter yield and forage quality are similar at all seeding rates greater than 12 lb/acre. In Minnesota, we recommend seeding of 10 to 12 lb/acre PLS. Seed coatings may increase alfalfa stand density, but do not consistently increase yield.

The efficacy of using any seed treatment depends on the additional cost of the treatment compared to the increased forage yield. Based on our trials, there is about a 10% chance of alfalfa and a 60% chance of birdsfoot trefoil yield increase due to use of coated seed to supply *Rhizobium*. With average seeding year yield increases of 0.1 and 0.6 tons/acre for alfalfa and birdsfoot trefoil, respectively, and using a forage value of $75.00/ton, the yield increase due to seed coating represents increased gross earnings of $7.50 and $45.00/acre. Consequently, the decision to use coated seed must be based both on the value of the forage produced and on the cost of the coated seed.

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