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Effects of commercial seed coating on alfalfa establishment in interior British Columbia

Canada

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Cover illustration
The dots on the map represent Agriculture Canada research establishments.

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SUMMARY

Seed coating of legumes involves pre-inoculation (inoculation with *Rhizobium* in bulk prior to sale) and as such frees growers from the task of field inoculation. In the coating process, *Rhizobium* inoculum is adhered to the seed, then the coat (mainly limestone with some phosphate) is added with an adhesive. Coating is claimed to increase alfalfa seedling emergence, seedling vigour and root nodulation. This technical bulletin contains our tests of these claims performed with commercial coats from three seed coating companies in seven seedings in the Kamloops area. All of the coats evaluated added about 50% to seed weight (i.e. coating represented 33% of the total weight of coated seed) and contained peat-based inoculum.

Coating increased seedling emergence by 11% when averaged over three coats and seven seedings. All alfalfa cultivars showed the same response to coating. Improved emergence was not due to a "starter" effect of the P_2O_5 in the coat because a greater amount of starter phosphorus applied with uncoated seed did not effect emergence. Nodulation with the three coats was equal to that with field inoculated bare seed. Coating did not increase the rate of seedling development. When sown at equal seed numbers, the coated seed treatments did not out-yield the field inoculated bare seed, in spite of some increases in plant density. When coated seed was sown at equal weights to bare seed (less seed for coated treatments), there were significant reductions in seedling numbers in all seedings and significant reductions in yield in two out of seven seedings. Yield reductions occurred under irrigation but not in dryland seedings. Based on improved emergence, some reduction in the weight of actual seed sown can be made without affecting yield but sowing at equal weights is not recommended.

This bulletin will assist the seed industry and extension specialists in informing alfalfa producers as to the costs and benefits of commercial seed coating. A more detailed version of this bulletin can be obtained from the Kamloops Research Station, 3015 Ord Road, Kamloops, B.C. V2B 8A9.

RÉSUMÉ

L'enrobage des semences de légumineuses suppose la pré-inoculation (inoculation avec le Rhizobium en vrac avant la vente) qui dispense les producteurs de la tâche de l'inoculation au champ. Dans le processus d'enrobage, l'inoculum du Rhizobium adhère à la semence et est ensuite recouvert d'un enduit (surtout composé de pierre à chaux et d'un peu de phosphate) additionné d'un adhésif. L'enrobage stimulerait la levée et la vigueur des plantules de luzerne, ainsi que la nodulation des racines. Nous avons voulu vérifier la véracité de cette affirmation. Ce bulletin technique expose donc les résultats de nos essais effectués sur des enduits commerciaux fournis par trois sociétés d'enrobage des semences pour sept semis dans la région de Kamloops. Tous les enduits évalués ajoutent environ 50 % au poids des semences (c'est-à-dire que l'enrobage représente 33 % du poids total de la semence enrobée) et renferment un inoculum à base de tourbe.

L'enrobage augmente de 11 % en moyenne la levée des plantules, et ce, sur trois enduits et sept semis. Tous les cultivars de luzerne réagissent de la même façon à l'enrobage. La stimulation de la levée n'est pas attribuable à un effet de «démarrage» du P_2O_5 contenu dans l'enduit, car l'application d'une plus grande quantité de P de démarrage avec la semence non enrobée n'influe pas sur la levée. La nodulation obtenue avec les trois enduits se compare à celle obtenue avec la semence nue inoculée au champ. L'enrobage n'augmente pas le taux de développement des plantules. Semés à quantités égales, les traitements de semences enrobées ne sont pas plus productifs que la semence nue inoculée au champ malgré certaines augmentations de la densité du peuplement. Lorsque la semence enrobée est semée à poids égal à la semence nue (moins de semence pour les traitements), on constate une réduction significative du nombre de plantules dans tous les semis et une baisse significative du rendement de deux semis sur sept. Les baisses de rendement surviennent en régime d'irrigation, mais pas en cultures non irriguées. D'après l'augmentation du taux de levée, une certaine réduction du poids de la semence réellement semée est acceptable sans nuire au rendement, mais le semis à poids égal n'est pas recommandé.

Ce bulletin aidera les semenciers et les spécialistes en vulgarisation à informer les producteurs de luzerne sur les coûts-avantages de l'enrobage commercial des semences. On peut se procurer une version plus détaillée de ce bulletin en s'adressant à la Station de recherches de Kamloops, 3015 Ord Road, Kamloops, B.C. V2B 8A9.

INTRODUCTION

The purpose of enclosing seeds in a lime coat is to provide a favorable microenvironment around the seed which will help a healthy seedling to develop in the face of environmental stresses. In the case of legumes, this micro-environment must also allow the applied Rhizobia to survive and proliferate until the seedling reaches a stage of development where infection can occur. The desired result is a healthy well-nodulated seedling which can fix atmospheric nitrogen. For forage seeds common environmental stresses are low soil moisture and cool soil. Low soil moisture accounts for many seeding failures in dryland seedings because of erratic rainfall. Even with adequate rainfall or with irrigation, periods of low moisture may be encountered by the young seedling due to the necessity of shallow planting. Low soil temperatures may occur with early spring planting or more commonly at high elevations.

The coating applied is mainly limestone (usually containing both calcium and magnesium carbonates) with some triple superphosphate added. The superphosphate neutralizes the lime and improves Rhizobial survival. On acidic soils this lime may enhance Rhizobial or seedling survival. The coat may also act as a carrier for micronutrients for the plant and/or mineral or organic nutrients for the Rhizobia. There is also the option of including pesticides (such as fungicides), growth promoting substances, or other microorganisms (other beneficial bacteria or mycorrhizal fungi) in the coat.

LITERATURE REVIEW

Many aspects of commercial seed coating are trade secrets including the adhesives used, types of Rhizobial nutrients and other additives, proportions of various components, the machinery used, and the coating process. The following description of the coating process is based on the original research papers dealing with coating clover seed published in New Zealand and on limited information on coating alfalfa supplied to us by North American seed coaters.

When coating legumes, the first step is to attach the Rhizobium inoculum (usually peat based) to the seed with an adhesive such as gum arabic. After drying slightly the inoculated seeds are mixed with water, an adhesive, limestone and super phosphate in a drum to form a pellet. After drying and hardening, the pellet may be coated with fine clay, lime or other material and sprayed with a sealant to form a protective outer layer. The super phosphate is included in the coat to balance the pH and thereby enhance survival of Rhizobia (Hastings and Drake 1962). A further innovation was to incorporate a layer of peat between the inoculated seed and the coat (Taylor and Lloyd 1968, cited by Lowther and McDonald 1973) also to enhance Rhizobial survival. Lowther and McDonald (1973) reported that after 17 days storage at 10-15°C, 2% of the applied Rhizobia remained alive with the lime coat, 6% when super phosphate was included in the coat, and 40% with a peat layer between the inoculum and lime with super phosphate coat. A three step coating process was described by Hely (1965) with the objective of providing much higher than normal Rhizobia numbers for aerial seedings. In this process a broth culture containing high Rhizobia numbers is applied along with a clay-limestone mixture after the applied peat-based inoculum dried, and then an outer coat of mainly calcium carbonate was fixed with an adhesive. This supplied approximately 750,000 Rhizobia per seed compared to about 2,000 by regular coating. In an aerial seeding on a podzolic soil (pH 5.5) this process increased the number of Rhizobia attached to the top of young roots from 189 per plant with peat under lime to 5600 with the three step process. The three step process increased the percentage of nodulated plants from 48 to 89. Whether or not such massive inoculation is of benefit in drilled seedings remains to be determined.

For forages, seed coating was first used with grasses. In New Zealand there were several reports that seed coating improved stand establishment of aerially sown grasses (Bartha and Clifford 1973; Scott 1975; Morton 1985). Results varied considerably with the species sown and experimental site. Vartha and Clifford (1973) found that coating improved establishment most on sites with moderate moisture stress. Scott (1975) found a similar pattern in his field studies and in a greenhouse experiment found that coating increased orchardgrass emergence 3% at low moisture stress, by 12% at moderate moisture stress and reduced emergence by 15% at high moisture stress. The most detailed report of the effects of soil moisture levels on the response to coating was performed with sugar beets (Veverba 1985) where coating narrowed the range of moisture levels over which emergence occured. Seedlings emerged with soil moistures ranging from 12.5 to 15% (w/w) with coating compared to a range of 10 to 25% for bare seed.

Coating may result in a similar narrowing in the range of soil moisture over which forage seedlings emerge. This may benefit establishment. On drought-prone sites this would help ensure that germination does not occur unless adequate moisture is available for establishment. Inhibition of germination at high soil moisture may help prevent the development of fungal diseases, especially with the lower soil temperatures encountered in the early spring. Although mineral nutrients added to the seed coat improved grass seedling establishment slightly, Scott (1975) concluded that it was mainly physical effects which enhanced emergence after noting similar positive effects for many types of coating materials.

Reports of the effects of seed coating on alfalfa establishment in drilled seedings have varied. Celpril Industries (1979) reported their seed coating process increased the number of established seedlings by 41% over 75 plantings in the midwestern U.S.A. In Minnesota, university researchers (Sheaffer et al. 1988) found that Rhizo-Kote (Celpril Industries) improved alfalfa emergence by 12% over nine seedings (with a range from 4% to 62%). In Illinois coating increased the number of alfalfa seedlings established by 10 to 17% when interseeded with tall fescue (Olsen and Elkins 1977). In contrast, field studies in North Carolina (Dougherty and Taylor 1981) and Quebec (Gasser et al. 1983) reported no change in alfalfa establishment with coating. The mechanisms behind the reported increases are unknown. When they are discovered it will be possible to predict under which conditions coating benefits establishment and obtain more consistent effects.

Soon after seed coating of forages began, the coating process was modified for legumes with the aim of increasing Rhizobial survival under adverse conditions such as in aerial seedings or in drilled seedings in acidic or dry soils. The lime coat protects the Rhizobia from light, dessication and temperature extremes (Hely 1965). Lime coating increased nodulation success of alfalfa when seeds were left for a short period in hot dry soils but not when irrigation was applied immediately after seeding (Clatworthy et al. 1974). In acidic soils the lime in the coat may increase Rhizobial survival and nodulation success as it increases the pH near the seedling. Kunelius and Gupta (1975) reported improved nodulation with coating on two acidic soils compared to uninoculated or inoculation with peat-based inoculum only. Coating was of no benefit after liming. Coating does not always increase nodulation success on acidic soils (Choe et al. 1980).

Coating alfalfa did not increase nodulation over normal innoculation in neutral soils (Clatworthy et al. 1974). Under these conditions the main benefit is increased convenience. Seed coating is a form of pre-inoculation which frees growers from the task of inoculation just before planting.

Seed coating is only one form of pre-inoculation (inoculation in bulk prior to sale) offered to producers by seed companies. Other processes include 1) use of a clay based inoculant that adheres to the seed by electrostatic forces; and 2) a vacuum process that forces the Rhizobia under the seed coat. The Fertilizer Act requires that pre-inoculated forage legume seeds carry a minimum of 1000 live Rhizobia per seed to be classified as satisfactory. Because a high percentage of the Rhizobia applied in the inoculant normally die soon after inoculation, excess inoculant should be applied when pre-inoculating. As mentioned above, coating reduces the death rate of Rhizobia during storage. Tests performed by the Plant Products Directorate of Agriculture Canada on pre-inoculated seed from commercial outlets have shown that seed coating is the most reliable form of pre-inoculation (Biederbeck and Geissler 1987).

It should be mentioned that storage conditions strongly affect the viability of Rhizobia on coated seeds. High temperatures and broadly fluctuating temperatures reduce Rhizobial survival (Biederbeck and Geissler, unpublished data). Storage at constant temperature between 0 and 5°C prolongs Rhizobial viability (Dr. W.A. Rice, personal communication).

The combined effects of seed coating on plant establishment and nodulation may be reflected in alfalfa dry matter yield. At or near an optimum seeding rate, we would expect only slight changes in first year yields if emergence is altered slightly by coating but nodulation is uneffected. This is because alfalfa has a great ability to compensate for reduced density by increasing individual plant size (Volenec et al. 1987). Coating could have much greater effects on yield if it enhanced nodulation. It has generally been found that coating increases dry matter yields over inoculation, only if nodulation is improved (Clatworthy et al. 1975; Kunelius and Gupta 1974). Where inoculation alone does not affect alfalfa yield, coating has little affect on yield as reported by Gasser et al. (1973) when coated seed was sown on a neutral soil in Quebec following a previous alfalfa crop. Similarly researchers in Minnesota found no significant increase in alfalfa seeding year yield with either inoculation of bare seed or coating (Sheaffer et al. 1988) in nearly neutral soils which were formerly planted with alfalfa.

Most reports indicate that any effects of coating on yield are short-lived. Dougherty and Taylor (1981) reported that seed coating increased first cut alfalfa yields over a bare inoculated control but not in later cuts. Similarly Clatworthy et al. (1974) reported that yield differences between coated and bare inoculated treatments which were apparent in the first cut of the seedling year were no longer apparent by the third cut and they reported no carry-over effect into the following year.

1987 SEEDING EXPERIMENT

Objectives

Commercially coated seeds of both forage legumes and grasses are marketed in Canada. Preliminary trials at the Prince George Experimental Farm (as presented in Appendix 2) showed that seed coating did not improve forage grass yield or germination but results from legume trials were less clear. In the following studies, seed coating was tested on alfalfa as it is potentially the most profitable forage crop. There are currently two major seed coating companies in Canada and several in the U.S.A, so it was desirable to test more than one product.

In 1987, three commercial alfalfa seed coatings were tested to determine if coating affected seedling emergence, rate of seedling development and seeding year dry matter yield. Because the literature indicated that the effects of seed coating are often site specific, tests were performed at three sites. For all tests, bare and coated seeds were sown at equal weights (i.e. fewer seeds for coated treatments) as is commonly recommended to producers (John Dawson, personal communication). It has been claimed that improved establishment with coating compensates for the reduced number of seeds sown. At Kamloops, a preliminary trial in 1986 indicated that when coated seed was sown at equal weights to bare 41% fewer seedlings emerged, resulting in a 10% yield reduction. Coated seed, at equal numbers of pure live seeds (PLS) to uncoated controls, was sown at one site to isolate coating effects from seeding rate effects.

Methods

SITE DESCRIPTIONS

The study was conducted at three sites near Kamloops, B.C. The first site was a flat irrigated field at the Kamloops Research Station. Prior to our trial the site had grown alfalfa, which had been inoculated before seeding. The second site was a dryland exclosure located in the middle grassland vegetation zone at an elevation of 766 m and approximately 5 km north of the Kamloops site. The third site was cleared forested range at Watching Creek at an elevation of 896 m and approximately 16 km north by northwest of the Kamloops site.

TREATMENTS AND SEEDING

Six coated seed treatments were compared to three control treatments. Seed of four alfalfa cultivars was obtained from one supplier (Table 1). Two kg lots of each cultivar were sent to each of three coating manufacturers for application of their products (Table 2). The three controls were: bare seed, bare seed plus Rhizobium meliloti inoculum, and bare seed plus inoculum plus P_2O_5. The inoculum was Nitragin brand peat base powder, mixed dry (at 5.7 mg/g seed) with the seed immediately before planting. The phosphate (at 5 kg/ha, as 0:45:0 granules) was mixed with the seed to match any "starter" effect of that in the coats (Table 3) on seedling growth. Plots (1.2 x 6.8 m) were seeded to four rows, spaced 30.5 cm apart at a 1 cm seeding depth. At the Station, plots were irrigated after seeding as required. The other sites were neither fertilized nor irrigated.

Table 1. Suppliers and product names for seed and seed coatings included in this trial.

Supplier	Address	Product	
		Type	Name
Dawson Seed Co.	175 Harbour Ave. North Vancouver, B.C. V7J 2E7	bare alfalfa seed	cultivars: Apollo II Pacer Peace Rangelander
Grow Tec Ltd.	Box 147 1805 - 8th St. Nisku, Alberta TOC 2G0	seed coating: commercial formulation experimental formulations	 Guardcoat Grow Tec 100 Grow Tec 110
Canadian Seed Coaters Ltd.	P.O. Box 219 Brampton, Ontario L6V 2L2	seed coating: commercial formulations	 Prillon Jetcote
CelPril Industries Ltd.	251 Oak St. Manteca, California U.S.A. 95336	seed coating: commercial formulation	 Rhizo-Kote

Research Station Experiment:

This experiment included all nine seed treatments (3 controls plus 6 coats). Control treatments were seeded at 12 kg/ha. Coated seed treatments (except Rhizo-Kote) were seeded at two rates; 12 kg/ha or at a rate that gave the same PLS as the controls. Three cultivars (Apollo II, Peace and Pacer) were used. Seeding was carried out on April 14 and 15, excluding Rhizo-Kote. Rhizo-Kote treated seed arrived later and so was sown May 4 at 12 kg/ha only. A control (inoculum plus P_2O_5) was substituted for the equal PLS treatment to account for delayed seeding.

Pruden's Pass Experiment:

The experiment at this site compared the six coatings with the controls (bare seed and bare seed with inoculum plus P_2O_5) all sown at 12 kg/ha.

Cultivars used were Peace and Rangelander. All treatments but Rhizo-Kote and a late control were sown on April 16. The late seedings were performed with Peace alfalfa only. Although late seedings were on April 28, seed sown at both times germinated simultaneously (following an estimated 30 mm of rain on April 30-May 1).

Watching Creek Experiment:

This experiment included the same treatments as at Pruden's but only with the cultivar Peace. Most treatments were seeded April 22 but Rhizo-Kote was seeded April 28 without a late control. As at Pruden's, germination was initiated following a rainstorm on April 30 - May 1.

Table 2. Available information on seed coating constituents.

Seed coat ingredient	Guardcoat	GT100	GT110	Jetcote	Prillon	Rhizo-Kote
	Coating (% of seed plus coat weight)					
Peat	Trace	Trace	Trace	Trace	Trace	2
Limestone	28	24	20	30	30	32
P_2O_5	5	5	5	3	3	0
Inorganic material[1]	0	4	8	0	0	0
Total	33	33	33	33	33	34
	Inoculum					
Rhizobium strain	#185 Nitragin Co.			#185 Nitragin Co.[2]		CelPril[2]
Organic nutrients[3]	+(A)	+(B)	+(C)	+	+	+
	Fungicide					
	None	None	None	None	None	None
	All coats had a polymeric adhesive					

[1]Boron and other micronutrients in trace quantities.
[2]Specific strain number not revealed by company.
[3]Unspecific organic nutrients are included (+) in all coats. Grow Tec used a different but unspecified organic nutrient (A, B or C) with each coat.

EXPERIMENTAL DESIGN AND DATA ANALYSIS

In all experiments treatment by cultivar combinations were randomized once within each of four blocks. The Research Station experiment involved 15 treatment combinations and three cultivars (Table 3). The Pruden's Pass experiment involved nine treatments and two cultivars (Table 4). As the late seedings involved only Peace alfalfa, the analyses of variance were run by specifying that the data for Rangelander in these treatments were missing. The Watching Creek experiment included eight treatments with Peace only (Table 5). Seedling counts and development involved subsampling so between-plot error (rather than between-subsample error) was used to test for effects in the ANOVA and Duncan's multiple range test. The model tested for treatment, cultivar and block effects and for a treatment by cultivar interaction.

Table 3. Effect of seed treatment and cultivar on seedling establishment under irrigation at the Kamloops Research Station in 1987.

Seed treatment or cultivar	PLS sown/30 cm	# Emerged/30 cm of row: Time after sowing 1 week	# Emerged/30 cm of row: Time after sowing 4 weeks	% of sown emerged: Time after sowing 1 week	% of sown emerged: Time after sowing 4 weeks
Seed treatment:					
Controls:					
No treatment	45.7	10.1 b	33.1 a	22.0 c	72.4 b
Inoculum	45.7	7.4 b	31.1 ab	15.9 c	68.6 b
Inoculum + P_2O_5	45.7	8.5 b	33.5 a	18.4 c	73.8 b
Same weight as controls:					
Prillon	25.5	5.4 b	16.9 e	20.8 c	65.9 b
Jetcote	25.7	5.4 b	15.9 e	20.3 c	61.8 b
Guardcoat	30.8	5.7 b	20.4 de	18.4 c	66.7 b
GT-100	29.5	7.6 b	19.9 de	25.6 c	67.3 b
GT-110	29.9	7.3 b	22.2 cde	24.3 c	74.1 b
Same PLS as controls:					
Prillon	51.5	8.4 b	25.5 bcd	17.7 c	55.2 b
Jetcote	45.7	12.0 b	33.6 a	35.8 c	73.6 b
Guardcoat	45.7	10.5 b	29.1 abc	22.6 c	63.6 b
GT-100	45.7	7.8 b	27.9 abc	17.1 c	60.8 b
GT-110	45.7	11.1 b	29.9 ab	23.6 c	65.4 b
Late seeded:					
Inoculum + P_2O_5	45.7	28.0 a	29.4 ab	64.6 b	68.0 b
Rhizo-Kote same wt.	26.8	26.0 a	27.3 abc	97.2 a	102.0 a
Cultivar:					
Apollo II	41.4	14.1 a	29.8 a	35.4 a	72.1 a
Pacer	35.0	8.4 b	24.1 b	26.6 b	69.1 a
Peace	39.7	9.7 b	25.4 b	25.4 b	66.6 a

Table 4. Effect of seed coat treatment and cultivar on seedling establishment at Pruden's Pass site 1987.

Seed treatment or cultivar	PLS sown/30 cm	# Emerged/30 cm of row		% of sown emerged	
		May 5	May 25	May 5	May 25
Treatment:					
No treatment	45.9	23.2 a	31.4 a	51.9 a	71.3 a
Inoculum + P_2O_5	45.9	17.7 a	30.0 ab	38.2 a	65.2 a
Inoculum + P_2O_5 late	45.9	13.0 a	22.9 bc	51.0 a	61.2 a
Prillon	26.0	15.5 a	21.9 bc	60.2 a	84.4 a
Jetcoat	25.5	14.3 a	21.2 c	58.8 a	87.0 a
Guardcoat	38.5	13.5 a	21.8 bc	47.1 a	76.6 a
GT-100	28.2	18.3 a	27.5 abc	64.6 a	97.7 a
GT-110	28.5	13.9 a	23.6 abc	51.0 a	86.2 a
Rhizo-Kote late	26.9	17.2 a	21.1 c	69.9 a	85.5 a
Cultivar:					
Peace	32.7	19.5 a	27.3 a	62.8 a	87.1 a
Rangelander	31.7	13.4 b	22.5 b	44.2 b	75.1 b

Table 5. Effect of seed coat treatment on alfalfa seedling establishment at Watching Creek in 1987.

Seed treatment	PLS sown/30 cm of row	# Emerged/30 cm of row		% of sown emerged	
		May 7	May 26	May 7	May 26
No treatment	47.6	26.4 abc	27.5 ab	55.5 b	57.7 a
Inoculum + P_2O_5	47.6	27.4 ab	32.0 a	57.6 b	73.3 a
Prillon	25.4	16.8 bc	17.6 b	66.3 b	69.2 a
Jetcote	24.9	14.8 c	17.5 b	59.2 b	70.3 a
Guardcoat	30.0	20.7 bc	20.8 ab	68.9 b	69.2 a
GT-100	29.4	18.6 bc	20.9 ab	63.2 b	71.2 a
GT-110	29.9	32.9 a	34.1 a	110.0 a	114.0 a
Rhizo-Kote late[4]	26.9	15.0 c	16.0 b	55.8 b	59.5 a
SE treatment		6.4	7.2	20.0	20.7

Results and Discussion

SEEDLING ESTABLISHMENT

Research Station:

At the Research Station comparison among controls indicates that neither inoculation nor P_2O_5 applied with the seed affected emergence at either count (Table 3).

For the early seeding, coated seed sown at equal weight to controls (12 kg/ha) had fewer seedlings emerging by 4 weeks (Table 3). This reflected a reduction in the number of seeds sown as percent emergence was unchanged. When coated seed was sown at equal PLS to controls, seedling numbers equalled those of controls, again because of unaltered percent emergence.

Percent of sown seeds emerging for late seeded Rhizo-Kote was considerably (34%) higher than for late seeded control or earlier seeded treatments (Table 3). This offset a 40% reduction in seeding rate and resulted in seedling numbers similar to the controls.

Pruden's Pass and Watching Creek:

At Pruden's Pass, emergence was not affected by either inoculation or phosphorus added with the seed (Table 4). Overall, fewer seedlings emerged when coated seed was sown at equal weights to the controls. However, there was a trend toward increased percent emergence with seed coating (not statistically significant) which resulted in seedling numbers almost equal to the controls for some coats (eg. GT-100 and Rhizo-Kote) in spite of a 40% reduction in the number of seeds sown.

At Watching Creek as well (Table 5), the number of seedlings emerging tended to be less when coated seed was sown at equal weights to the controls. One coat (GT-110) appeared to increase percent emergence so that seedling numbers were as great as the controls in spite of the lesser number of seeds sown. In contrast to results at the Station and Pruden's, Rhizo-Kote did not affect percent emergence. GT110 had an emergence of 114%. The number of live seeds sown was based on a seven day germination test in petri plates - this may underestimate the number which could emerge with a longer duration under field conditions. The results at Watching Creek should be interpreted with caution because of greater experimental error (larger SE). Seed distribution may have been more uneven at this site due to greater surface stoniness. Percent emergence was similar at all three sites (Station 69%, Pruden's Pass 79%, Watching Creek 73%).

SEEDLING DEVELOPMENT

The percentage of seedlings with at least two trifoliate leaves was used as an index of the rate of seedling development. At the Research Station neither inoculation nor phosphorus added with the seed affected this percentage. Seed coating (with either equal weights or numbers of seeds relative to controls) did not affect the rate of seedling development (data not shown).

The similar development of seedlings from coated seeds sown at the two rates suggests that interplant competition was not affecting seedling development at this time. At Pruden's Pass and Watching Creek sites there also was no indication that any of the seed treatments affected the rate of seedling development (data not shown).

DRY WEIGHT YIELDS

Research Station: Inoculation of uncoated seed did not increase dry matter yield (Table 6). Dry weight yield was similar when coated seed was sown at equal weight to uncoated (Table 6) in spite of a reduction in plant population (Table 3). This suggests that individual plants were more vigorous. This could be due either to a coat effect or to reduced interplant competition in the less dense stand. If the coats were increasing plant vigour, we would expect increased yield with equal PLS of coated seed to controls; but there was no significant increase (Table 6). Due to the ability of irrigated alfalfa to compensate for lower plant numbers by increasing the number of branches per crown, yield differences are small when seeding rates of 5 and 10 kg/ha are compared. Under irrigation at Kamloops, Hubbard (1981) found an 8.5% yield increase with a 100% increase in seeding rate (from 5.6 to 11.2 kg/ha). In South Dakota, Hansen and Kruger (1973) found a 15% yield increase, again with a 100% increase in seeding rate (from 4.5 to 9 kg/ha) of PLS. In the 1986 seed coating trial, we found a 10% lower yield when coated seed was sown at the same weight as uncoated (actual seeding rates 9.0 vs 5.6 kg/ha or 38% less PLS). We therefore expected a significant yield reduction in this year's trial when coated seed was sown at equal weights to bare seed but the 2.9% reduction observed was not significant. There may have been less yield reduction in 1987 because the longer growing season (1.5 mo longer) may have allowed more compensatory growth.

Pruden's Pass and Watching Creek: Dry matter yields were considerably lower at these sites (Table 7) than at the Station (1% and 0.5% at Pruden's and Watching, respectively). This reflects drought stress without irrigation. As seedling counts were similar at all three sites, this stress probably occurred following the emergence period. The yield at Watching was only one half of that at Pruden's. The yield at Watching was probably lower because the stoney soil had less water holding capacity than the mainly stone-free soil at Pruden's.

There were no yield differences among controls, indicating that neither inoculation nor phosphorus added with the seed had an effect (Table 7). At both sites, soil moisture rather than availability of nitrogen or phosphorus was the main factor limiting plant growth.

At both dryland sites, dry weight yields were similar when coated seed was sown at the same weight as bare seed, in spite of a reduction in the number of seeds sown. Guardcoat may have had a yield advantage over GT110 and Jetcote but this was based on an unprotected Duncan's test since the ANOVA indicated no significant treatment effects.

Table 6. Effects of seed treatment and cultivar on dry weight yield (kg/ha) of alfalfa under irrigation at the Kamloops Research Station in 1987.

Seed treatment or cultivar	Yield			
	Cut 1 (Jul 15)	Cut 2 (Aug 31)	Cut 3 (Oct 7)	Total
Seed treatment:				
Controls:				
No treatment	4045 abc	4478 ab	1882 ab	10405 ab
Inoculum	3792 bc	4224 ab	1848 ab	9705 ab
Inoculum + P_2O_5	4124 abc	4483 ab	1811 b	10419 ab
Same wt. as controls:				
Prillon	3737 c	4250 ab	1710 b	9696 ab
Jetcote	3694 c	4042 b	1737 b	9474 b
Guardcoat	3997 abc	4433 ab	1861 ab	10290 ab
GT-100	3958 abc	4337 ab	1712 b	10007 ab
GT-110	3971 abc	4328 ab	1659 b	9957 ab
Same PLS as controls:				
Prillon	4126 abc	4499 ab	1912 ab	10538 a
Jetcote	3928 abc	4418 b	2081 a	10427 ab
Guardcoat	4245 a	4617 ab	1829 ab	10691 a
GT-100	4213 ab	4580 ab	1889 ab	10686 a
GT-110	3999 abc	4346 ab	1782 b	10127 ab
Late seeded:				
Inoculum + P_2O_5	2970 d	3420 c	1736 b	8125 c
Rhizo-Kote same wt.	2766 d	3227 c	1709 b	7702 c
SE treatment	132	151	81	317
Cultivar:				
Apollo II	4093 a	4514 a	2328 a	10918 a
Pacer	3730 b	4142 b	1924 b	9795 b
Peace	3694 b	4081 b	1180 c	8955 c

Table 7. Effects of seed treatment and cultivar on dry weight yield (kg/ha) at two dryland sites in 1987.

Site	Yield: Pruden's Pass	Yield: Watching Creek
Seed treatment:		
No treatment	138.8 a	64.0 ab
Inoculum + P_2O_5	131.4 a	71.9 ab
Inoculum + P_2O_5 late[2]	145.0 a	---
Prillon	132.8 a	81.3 ab
Jetcote	126.6 a	39.0 b
Guardcoat	159.1 a	100.8 a
GT-100	132.4 a	88.2 ab
GT-110	157.8 a	44.8 b
Rhizo-Kote late[2]	143.0 a	57.3 ab
SE treatment	15.5	14.8
Cultivar:		
Peace	146.6 a	69.2
Rangelander	134.4 a	---
SE cultivar	7.7	---

Summary

In this the second year of the study we found that some changes in our experiments provided more effective tests of seed coating. Seeding in April rather than June apparently challenged the seeds with some low temperature stress because percent emergence was lower this year (at the Station emergence was 60 to 70% compared to near 100% in the previous year). Adding plantings of coated seed with PLS numbers equal to those of the controls allowed direct evaluation of coating effects without the complicating factor of unequal seeding rates when coated and uncoated seeds were sown at equal weights. Emergence can be corrected for unequal numbers mathematically as seedling number has little effect on emergence. Yield cannot be corrected for unequal seedling numbers due to the ability of alfalfa to compensate for reduced numbers by increasing individual plant weights.

The main effect of seed coating was on seedling emergence. Under irrigation, one coat (Rhizo-Kote) caused a 34% increase in percent emergence of sown seed while the other coats had no effect. Because Rhizo-Kote treated seed was sown later, it is not possible to directly compare it with the other coats.

It is possible that the other products would have had similar beneficial effects with later seeding. At the two dryland sites, all coatings produced slight increases (not statistically significant) in percent emergence of sown seed. This involved a 31% increase at Pruden's and a 15% increase at Watching Creek. Seed coating did not affect the rate of seedling development at any site.

At the Station, sowing equal PLS of coated and uncoated seed showed that seed coating did not effect dry weight yield. At all sites sowing equal weights of coated seed to uncoated seed resulted in similar yields in spite of generally lower plant counts for the coated seed. This suggested that individual plant size was greater due either to the well-known ability of alfalfa plants to produce compensatory growth or to seed coating. In 1988, our studies were designed to separate the effects of compensatory growth and seed coating on dry weight yield.

1988 SEEDING EXPERIMENTS

Objectives

Three changes in experimental design were made from 1987 to 1988. First, we replicated the same experiment at three sites so clear cross site comparison could be made. Secondly, a new high-elevation site was prepared to test whether seed coating improved alfalfa nodulation. We included two bare seed controls, one with and one without field inoculation. This would allow us to determine: 1) whether inoculation was beneficial at a site and 2) whether coated seed provided nodulation similar to field inoculation. The third change was the replication of the seed treatments over four seeding rates to determine if there were seed treatment by seeding rate interactions. For example, does seed coating affect yield at a lower than normal seeding rate but not at normal seeding rates?

Methods

SITE DESCRIPTIONS

In 1988 the same seed coating trial was performed at three sites each with different characteristics (Table 8). To test the inoculating ability of the coated products, sites which had not previously grown alfalfa were used. All sites had adequate P, K and S for seedling alfalfa and so no fertilizer was applied.

Table 8. Summary of site characteristics in the 1988 alfalfa seed coating trials.

	Site		
Characteristic	Station	Pruden's Pass	Horse Pasture
Latitude	50°42'N	50°46'N	50°49'N
Longitude	120°24'W	120°26'W	120°29'W
Elevation (m)	349	766	890
Slope	level	8%	1%
Aspect	---	south	south
Surrounding vegetation	*Artemisia-Agropyron* lower grassland	*Stipa-Poa* middle grassland	Douglas fir - pinegrass forest
Cropping history	irrigated grass, 1982-86; fallow 1987	dryland grass, 1983-87	flood irrigated grass pasture, ? - 1987
Soil texture	loam	sandy loam	loam
% Organic matter	7.7	5.5	6.7
pH	7.5	7.3	7.1
Conductivity ($mmohs/cm^2$)	1.8	0.4	0.2
Available nutrients (ppm 0-15 cm):			
NO_3-N	130	34	7
P_2O_5	24	35	34
K^2	62	600	193
S	139	19	14
B	0.81	0.96	0.64

EXPERIMENTAL DESIGN AND PLOT ESTABLISHMENT

The same experimental design was used at all three sites. Four replicates for each of 20 combinations of five seed treatments by four seeding rates (cv. Peace) were applied in a randomized complete block design.

The seed treatments were: 1. Uninoculated bare - seeder was cleaned with 95% ethanol and compressed air before seeding to prevent contamination with inoculant from other treatments. 2. Inoculated bare - Nitragin inoculum was applied according to manufacturer's recommendations by the slurry method (142 g of inoculum and 500 ml water/25 kg seed). On a plot scale, 20 ul water/g of seed were mixed with approximately 5.7 mg inoculum/g seed in a 3.5 cm diam. test tube, then seed was added, and the seed mixed until the seed flowed. Inoculum was measured with a scoop calibrated to deliver 12.0 mg of inoculum which was the amount for the lowest seeding rate (2.8 kg/ha). 3. Guardcoat - produced by Growtec Ltd., with an altered formulation from the previous year's trial to increase Rhizobia number. 4. Jetcote - one of Canada Seed Coater's products. 5. Rhizo-Kote - the product of Celpril Inc. All coated seeds were stored at 5°C until sown. The seeder was cleaned with compressed air between sowing of different coated treatments.

Before seeding, lab tests were performed to determine live seeds per gram of the coated and uncoated seed. Then the seeding rates of coated products which gave the same number of live seeds as the uncoated seed sown at 2.8, 5.6, 8.4 and 11.2 kg/ha were determined. Over all coats, seeding rate was increased by 63% (Table 9) mainly to account for the coat weight. The coat accounted for 35.2% of coated seed weight for Guardcoat, 36.2% for Jetcote and 37.4% for Rhizo-Kote. The seeding rate for a coated product was also influenced by the effects of the coat or coating process on germination. Jetcote appeared to reduce germination slightly and therefore was sown at a higher rate than suggested by its coat weight alone (Table 9). Rhizo-Kote increased germination slightly; therefore it was sown at a lower rate than suggested by its coat weight alone.

Table 9. Seed weights, germinations and seeding rates as influenced by seed treatment.

	Seeds/g	Germination %	Live seeds/g	Lowest seeding rate (kg/ha)	Wt/seed (mg)	Coat wt/seed (mg)
Uncoated	496 a	66.8 a	329 a	2.80	2.02 c	0.00 c
Coated:						
Guardcoat	321 b	64.7 a	208 b	4.45	3.12 b	1.10 b
Jetcote	315 b	59.2 b	186 c	4.96	3.17 ab	1.15 ab
Rhizo-Kote	309 b	68.9 a	213 b	4.32	3.23 a	1.21 a

Rhizobia counts (4 determinations/coat) were performed on the coated products by the plant infection technique at the Agriculture Canada Microbiology laboratory in Swift Current. Guardcoat supplied 117,000 viable Rhizobia per seed, Jetcote provided 4,650 per seed, and Rhizo-Kote provided 4,670 per seed. These were all in excess of the 1000 per seed required by the Plant Products Division. We did not determine the number of Rhizobia supplied per seed by our field inoculation but assuming the inoculum was of standard quality we would have supplied about 1000 viable Rhizobia per seed by following the manufacturer's recommendations.

FIELD SAMPLING

Plots (1.2 x 6.8 m) were seeded with four rows spaced 30.5 cm apart and seeding depth was 1 cm. The Pruden's Pass site was seeded April 8, the Station site was seeded April 12, and the Horse Pasture site was seeded May 10.

The Station site was irrigated immediately after seeding and as required throughout the season. Emergence was 8 days after seeding. Pruden's Pass received no irrigation. Emergence was noted 18 days after seeding. The Horse Pasture received about 2 cm of irrigation after planting, 5 cm 20 days after planting and 5 cm at the bud stage.

Seedling emergence was evaluated when most seedlings were at the second trifoliate stage (May 9 at the Station, May 16 at Pruden's Pass and June 9 at the Horse Pasture). Root nodulation was investigated at the Horse Pasture on June 16 to 17 and again on July 26 to 27. The total number and number of pink nodules located on the top 15 cm of six roots were recorded; the number out of ten plants with nodules was also recorded. At the Research Station and Pruden's Pass, plots were hand harvested at 10% bloom (July 15-18). At the Horse Pasture, harvests were performed on July 29 (bud stage) and Sept. 12 (vegetative stage). Nitrogen content was determined on these samples.

DATA ANALYSIS

Analyses of variances (ANOVA) tested for seed treatment, seeding rate and block effects and seed treatment by seeding rate interactions. Comparisons were made among seed treatments and among seeding rate means using Duncan's Multiple Range test. Dry matter yield differed greatly among sites; therefore, it was not necessary to compare sites statistically. For seedling emergence, however, site means and response to seed treatment followed similar trends at all three sites; therefore, we combined the data for the three sites and analysed for between site, between seed treatment and between rate differences and for a seed treatment by rate interaction. Because the effects of a coat on germination in a petri dish may not be the same as in the field, the number of seedlings emerging was divided by the total number of seeds sown to determine percent emerged.

Analysis of covariance (ACOV) was performed to determine if seed treatments had an effect on mean weight per plant other than that caused by altered density. We performed regressions between yield and product weight.

The results of data analyses are presented in tables as seed treatment and seeding rate means within sites. In all tables, means followed by the same letter are not significantly different by Duncan's multiple range test ($P < 0.05$). It should be noted that the seed treatment by seeding rate interaction was not significant for most characteristics.

Results and Discussion

SEEDLING EMERGENCE

Over all sites, the number of seedlings emerging (Table 10) was similar for the two bare seed treatments (ie. field inoculation did not effect emergence). Compared to the two bare controls, the overall number of seedlings emerging was significantly increased by Jetcote and Rhizo-Kote but not by Guardcoat. At the Station, increases were significant only for Rhizo-Kote, at Pruden's Pass only for Jetcote, and at the Horse Pasture were not significant for any coat.

If petri plate germination does not equal field germination, direct comparisons of seedling numbers would lead to misleading conclusions concerning the relative effects of the three coats on emergence. Jetcote was seeded at a higher rate (a 77% increase over the controls) than Guardcoat (a 58% increase) and Rhizo-Kote (a 54% increase), mainly due to lower lab germinations (Table 9). In calculating the seeding rates necessary to give equal live seeds, it was assumed that germinations in the laboratory would equal those in the field. If Jetcote did reduce germination in the field, then the increased seeding rate used would have to be balanced against the increased number of seedlings which emerged. A more reliable indicator of the effects of coats on emergence is the percent of the total number of seeds sown which emerged (Table 11). These percentages showed that the three coats had quite different effects on emergence. With Rhizo-Kote, the overall mean percent emergence was significantly greater than either control or the other two coats. At all three sites, Rhizo-Kote tended to increase emergence (the increase relative to the combined controls was 20% at the Station, 23% at Pruden's Pass and 20% at the Horse Pasture). Jetcote and Guardcoat had little effect on emergence at any site and at no site did either coat increase emergence over both controls.

Over all sites, the number of seedlings which emerged increased with increasing seeding rate (Table 10). At Pruden's Pass and Horse Pasture there was a linear increase over the whole range but at the Station there was a decline in percent emergence at the two highest seeding rates (Table 11), which resulted in a levelling off of seedling numbers (Table 10).

Table 10. Effects of seed treatments and seeding rate on the mean density of Peace alfalfa seedlings at three sites in 1988.

	Seedlings m^{-2}			
	Station	Pruden's Pass	Horse Pasture	Overall
Site	228	250	258	245
Seed treatment:				
Uncoated:				
Uninoculated	210 b	249 b	249	236 b
Inoculated	222 b	204 c	248	225 b
Coated:				
Guardcoat	212 b	253 ab	246	237 b
Jetcote	236 ab	287 a	267	271 a
Rhizo-Kote	259 a	260 ab	279	258 a
Seeding rate (kg/ha):				
2.8	104 d	97 d	103 d	101 d
5.6	187 c	206 c	204 c	199 c
8.4	268 b	287 b	279 b	278 b
11.2	353 a	411 a	445 a	403 a

Table 11. Effect of seed treatment and seeding rate on the percent emergence of total Peace alfalfa seeds sown at three sites in 1988.

	Emergence as percentage of seeds sown			
	Station	Pruden's Pass	Horse Pasture	Overall
Site	66.3	70.4	72.6	69.8
Seed treatment:				
Uncoated:				
Uninoculated	61.7 b	68.9 ab	70.9	67.2 b
Inoculated	65.8 b	58.6 b	71.4	65.3 b
Coated:				
Guardcoat	59.8 b	70.6 a	67.5	66.0 b
Jetcote	67.9 ab	75.4 a	67.6	70.3 b
Rhizo-Kote	76.6 a	78.6 a	85.1	80.1 a
Seeding rate (kg/ha):				
2.8	73.8 a	68.6	73.0	71.8
5.6	66.1 ab	72.9	72.4	70.5
8.4	63.2 b	67.6	65.8	65.5
11.2	62.2 b	72.7	78.8	71.2

ROOT NODULATION

At the Station no nodules were observed on alfalfa roots for any treatment, even by 10% bloom. The high soil NO_3-N levels encountered there (Table 8) may have inhibited nodulation.

At Pruden's Pass no nodules were observed in three of the four blocks, perhaps also due to high soil nitrate (Table 8). In one block where a low level of nodulation was observed, there was no difference in the number of nodules per root or percent nodulation between field inoculation and coating.

In contrast to the other two sites, alfalfa root nodulation was very extensive at the Horse Pasture (Table 12). This may have been due to the lower NO_3-N levels at this site (Table 8). High soil nitrate levels inhibit alfalfa root nodulation (Richardson et al. 1957). At the third trifoliate stage, the total number, number of pink nodules (which are presumably those fixing nitrogen) and percentage of pink nodules per plant increased with field inoculation (Table 12). At this early stage of plant development, Guardcoat, which carried very high Rhizobia numbers, resulted in higher total nodule number and pink nodule numbers/root than either Rhizo-Kote or field inoculated seed. All coats provided nodulation as good or better than field inoculation with peat based inoculum. The presence of nodules on some of the roots in uninoculated controls suggests that there was a population of native Rhizobia in the soil; these did not appear to nodulate as quickly or to be as effective (lower percent pink) as the Rhizobia supplied by field inoculation or coating. Massive inoculation is often recommended to form effective nodules in soils containing ineffective Rhizobia in the rhizosphere (Burton 1972). The Guardcoat product clearly provided more massive inoculation (25 times that provided by the other two products) but the increase in effectiveness was not proportional to the increase in numbers. Increasing inoculum level increases nodulation success in the face of competition from native Rhizobia and coating may enhance this effect (Wade et al. 1972). By the bud stage of development, the number of nodules per root had more than doubled (Table 12). Nodule numbers were no longer significantly greater with field inoculation or coating. Seeding rate did not significantly effect nodulation-related characteristics at either sampling time (Table 12).

ALFALFA SHOOT NITROGEN CONTENT

Due to the differences in nodulation observed at the Horse Pasture, N content of alfalfa shoots from each treatment was measured. Shoot nitrogen content averaged about 3.5% which is equivalent to 22% crude protein. This is consistent with the literature for alfalfa at the early bud stage (Marten et al. 1988). Seed treatments did not effect percent nitrogen: the treatment means were almost identical. Nitrogen yield did not differ significantly among seed treatments. Percent nitrogen was unaffected by seeding rate. However, the lowest seeding rate gave lower nitrogen yields than the others.

Table 12. Alfalfa nodule characteristics at 30 and 70 days after emergence at the Horse Pasture site in 1988.

	30 day (trifoliate leaf stage)				70 days (bud stage)
	Nodules per root	Pink nodules per root	% of nodules pink	% of roots nodulated	Nodules per root
Seed treatment:					
Uncoated:					
Uninoculated	3.2 c	2.3 c	71.8 b	75.4 b	11.3
Inoculated	6.3 b	5.2 b	84.1 a	94.9 a	14.7
Coated:					
Guardcoat	7.9 a	6.4 a	81.8 a	100.0 a	14.8
Jetcote	6.6 ab	5.7 ab	85.9 a	98.5 a	15.5
Rhizo-Kote	6.1 b	5.2 b	87.1 a	92.7 a	15.1
Seeding rate (kg/ha):					
2.8	5.9	4.8	78.6	89.1	15.3
5.6	5.4	4.5	83.3	90.0	15.2
8.4	6.7	5.7	84.7	96.8	12.4
11.2	6.1	4.9	83.4	92.3	14.3

WEIGHT PER PLANT

Mean weight per plant was greatest at the Station, intermediate at the Horse Pasture and least at Pruden's Pass (Table 13). Initial analyses of variance indicated that there were significant seed treatment effects ($P \leq .05$) at Pruden's Pass and that the effects at the other two sites approached significance ($P = .10$). At Pruden's Pass, the uncoated treatments resulted in greater mean weight per plant than the coated treatments. This is misleading because mean weight per plant is strongly affected by plant density and at Pruden's some coats increased plant density. To remove the effect of differences in plant density among treatments and clearly show seed coating effects on individual plant weight, we performed analyses of covariance on plant weight using density as a covariate.

Analysis of covariance removed any seed treatment effect at the Station and Pruden's. The similarity of adjusted treatment means indicated that what initially appeared to be a negative effect of coating on plant weight was due to increased plant density. At the Horse Pasture, analysis of covariance did not remove differences between seed treatments (Table 13). The adjusted means were slightly greater for treatments which supplied inoculum than for the uninoculated control. Because mean weight per plant did not exceed the inoculated control at any site we can conclude that coating did not increase plant vigour.

Table 13. Effect of seed treatment on mean weight per Peace alfalfa plant at three sites in 1988.

Seed treatment	Weight per plant (mg)					
	Station		Pruden's Pass		Horse Pasture	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Uncoated:						
Uninoculated	3311	2931	514 ab	392	833	685 b
Inoculated	3688	2948	594 a	393	1064	761 a
Coated:						
Guardcoat	3504	2931	475 ab	390	965	753 ab
Jetcote	2980	3044	402 b	390	910	809 a
Rhizo-Kote	3090	3131	423 b	387	781	713 b

DRY WEIGHT YIELDS

Yield with equal number of bare and coated seeds: Of the three sites, dry matter yield was the greatest at the Research Station. The yield at the Horse Pasture was one-quarter of that at the Station (Table 14 and 16); this was due to some moisture stress and cooler temperatures at the higher elevation site. Yield at Pruden's Pass was one-seventh that at the Station (Table 14 and 15) due to greater moisture stress at this dryland site.

At the Research Station seed treatments had no significant effect on total or single cut yields (Table 14). First cut yields increased with increasing seeding rate. This trend was not as apparent in the second or third cuts. By the second cut the more established plants may have been capable of greater compensatory growth to offset reduced populations at the lower seeding rates.

At Pruden's Pass yields were not affected by seed treatments at either cut or in total (Table 15). Owing to the increases in seedling number on coated treatments at this site (Table 10), we may have expected yield increases. However examination of seeding rate trends show that even a four-fold increase in seeding rate did not affect first cut yield at this site. At the second cut there was a slight depression in yield with the highest seeding rate. The plant population with this seeding rate may have been supraoptimal for available moisture at this site. Therefore, because of limited available moisture at this site, seeding rate had little effect on yield and the coating effect on seedling establishment was not reflected in yield.

Table 14. Effects of seed treatment and seeding rate on the dry weight yield (kg/ha) of alfalfa under irrigation at the Kamloops Research Station in 1988.

Seed treatment or rate	Yield (kg/ha) Cut 1 (Jul 13)	Cut 2 (Aug 31)	Cut 3 (Oct 12)	Total
Seed treatment:				
Uncoated:				
Uninoculated	2314	3058	615	5987
Inoculated	2272	3135	610	6017
Coated:				
Guardcoat	2398	2926	690	6014
Jetcote	2523	2967	734	6224
Rhizo-Kote	2543	3260	611	6414
Seeding rate (kg/ha):				
2.8	1665 c	2895 b	578 b	5292 c
5.6	2419 b	3050 ab	630 b	5945 b
8.4	2651 ab	3077 ab	626 b	6353 b
11.2	2906 a	3254 a	775 a	6935 a

Table 15. Effects of seed treatment and seeding rate on the dry weight yield (kg/ha) of Peace alfalfa under dryland conditions at Pruden's Pass in 1988.

Seed treatment or rate	Yield (kg/ha) Cut 1 (Jul 18)	Cut 2 (Sept. 13)	Total
Seed treatments:			
Uncoated:			
Uninoculated	499	347	846
Inoculated	499	343	842
Coated:			
Guardcoat	497	346	842
Jetcote	502	345	847
Rhizo-Kote	480	359	838
Seeding rate (kg/ha):			
2.8	503	361 a	864
5.6	509	357 a	867
8.4	478	346 ab	823
11.2	492	327 b	820

At the Horse Pasture site there were significant seed treatment effects for first cut and total yield (Table 16). At the first cut, linear contrasts showed inoculation affected yield, and that yield from coated treatments did not differ from the inoculated bare treatment. Seed treatments did not affect second cut yield. Nodulation data (Table 12) indicated that, by the first cut, nodule number for the uninoculated controls was equal to the inoculated treatments. As a result, differences in second cut yields between inoculated and uninoculated treatments would not have been expected (Table 16). At the Horse Pasture site, there were significant seeding rate effects for yield at both cuts and in total. The response levelled off at 5.6 kg/ha for the first cut and at 8.4 for the second cut.

Dry weight yield with equal weights of bare and coated seed: It is sometimes suggested that growers sow coated seed at the same product weight as uncoated. This practice reduces plant population; what effect would it have on yield? In the 1988 field experiments, seed treatments were sown at equal pure live seed rates but analysis of covariance can be used to adjust yields for sowing at equal product weights. Regressions of product weight on yield were statistically significant at the Research Station and the slopes of yield versus product weight were similar for the five seed treatments so that analysis of covariance with product weight as a covariate was justified. The Horse Pasture and Pruden's Pass data showed no significant relationship between product weight and yield so analysis of covariance was unjustified.

Table 16. Effects of seed treatment and seeding rate on the dry weight yield (kg/ha) of Peace alfalfa under partial irrigation (see text) at the Horse Pasture site in 1988.

	Yield (kg/ha)		
Seed treatment or rate	Cut 1 (Jul 29)	Cut 2 (Sept 12)	Total
Seed treatment:			
Uncoated:			
Uninoculated	699 b	849	1549 b
Inoculated	791 ab	993	1784 a
Coated:			
Guardcoat	793 ab	927	1720 ab
Jetcote	874 a	924	1799 a
Rhizo-Kote	760 ab	880	1641 ab
Seeding rate (kg/ha):			
2.8	617 b	827 b	1445 c
5.6	796 a	875 b	1671 b
8.4	847 a	927 ab	1774 ab
11.2	874 a	1030 a	1904 a

The adjusted means (Table 17) represent what the yields would be if all seed treatments were sown at one product weight. For two of the coats there would be significant reductions in first and second cut yields and overall. For Guardcoat and Jetcote the reduction would be about 12% at the first cut and 8% at the second cut and overall. For Rhizo-Kote there would be slight but not statistically significant reductions in yield (a 5% reduction at cut 1 and 2% overall). Apparently the increase in emergence noted with this treatment was great enough to offset some of the negative yield effects of sowing at equal product weight.

Table 17. Effect of seed treatment on dry matter yield of Peace alfalfa adjusted by analysis of covariance for sowing at equal product weight at the Research Station in 1988.

	Adjusted yield (kg/ha)			
Seed treatment	Cut 1	Cut 2	Cut 3	Total
Uncoated:				
Uninoculated	2582 a	3112 ab	655	6349 a
Inoculated	2540 a	3189 a	650	6379 a
Coated:				
Guardcoat	2252 b	2896 b	666	5816 b
Jetcote	2248 b	2912 b	692	5853 b
Rhizo-Kote	2429 ab	3237 a	594	6260 ab

Summary

The 1988 trials showed that seed coating can increase alfalfa seedling emergence. The response varied with coating process. Over all three trials Rhizo-Kote significantly (20%) increased the percent of seed which produced emerging seedlings. Over all three trials, Jetcote (6% increase) and Guardcoat (0.5% reduction) did not significantly affect emergence. How seed coating increases emergence remains to be determined.

A major purpose of coating legume seed is to provide Rhizobium inoculum. Our results at the Horse Pasture site show that for drilled seedings in neutral soils, seed coating does not improve nodulation over field inoculation with peat based inoculum supplied by the slurry method. Coated products did result in nodulation which was as effective as field inoculation, so if the convenience of pre-inoculation is desired, coated seed is a reliable way to provide it.

Seed coating gave similar yields to the field inoculated controls at all sites. At the one site where inoculation was beneficial, field inoculation and pre-inoculation by coating produced similar yield increases relative to uninoculated bare seed. This suggests that the yield increases with coating were due to the inoculum applied during coating and not to any coat characteristic.

CONCLUSIONS

The major claims made about the benefits of coating alfalfa seed include improved establishment, more rapid seedling development, increased plant vigor and improved nodulation. Another claim sometimes made is that coated seed can be sown at the same weight as uncoated seed without reducing yield. Our field studies were designed to test these claims using commercially coated seed. Three commercial coats were tested at three sites in 1987 and in 1988, and one of them in 1986. We believe that seven seedings constitute an adequate test of these products and our conclusions are outlined below.

The one claim which was supported by our trials is that coating can increase seedling emergence. When the change in emergence due to coating is examined over the seven seedings (Table 18) it is apparent that there was at least one coat which increased percent emergence by more than 10% in six of the seven trials. Over all seedings, the coats increased emergence by 11% over the bare controls.

Secondly this emergence effect varied among sites. In two years when three sites were seeded, the greatest increases were observed at what was the driest site during establishment, Pruden's Pass. This supports the often-cited observation that coating has its greatest effect on droughty sites.

Thirdly not all coats were equally effective at increasing emergence. The most effective was Rhizo-Kote which increased emergence by 24% over six seedings and increased emergence by $\geq$20% in all but one seeding. These increases were statistically significant at three of the six sites. Jetcote was less effective: there was an 8% increase overall and in two of the trials the increase was near 20%. Guardcoat was the least effective: overall there was a 1% increase and at no site did emergence increase by 20%.

It is sometimes suggested that growers sow coated seed at the same weight as bare seed to offset the cost of coating. This practice causes considerable reductions in plant density and therefore is not recommended. Coating can cause some increase in emergence but the increases observed were not great enough to result in the same plant population when coated seed was sown at the same weight as bare. The coated seeds now available weigh about 1.5 times as much as bare seed: therefore a 50% increase in emergence would be required to get the same population but not necessarily the same yield. Coat weight and emergence enhancement were incorporated into an equation to determine the weight of coated seed required to give a desired planting density (Appendix 1). This equation allows growers to calculate what seeding rate of coated seed is required to give the same population as a given rate of bare seed.

The second claim we tested was that coating results in more rapid seedling establishment. In 1986 and 1987 we compared the stage of phenological development of alfalfa seedlings with or without coating and found that seed coating had no effect.

Table 18. Summary of the effects of three seed coats on alfalfa seedling emergence by site in the 1986, 1987 and 1988 seeding experiments.

Trial	Emergence (% of bare controls)			
	Guardcoat	Jetcote	Rhizo-Kote	All coats
1986:				
Research Station	---	96.7	---	96.7
1987:				
Research Station	91.0	94.6	150.0	111.9
Pruden's Pass	112.2	127.4	139.7	126.4
Watching Creek	105.6	107.3	90.7	101.2
Mean	102.9	109.8	126.8	113.2
1988:				
Research Station	93.9	106.6	120.0	106.8
Pruden's Pass	111.7	118.2	123.2	117.4
Horse Pasture	94.9	94.9	119.5	103.1
Mean	99.8	106.6	120.9	109.1
Overall Mean	101.4	106.6	123.9	110.6

Nodulation was very site specific so that an adequate test of the ability of coated seed to provide Rhizobium inoculum could be performed at only one site. Here both field inoculation and coating improved nodulation compared to uninoculated bare seed. Coating resulted in nodulation similar to field inoculation with peat-based inoculum applied by the water slurry method. Coating is a reliable way of inoculating seeds but was no better than field inoculation in drilled seedings under our conditions. The literature indicates that coating may be of greater value in areas with acid soils or in broadcast seedings.

We tested the effects of coating on seeding year dry matter yields. One test in 1987 and three in 1988 were performed with equal live seeding rates of coated and bare seed. From these we can conclude that coating does not affect alfalfa dry matter yield. In the one trial where inoculation affected yield, the coated products did not outyield the bare field inoculated seed.

The last question addressed was whether there is a yield reduction when coated seed is sown at equal weight (fewer seeds) to bare seed. Coated seed was sown at the same weight as bare seed at the Research Station in 1986 and 1987. In 1986 there was a statistically significant (10%) reduction in yield with the two coats tested but in 1987 there was no significant reduction. This was due to compensation by plants with the lesser density rather than to increased plant size with coating. Analysis of covariance on the 1988 Research Station data indicated that if the coated products had been sown at equal weight to bare seed, there would have been significant (8%) yield reductions for two of the products. Though yield reductions do not always occur, it is a risky practice. We cannot always depend on crop compensation to maintain yields when we reduce plant density. The recommended seeding rate should result in more plants than needed for optimum yield if ideal seed bed and environmental conditions occur. These extra seedlings are a form of insurance to account for seedling mortality and uneven seed distribution which are much more likely to occur in large fields than in plot scale work. The practice of sowing coated seeds at equal weights to those recommended for bare removes this insurance and therefore should be discouraged.

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APPENDICES

Appendix 1. Comparison of seeding rates and costs of seeding coated and uncoated seed.

To determine the actual costs of seed coating we must first determine what weight of coated seed is necessary to give the same "target" population as the recommended rate of bare seed. The target population is the seedling density which ensures adequate established plant densities in the second year. The target population varies with site conditions. In B.C. a pure stand of irrigated alfalfa is usually sown at 11 kg/ha (Hubbard 1981). If the germination is 100%, this gives a target population of 500 plants/m^2. In dryland seedings a lower rate is recommended, 5 kg/ha (McLean and Bawtree 1982), which gives a target population of 250 plants/m^2. In mixtures, alfalfa rates should be reduced (Fairey and Bonin 1987).

The inputs to calculate the seeding rate of bare or coated seed needed to give a target population are:

Inputs:

a) <u>number of plants/m^2</u>: For example, the target population of 500 plants/m^2 is appropriate for irrigated alfalfa.

b) <u># seeds</u>: The number of seeds in a kg of uncoated seed. Determine yourself or use the general value of 450,000 seeds/kg for alfalfa (Heath et al. 1973). Note: this number can vary considerably between cultivars and to a lesser degree between seed lots.

c) <u>pgerm.</u>: The proportion of the seed which is expected to germinate (% germination/100). For certified seed percent germination is on the crop certificate. For old or non-certified seed perform your own test.

d) <u>pseed</u>: For coated seeds this is the ratio of seed weight to coated seed weight. For the coats available in 1987 this was 1/1.5 or 0.66. If the coat weight is reduced to 20% as is contemplated by Grow-tec (T. Cabral, personal communication) of total weight, pseed will be 1/1.2 = 0.833.

e) <u>pemerge.</u>: The ratio of emergence with coating to emergence without coating. This requires field testing.

Formulae to calculate seeding rates:

1. Formula to calculate the seeding rate of bare seed to get a desired seedling density:

$$\frac{\text{number of seedlings}}{m^2} \times \frac{10{,}000\ m^2}{\text{ha}} \times \frac{1\ \text{kg}}{\#\ \text{seeds (pgerm.)}} = \text{kg/ha bare seed}$$

2. Formula to calculate the seeding rate of coated seed to get a desired seedling density:

$$\frac{\text{number of seedlings}}{m^2} \times \frac{10{,}000m^2}{ha} \times \frac{1\ kg}{(\#\ seeds)\ (pgerm.)\ (pseed)\ (pemerge.)} =$$

$= kg/ha$ coated seed

Examples:

i) How much bare seed with 80% germination (pgerm = .80) is required to get a seedling density of 500 plants/m^2?

$$\frac{500\ seeds}{m^2} \times \frac{10{,}000\ m^2}{ha} \times \frac{1\ kg}{(450{,}000)(0.80)} = 13.9\ kg/ha$$

ii) A seed lot with 80% germination is coated by a process which increases seed weight by 50% (pseed = 0.666) and no enhancement of emergence is proven (pemerge = 1.0). What seeding rate gives the same density as i)?

$$\frac{500\ seeds}{m^2} \times \frac{10{,}000\ m^2}{ha} \times \frac{1\ kg}{(450{,}000)(0.80)(0.666)(1.0)} = 20.9\ kg/ha$$

iii) The same lot as ii) has been shown to increase emergence by 11% (pemerge = 1.11) what seeding rate gives the same density as i)?

$$\frac{500\ seeds}{m^2} \times \frac{10{,}000\ m^2}{ha} \times \frac{1\ kg}{(450{,}000)(0.80)(0.666)1.11} = 18.8\ kg/ha$$

iv) A seed lot with 80% germination is coated by a process which increases seed weight by 20% (pseed = 0.833) and no enhancement of emergence is proven. What seeding rate gives the same density as i)?

$$\frac{500\ seeds}{m^2} \times \frac{10{,}000\ m^2}{ha} \times \frac{1\ kg}{(450{,}000)(0.80)(0.833)(1.0)} = 16.7\ kg/ha$$

v) As in iv) but an 11% enhancement of emergence has been proven.

$$\frac{500 \text{ seeds}}{m^2} \times \frac{10{,}000 \text{ m}^2}{\text{ha}} \times \frac{1 \text{ kg}}{(450{,}000)(0.80)(0.833)(1.11)} = 15.0 \text{ kg/ha}$$

To determine inoculated seed costs:

1. Field inoculation of bare seed:

Cost = seeding rate (cost of bare seed + cost of inoculum + cost of labour)
(\$/ha) (kg/ha) (\$/kg)

Cost of seed = \$5.95/kg for Peace alfalfa (Prairie Brand Seeds 1988 price list)

Cost of inoculum = \$2.75/25 kg of seed = \$0.11/kg

Cost of labour = (0.5 hr x \$15/hr) ÷ 25 kg/bag = 0.30 \$/kg

From example i):

Cost = 13.9 (5.95 + 0.11 + 0.30)
(\$/ha) (kg/ha) (\$/kg)

= 88.40 \$/ha

2. Coated seed:
Note: coated seed is sold for the same price per kg as bare seed

Cost = seeding rate of coated seed (cost of coated seed)
(\$/ha)

Cost = 20.9 kg/ha x 5.95 \$/kg = \$124.36
(\$/ha)

The increase in cost of inoculated seed due to coating in the examples is summarized below:

Example	Seeding rate (kg/ha)	Inoculated seed costs (\$/ha)	Increase over field inoculated (\$/ha)
i	13.9	88.40	---
ii	20.9	124.36	35.96
iii	18.8	111.90	23.50
iv	16.7	99.37	10.97
v	15.0	89.25	0.85

Appendix 2. A test of grass and legume seed coating at Prince George[1].

Klaas Broersma

Introduction

Commercially coated seed of both legume and grass forage seed is available in Canada. Improvements in germination, emergence and establishment with coated seed have been reported in the literature. The purpose of this study was to determine if commercial seed coating affects the establishment and yield of three grasses and three legumes adapted to the Prince George region. This was the preliminary study which led to the alfalfa seed coating studies performed at the Kamloops Research Station.

Methods

Three legumes and three grasses in bare and coated (Prill-on, Canadian Seed Coaters Ltd.) form were chosen to make a balanced experimental design. The grasses and legumes were seeded into separate blocks in close proximity to facilitate their different management requirements. The legume and grass tests were in a randomized replicated block design with the bare and coated treatment being a split plot. All seedings were replicated 4 times. The plots were seeded on June 29, 1982 using a hand propelled V-belt, single row seeder. The plot size was 1.5 m by 8 m with a row spacing of 0.3 m resulting in 5 row plots. Seeding rates used were corrected to correspond to a 100% germination from actual germination percentages (Table I). Seeding rates used were 8 kg/ha for legumes and 10, 8 and 6 kg/ha for meadow foxtail, reed canarygrass and timothy, respectively. Seeding rates for coated seeds were increased so that the same number of seeds were sown as uncoated seeds. The trial was first harvested in 1983 with 2 cuts (July 5 and September 2). The legumes were harvested at various stages of bloom while the grasses were harvested in the early to late heading stages. During the winter of 1983-84 the legumes were severely winterkilled leaving only the grass trial for 1984. The grass was only harvested once during the 1984 growing season (June 22). Crude protein content was determined on the 1983 samples using the macro-Kjeldahl procedure. The data were analyzed using analysis of variance.

Results

Before using the coated and bare seed for use in the field, the amount of coating on the different seed species and varieties were determined (Table II). The legume seed accumulated less coating, on a weight basis, than did the grass seed. Coating increased the weight of alsike clover, red clover and birdsfoot trefoil seed by 57, 68 and 145%, respectively, and increased reed canarygrass, timothy and meadow foxtail seed by 152, 166 and 326%, respectively.

[1]Agriculture Canada, Experimental Farm, R.R. 8, RMD #6, Prince George, B.C. V2N 4M6.

There were changes in the percent germination of bare and coated seeds (Table I). Germination of coated legume seeds increased from 4 to 19%. Germination of the grass seeds decreased 10-13% with coating.

The effects of seed coating on the yield and crude protein content of the legumes are presented in Table II. In the establishment year, legumes were visually rated April 25, 1983 on a scale of 1 to 10 based on vigour, stand cover, plant height and colour; yields were not obtained. Although the ratings of the coated seed treatments were higher than bare seed, this did not translate into yield increases or differences in the year following establishment.

No significant differences were observed between bare and coated seedings for cut 1, 2 or the total cut in 1983. The protein content of the first cut was not significantly different between seed treatments but the protein content was lower for all coated seed treatments for the second cut.

The yield and protein content of the three grasses for 1983 and the yield for 1984 for bare and coated seed treatments are presented in Table III. In 1982, no yields were determined because establishment was slow and inadequate. Grasses were visually rated May 19, 1983 on a scale of 1 to 10 based on vigour, stand cover, plant height and colour. The visual ratings of the coated treatments were higher but there were no significant differences observed between the bare and coated seed treatments for yield and protein content.

Conclusions

The amount of coating on grass seeds was considerably greater than that of the legume seeds (Table I). Under controlled conditions, coated seed increased germination for legumes but decreased germination for grasses (Table I). The legume yield from both cuts and the protein from the first cut showed no differences due to seed coating (Table II). The protein content of the second cut was significantly lower for legumes from the coated seed treatment (Table II). No significant differences were observed for yield and protein content for 1983 and 1984 between the coated and bare grass seed treatments (Table III).

Table I. One hundred seed weight and germination tests of coated and bare seed (n=3).

Species	Variety	100 seed weight (mg) Bare	Coated	Weight increase (%)	Germination (%) Bare	Coated	% Change
Alsike clover	Tetra	126	198	57	90	94	4
Red clover	(double cut)	186	312	60	87	87	5
Birdsfoot trefoil	Leo	094	230	145	74	93	19
Meadow foxtail	common	100	426	326	65	55	-10
Reed canarygrass	common	085	214	152	30	17	-13
Timothy	Toro	044	117	166	92	82	-10

Table II. Effect of seed coating and yield and crude protein of three legumes suitable for the Prince George region for 1983.

	Yield (kg/ha) Cut 1	Cut 2	Total	Protein (%) Cut 1	Cut 2
Birdsfoot trefoil:					
bare	3133	3343	6476	16.5	12.9
coated	2714	3112	5826	15.9	11.8
Red clover:					
bare	1179	3310	4488	17.4	13.4
coated	1191	3744	4934	18.4	13.2
Alsike clover:					
bare	3246	3004	6250	15.0	13.7
coated	3263	3320	6583	17.5	11.9
Mean bare	2519	3219	5738	16.3	13.3
Mean coated	2389	3392	5781	17.2	12.3
F(1,9) calculated	0.7	1.2	0.0	3.0	12.6
Level of significance	N.S.	N.S.	N.S.	N.S.	**[1]

[1]N.S. = not significant, ** highly significant ($P \leq 0.01$).

Table III. Effect of seed coating on yield and crude protein content of three commonly grown grasses suitable for the Prince George region in 1983 and 1984.

	Yield (kg/ha)			Protein (%)		1984** yield (kg/ha)
	Cut 1	Cut 2	Total	Cut 1	Cut 2	cut 1
Meadow foxtail:						
bare	4105	2131	6236	9.99	6.53	3479
coated	4715	1829	6545	8.78	6.66	2660
Reed canarygrass:						
bare	5451	2104	7555	7.14	7.64	2914
coated	5436	1971	7407	8.00	8.05	2346
Timothy:						
bare	4920	1859	6779	8.20	4.47	3781
coated	5069	2365	7423	7.52	4.08	3845
Mean bare	4825	2031	6856	8.44	6.21	3391
Mean coated	5073	2051	7125	8.10	6.26	2950
F(1,9)	2.0	0.05	2.1	2.1	0.13	1.8
Level of significance	N.S.[1]	N.S.	N.S.	N.S.	N.S.	N.S.

[1]N.S. = not significant.