CROP ROTATIONS: THE ROLE OF LEGUMES

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Inclusion of a legume in cropping rotations has long been recognized as a recommended practice to improve crop productivity. The beneficial effect of legumes is usually associated with the ability of the legume to fix atmospheric nitrogen. Also, it is often suggested that deep-rooted legumes such as sweet clover and alfalfa improve subsoil aeration, moisture infiltration and root penetration by subsequent crops. Research efforts in the Beaverlodge Research Station have been directed towards understanding the effects of legumes on the soil and subsequent crops, with the goal of making the legume a more effective component in the cropping systems.

Do legumes in rotation increase the yield of cereal crops?

Over the years, several field tests have been conducted in the Peace River region to measure the effect of legumes on the production of subsequent cereal crops. The results of these tests are summarized in Table 1. The early work (1934-44 and 1949-54) indicated that replacement of summerfallow with a sweet clover crop provided a slight advantage for wheat production. In tests since 1954, when the yield of barley or wheat following a legume was compared to yield following the respective cereal crop, or fallow following the cereal crop, there was often a substantial yield increase following the legumes. For example, the 7-year total yield increase following several legumes ranged from 2400 to 4100 kg/ha (45 to 76 bu/acre) on a Gray Luvisol soil. The tests also showed that legumes do not always have a positive effect on subsequent grain crops. In two tests there was an overall negative effect from the previous legumes.

Although it is clear that legumes grown in rotation affect the yield of subsequent cereal crops, the cause and the amount of the beneficial effect and why the benefit fails to occur in some soils are not completely understood.

Do deep-rooted legumes improve subsoil permeability?

It has often been suggested that good crops of cereals follow sweet clover and alfalfa because the penetrating tap-roots improve aeration, increase moisture-holding capacity and allow access to nutrients which have been leached into the subsoil. These suggestions are partially supported by experimental data but require further experimental confirmation.

The results of a field experiment begun in 1960 at McLennan on an Orthic Grey Luvisol (Nampa) are of interest. Wheat was grown continuously from 1962-1976 after alfalfa, alfalfa-brome mixture or fallow of a fallow-wheat rotation. Over the 16 years, wheat following alfalfa has yielded 70% more than following fallow-wheat and 54% more following alfalfa-brome. The effect of the preceding alfalfa on wheat yield was still evident in the sixteenth year. Such a prolonged effect is undoubtedly due to factors in addition to N_2 fixation, indirectly suggesting that the three factors mentioned above are of importance.

The experimental evidence for the effect of deep-rooted legumes on improvement of subsoil is indirect,

Table 1.
The effect of legumes in rotation on the yield of cereal crops.

						Total** yield of test crop — 100 kg/ha (bu/acre)					
						previous crop in rotation					
Soil	Test date	Test* years	Test crop	Fallow	Test crop	Alfalfa	Birdsfoot trefoil	Alsike clover	Red clover	Sweet-clover	Brome-alfalfa
Gray Luvisol	1934-44	2	wheat	26(38)	—	—	—	—	—	29(43)	—
Black Solod	1949-54	2	wheat	32(48)	27(40)	—	—	—	—	31(47)	—
Gray Luvisol	1955-66	4	wheat	38(57)	—	67(99)	—	—	—	—	58(86)
Gray Luvisol	1967-75	7	barley	—	119(221)	152(282)	150(279)	160(297)	159(296)	143(266)	—
Gray Luvisol	1967-75	3	barley	—	74(138)	66(122)	—	69(129)	61(113)	56(108)	—
Gray Luvisol	1967-75	3	barley	—	51(96)	72(135)	—	70(130)	73(136)	61(113)	—
Black Solod	1967-75	5	barley	—	147(273)	172(321)	179(333)	167(310)	164(305)	164(305)	—
Black Solod	1967-75	3	barley	—	91(162)	68(127)	69(129)	68(126)	70(129)	64(120)	—
Gray Luvisol	1968-76	3	barley	—	57(106)	—	—	—	—	—	71(133)

* Number of years of test crop following legume, test crop and/or fallow.
** Total yield for the number of test-years shown in 3rd column.

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The Option for Change

As we view the future of our forage seed industry we look for ways to improve the present system. Changes in production techniques will occur and legislation giving plant breeders patent rights to their varieties will increase the demand for the best distribution system possible. We have already seen the effect of this trend with the distribution of private varieties in Canada. SeCan Association, a relatively new organization, is becoming the primary outlet for new Canadian public forage varieties and the result of this is that growers will need to be aware of the opportunities. In turn, this means increased demand for contract production and access to processing facilities.

One way to assist expansion of our production base and tackle the quality analysis problem is to develop a full training program for forage seed plant operators, incorporating a full line of equipment for teaching equipment operation with the ability to perform the function of arbitrator in the determination of dockage submitted by any party.

A less elaborate, but yet another option to consider, would be a basic dockage centre. This facility could determine the amount of foreign material excluding the extremely difficult to remove weed seeds using present standardized methods. Purity tests would then be done at the present institutions in the same manner that processed seed lots are done.

The Alberta Forage Seed Council would like to hear the views of our readers on this matter, especially those of you presently growing forage seeds, since it would be primarily intended as a service to you. In other words, is there a need for additional quality analysis services for the industry and to what extent would this be useful?

Please address your comments to Marcel Maisonneuve, Chairman, Alberta Forage Seed Council, 601 Agriculture Building, Edmonton.

Another Look at Our Legumes

In western Canada summerfallow continues to make up a significant portion of our cultivated acreage. In fact in 1980 we expect that 24 million acres or 25% of cultivated land will be fallowed to conserve moisture, control weeds, release nitrogen as well as provide quota acres for the marketing of our major cereal and oilseed crops.

The increasing cost of commercial fertilizers, higher fuel prices and a need to conserve soil quality cause producers to evaluate alternatives to their present management practices. It is hoped that future market opportunities will develop in such a manner that less land will be removed from crop production each year.

One alternative that we feel has merit is the expanded use of legumes in our crop rotations. Livestock producers use alfalfa, clovers and other legumes for pasture, hay or silage and increase productivity of their soils. Forage seed producers have also accomplished this objective by growing legume seed crops. There is room, however, for expansion of legume use as a plowdown or green manure where the crop replaces part of the fallow year and is turned under during the months of July and August.

Of particular interest are legume seed crops that would fit well into a short term rotation — alsike, red clover and sweet clover. They can be seeded with a companion crop during the last year of a cereal or oilseed rotation, allowed to develop growth until mid summer of the following year and then worked under. This practice would build up soil nutrient content and in turn lower the fertilizer requirements for the next crop.

Good seed harvests of these legumes during the past few years in Alberta have resulted in very poor producer returns and we expect a cut back in acreage this year. It is therefore a good opportunity for increasing the use of these crops to strengthen our seed market by reducing present carryover and pressure on the lack luster performance of the export market. Of equal importance would be the development of a good domestic Canadian market which would reduce our dependence on traditional export markets.

We present the following article by Dr. Wendell Rice and Paul Hoyt of the Agriculture Canada Research Station at Beaverlodge on the "Role of Legumes in Crop Rotations" as evidence to the need for more legume use.

Marcel Maisonneuve, Chairman
Alberta Forage Seed Council

but field observations and demonstration rotations indicate that lasting benefits can be obtained by growing a deep-rooted legume such as sweet clover soon after new land is broken. Experiments currently being conducted by the Beaverlodge Research Station will hopefully provide some direct evidence on the effect of legumes on sub-soil permeability.

How much nitrogen do legumes add to the soil?

Estimates of the amount of nitrogen fixed annually by several legumes grown on three Peace River region soils vary from 0 to 442 kg N/ha (0 to 394 lb N/acre) in 3 years (establishment year plus 2 years) (Table 2). These data reflect variations due to soil type and legume species, with soil type being an important factor. The nitrogen-fixation potential of legumes is greater on Gray Luvisol soils than on Black solod soils. High nitrogen fixation is related to high legume herbage yields. Year to year variation in nitrogen fixation by alsike clover and red clover grown on two soils (Table 3) indicate that climatic factors exert considerable influence on nitrogen fixation.

The amount of nitrogen added to the soil will be equal to the amount fixed if the crop is not harvested for forage and the whole plant is incorporated into the soil (i.e. green-manuring). When the herbage was removed, the amount of nitrogren added to the soil by five legumes after two years of growth was considerably less than the total amount of nitrogen fixed (Table 4, of Table 2). For the Rycroft soil (Black solod) there was a substantial depletion of soil N by all legumes. A vigorous healthy stand may fix several kilograms of nitrogen per hectare and add significantly to the soil N particularly if the legume crop is green-manured. However, it is possible that a poor stand, which is ineffective in fixing nitrogen will deplete the nitrogen content of the soil.

Legume species differ in the rate at which nitrogen is fixed. For example, by the end of July alsike clover fixed 85% of its total annual potential and red clover fixed only 73% of its total annual potential (Fig. 1). That is, if both clovers had a total annual fixation potential of 150 kg N/ha (134 lb N/acre), by the end of July, alsike clover would fix 128 kg N/ha (114 lb N/acre) and red clover would fix 110 kg N/ha (98 lb N/acre). When a legume crop is green-manured, it is often desirable to provide a partial summerfallow to obtain a complete kill of the legume and to prepare a good seedbed for the following crop. Alsike clover has the potential to add more nitrogen to the soil than red clover if the legume is plowed down at mid season.

The use of legumes offers an alternative for nitrogen fertilizers which are steadily increasing in price. Table 5 shows that replacement of the summerfallow year in a fallow-rapeseed-barley-barley rotation with a green-manured legume crop adding 125 kg N/ha (111 lb N/acre) to the soil can reduce the total fertilizer N requirement from 218 kg N/ha (195 lb N/acre) to 112 kg N/ha (100 lb N/acre), a reduction of nearly 50%. Even when this is balanced against the increase costs for legume seed, the savings in input costs will be considerable.

Table 2.
Total yields and estimates of nitrogen fixation by 5 legumes grown on 3 soils for 2 years after establishment. Nitrogen fixation estimates determine by measuring the nitrogen in the herbage and in barley crops following the legumes.

	Yield — 100 kg/ha (tons/acre)			Nitrogen fixation — kg N/ha (lb N/acre)		
	Gray Luvisol (Beryl)	Black Solod (Landry)	Black Solod (Rycroft)	Gray Luvisol (Beryl)	Black Solod (Landry)	Black Solod (Rycroft)
Alfalfa	14.8(6.6)	10.8(4.8)	8.3(3.7)	442(394)	171(153)	10(9)
Sweet clover	9.3(4.2)	10.8(4.8)	7.7(3.5)	214(191)	125(112)	0
Alsike clover	10.5(4.7)	10.8(4.8)	4.7(2.1)	303(271)	152(135)	0
Red clover	11.8(5.3)	12.5(5.6)	4.1(1.8)	334(298)	250(224)	0
Birdsfoot trefoil	8.1(3.6)	9.7(4.4)	6.8(3.0)	190(170)	145(129)	0

Table 3.
Annual nitrogen fixation by alsike clover and red clover grown on 2 soil types. Nitrogen fixation measured by the acetylene reduction technique.

Year		Annual nitrogren fixation — kg N/ha (lb N/acre)			
		Alsike Clover		Red Clover	
Planted	Measure	Gray Luvisol (Hazelmere)	Black Solod (Landry)	Gray Luvisol (Hazelmere)	Black Solod (Landry)
72	73	83(74)	31(28)	58(52)	14(12)
72	74	100(89)	42(37)	52(46)	23(20)
73	74	137(122)	49(44)	77(68)	25(22)
73	75	21(19)	7(6)	16(14)	5(4)
74	75	62(55)	16(14)	45(40)	12(11)
74	76	83(74)	50(44)	41(36)	38(25)

Table 4.
Estimates of nitrogen added to 3 soils by 5 legumes grown for 2 years after establishment. Estimates determined by measuring nitrogen uptake by barley. Legume stand were cut for hay.

	N added to soil — Kg N/ha (lb N/acre)		
	Gray Luvisol (Beryl)	Black Solod (Landry)	Black Solod (Rycroft)
Alfalfa	106(94)	82(73)	-98(-82)
Sweet clover	51(45)	76(68)	-117(-105)
Alsike clover	79(70)	73(65)	-102(-91)
Red clover	69(62)	62(55)	-108(-96)
Birdsfoot trefoil	60(54)	102(91)	-114(-102)

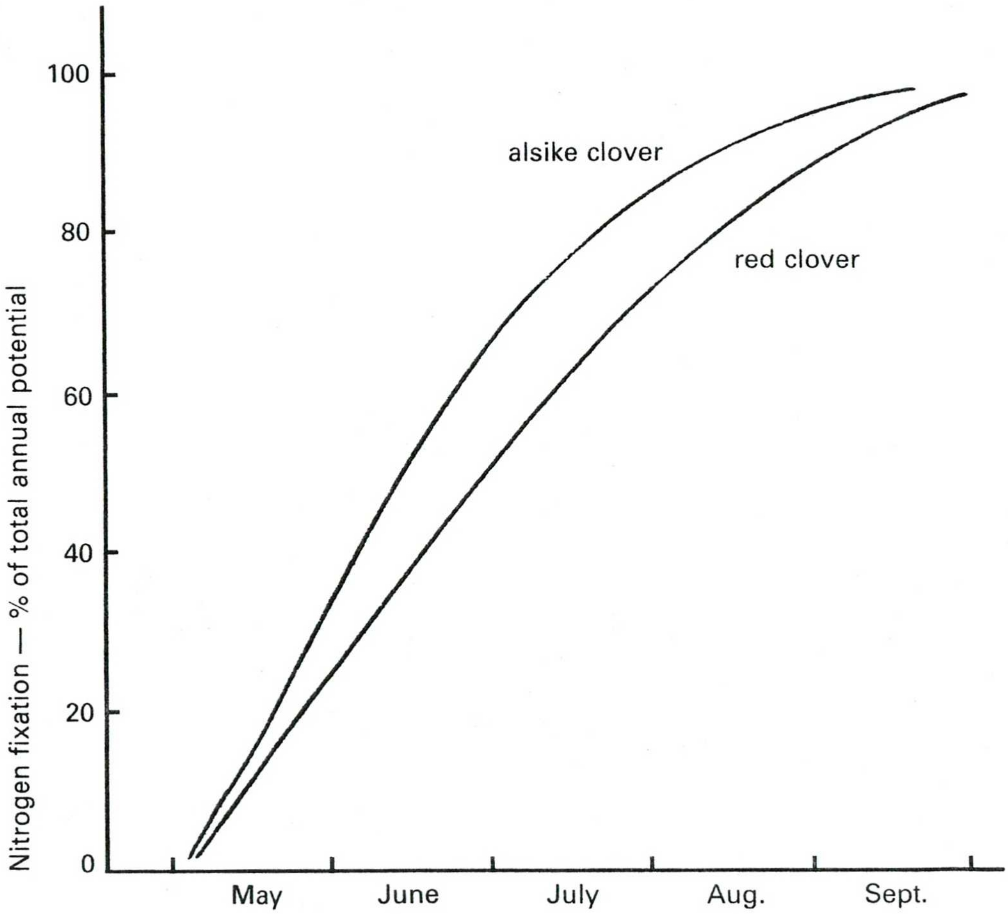

Fig. 1. Seasonal nitrogen accumulation from nitrogren fixation by alsike clover and red clover.

Table 5.
Comparison of fertilizer N requirements for a fallow-rapeseed-barley-barley rotation and a legume-rapeseed-barley-barley rotation. Calculations based on nitrogen fixation by the legume crop of 125 kg N/ha (111 lb N/acre).

	Fertilizer N required — kg N/ha (lb N/acre)	
	Fallow-Rape-Barley-Barley	Legume-Rape-Barley-Barley
Rape	50 (45)	18 (16)
Barley	84 (75)	39 (35)
Barley	84 (75)	55 (49)
Total	218 (195)	112 (100)

TABLE 7

1	2	3	4	5*	6	7	8	9
	Maximum number of seeds per 25 grams except where otherwise stated						Minimum percent germination	Maximum percent hulled seed in timothy by count
	Noxious weed seeds		Total weed seeds	Sweet clover	Seeds of other crops			
	Primary	Primary plus secondary			In timothy	In other kinds		
1. Canada Foundation No.1	0	1	10	1	20	10	85	50
2. Canada Foundation No. 2	0	2	75	1	100	50	70	100
3. Canada Registered No. 1	0	1	10	1	20	10	85	50
4. Canada Registered No. 2	0	2	75	1	100	50	70	100
5. Canada Certified No. 1	0	5	75	25	2% by mass	2% by mass	80	50
6. Canada Certified No. 2	0	10	100	50	3% by mass	3% by mass	70	75
7. Canada No. 1 Seed	0	5	75	25	2% by mass	2% by mass	80	50
8. Canada No. 2 Seed	5	15	150	100	3% by mass	3% by mass	70	75
9. Canada No. 3 Seed	10	50	300	less than 1% by mass	less than 5% by mass	less than 5% by mass	60	100

* Column 5 does not apply to Sweet clover
SOURCE: Canada Seeds Act

Weed Seeds Order

Class 1. Prohibited Noxious Weed Seeds

(1) Dodder
(2) Field bindweed
(3) Hologeton
(4) Hoary Cress
(5) Horse nettle
(6) Leafy spurge
(7) Russian Knapweed
(8) Tansy ragwort

Class 2. Primary Noxious Weed Seeds

(1) Bladder campion
(2) Couch grass
(3) Great ragweed
(4) Ox-eye daisy
(5) Perennial sow thistle
(6) Toad flax
(7) White cockle
(8) Wild mustard
(9) Wild radish
(10) Yellow rocket or winter cress

Class 3. Secondary Noxious Weed Seeds

(1) Cleavers
(2) Canada thistle
(3) Chicory
(4) Common ragweed
(5) Dock
(6) Dogmustard
(7) False flax
(8) Field peppergrass
(9) Night-flowering catchfly
(10) Ribgrass
(11) Stickseed
(12) Stinkweed
(13) Tall hedge mustard
(14) Wild carrot
(15) Wild oats

Summary

1. Inclusion of a legume in cropping rotations is generally beneficial, particularly if the legume stand is healthy, vigorous and actively fixing nitrogen. Yields of cereals can be increased substantially by growing them in rotation with legumes. However, there can also be a negative effect, resulting in decreased yields of cereal crops following legume stands which do not fix nitrogen.
2. It is generally accepted that deep-rooted legumes such as sweet clover and alfalfa improve sub-soil permeability. Research results indirectly support this view.
3. Forage legumes that are commonly grown in the Peace River region have the capacity to fix up to 220 kg N/ha (197 lb N/acre) annually. The ability to obtain fixation rates approaching the upper end of the range mainly depends on obtaining a healthy vigorous stand. Nitrogen fixation is generally lower on soils with high organic matter content (Black) than soils with low organic matter content (Grey Luvisols). Nitrogen fixation varies with legume species, soil type, and yearly climatic factors (precipitation, temperature, etc.)
4. The amount of nitrogen added to the soil depends on the amount of nitrogen fixed by the legume under a given set of environmental conditions. Also, the amount of nitrogen added can be greatly increased if the legume crop is green-manured. The time of plow-down of green manure crop can influence the amount of nitrogen added to the soil. Approximately 80% of the annual potential nitrogen fixation has occurred by late July to early August.
5. Replacement of a summerfallow year with a green-manure legume crop can save approximately 112 kg/ha (100 lb/acre) of fertilizer nitrogen in a four year rotation.

U.S. Imports of Grass and Legume Seeds

	July 1, 1979 to December 31, 1979 (pounds)	July 1, 1978 to December 31, 1978 (pounds)
Alfalfa	810	13,069
Clover, alsike	994,952	1,365,207
red	995,767	1,470,442
white	643,880	311,447
Fescue, red	6,902,744	4,634,700
Sweet clover, yellow	1,927,020	2,631,116
yellow & white	69,780	27,200
Timothy	514,192	594,147
Trefoil, birdsfoot	127,710	130,092
Wheatgrass, crested	83,000	360,100
slender	0	4,950
tall	37,500	90,400
Wild ryegrass, Russian	137,815	0
Legume mixtures	606,208	258,499

SOURCE: USDA Agricultural Marketing Service

The Canada Seeds Act

When purchasing seed it is important to understand what is meant by the grade on the seed tag. Whether the seed is pedigreed or commercial there are restrictions on the type and quantity of weed seeds as well as a minimum germination expressed as a percent of good seed. Table 7 of the Canada Seeds Act is presented below and is only one of 17 tables which apply to seed sold in Canada. It applies to alfalfa, red clover, sweet clover, and timothy as well as a few other less known seeds. The weed seed order of the Seeds Act is also presented in order that you may distinguish between prohibited, primary or noxious weeds. The purchaser of any seed has the right to request and receive from the seller a copy of the purity and germination analysis of seed he wishes to buy. To avoid buying seed that contains weed seeds you might not wish to have on your farm it is advisable to order early and discuss your requirements with your seed dealer.