GRAIN LEGUMES AS COMPONENTS IN FARMING SYSTEMS

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The number of combinations in which grain legumes are used in farming is probably approximately the number of farmers growing grain legumes. During this conference we will have individual discussions of some of the major grain legumes. Thus, my objectives are to: 1) review the advantages of legumes in farming systems 2) briefly review examples of different grain legume production systems, and 3) identify management differences between grain legumes and forage legumes in farming systems.

Traditional reasons for inclusion of grain legumes in a farming system are:

- Sustained high yield
- Increased economic gain per unit of land area
- Maintain soil organic matter, fertility and tilth
- Reduce incidence and/or losses due to weeds, insects and diseases
- Capture, conserve and increase water use efficiency
- Minimize soil erosion and water pollution
- More efficiently distribute labor requirements
- Reduce risk factors

SUSTAINED HIGH YIELD.

The benefits of rotations on enhancing yields is well documented via long term rotations such as the Morrow plots in Illinois (established in 1876). The Sanborne plots in Missouri (established in 1888) and the Rothamsted plots in England (established in 1851). Yield data presented in Figure 1 for corn yields indicates the benefit of rotations. Welch et al. (1976) summarized the lessons learned to date from the Morrow plot rotations where soybeans were introduced into the rotation in 1967.

Lessons learned from 1876-1904:

1) High fertility prairie soils could be depleted with cropping.
2) Depletion could be postponed by rotations.

Lessons learned from 1904-1955

3) The use of manure, lime and phosphorus increased crop yields but did not replace rotation effects.
4) Rotation alone did not replace the effect of fertility action. The highest yields were from rotation with manure, lime, and phosphorus (MLP).

Lessons learned from 1955-1975

5) If top soil remains, fertilizer (lime NPK) can quickly restore productivity to 91% of those receiving LPK since 1904.
6) Continuous corn yielded 87% of corn-soybean rotation.

7) Soybeans are less affected by soil treatments than corn.

Welch (1984) summarized the benefits of rotations to other crops following soybean from studies in Iowa, Illinois, Indiana, Kansas, Minnesota and Wisconsin. The yield increase ranged from 6.5 to 113.4%. The highest increases occurred when compared to continuous cereal grain without fertilizer. Under high fertility situations the rotation effect averaged 14.0% increase. Grain legumes also respond to rotations with other crops. Rotation studies in Michigan produced 18.6, 17.3 and 16.3 cwt/A when dry beans were in the rotation 25%, 50% and 75% of the cropping years (Christensen et al. 1982).

Crookston (1987) found in Minnesota that soybean yields increased 12.5, 16.7 and 27.1% compared to continuous soybeans when corn occurred in the rotation 25, 50 and 75% of the cropping years. Welch (1984) reported an average increase of 14% among studies from 3 states for corn-soybean rotations versus continuous soybeans.

Economic gain per unit of cropping area is strongly influenced by commodity prices and yield, machinery and labor requirements, risks or hazards, and government policies and programs. All have varying degrees of influence on profitability and all have varying short run, and long-run implications. Systems perspective implies that both short and long run effects must be noted.

Maintain soil organic matter, fertility and tilth. Rotations of crops with or without legumes maintains soil organic matter at higher levels than do continuous monocrops, especially row crops. The benefits of rotations on soil organic matter is illustrated in figure 1.

REDUCE CROP LOSSES DUE TO PESTS.

Weeds. Grain legumes differ in their competitive ability with weeds. Competitive ability compared to soybeans is soybeans = cowpea > faba > field pea > field bean > lupine > adzuki > lentil. Among crops classified as "smoother crops" for their ability to compete with weeds when sown at high seeding rates under favorable environmental conditions for rapid growth only soybeans and cowpeas are listed. Table 1 partially illustrates the relative competitiveness of the several grain legumes with oats and flax. As with other crops, growth habit (upright vs. prostrate and determinant vs. indeterminant) growing season adaptation (cool season vs. warm season) dictate the mixture of weeds which are a problem in the crop and the weed seed bank affecting subsequent crops. The data of Dotzenko et al. in table 2 illustrate the effect of dry beans (Phaseolus) on weed populations in subsequent sugar beet crops. The early cool season weed species were effectively controlled culturally by the normal late May-June planting of the dry beans.

Diseases. Rotations are effective in reducing the incidence of many soil borne diseases. The grain legumes: faba, lupine and lentils have commonly been used as "break crops" in cereal grain rotations to reduce crop losses in northern Europe. Grain legumes provide effective "break crops" for cereals against take-all (*Gaeumannomyces graminis*), *Fusarium* spp., eyespot

(Pseudocercosporella herpotrichoids). Root rot complex (Pythium, Rhizoctonia, Fusarium and Schlerotium) limit the frequency of grain legumes in rotations. The grain legumes are also susceptible to sclerotium spp., Blight, (Ascochyta Psuedmonas and Xanthomonas sp.), Grey mold (Botrytis spp.) and seed borne virus diseases are common among the grain legumes but the severity varies with the species. Rusts appear as the most common and serious post-flowering disease. See Table 3 for listing of common diseases affecting grain legumes.

Insects. Many of the insects which cause serious crop losses to grain legumes are not present in the U.S. or in Minnesota. The insect most likely to cause problems are the lygus which maybe prevalent on other legume species, white grubs, wireworms, seed corn maggot and cutworms which all have wide host specificity. Pod borers may cause economic losses in warmer climates but seldom are economically important in the more temperate climates.

SOIL EROSION AND WATER CONSERVATION.

Crop rotation effects on soil erosion and water conservation is often interrelated, i.e. as water infiltration increases soil erosion decreases as is illustrated in table 4 for data from a series of Ontario, Canada water sheds. Soil losses from land areas cropped to grain legumes typically are greater than for cereal grains, table 5. This appears to be the result of the rapid rate of residue breakdown due to low C/N ratio favoring high rates of microbial activity. In addition the quantity of residue left on the soil surface after harvest of grain legumes is typically 1/2 to 2/3 that of small grains or corn in Minnesota. Annual grain legumes leave the soil more erodible than cereals for the next cropping season due to smaller mean soil aggregate size. McCracken et al. (1984) cites Indiana studies showing spring residue cover following soybeans is only 1/3 of corn in several different tillage systems.

FARMING SYSTEMS UTILIZING GRAIN LEGUMES.

Continuous monocropping of grain legumes is not recommended because most are susceptible to the soil inhabiting root rot complex. Rotations are the most reliable options for control of this problem.

Multi-cropping

Intercropping - is intensification of cropping with two or more crops in the field at the same time. These maybe planted at the same time or staggered over the growing period. Alfalfa interseeded with oats would be an example. This is typical in developing countries but does not appear suitable as a system for grain legumes in a mechanized crop production system and high yield environments.

Relayed cropping is growing two or more crops in a sequential manner during a growing season. Double cropping of small grains and soybeans represents an example of this practice. Because of growing season limitations this system does not appear viable at this time for existing species and cultivars of grain legumes under Minnesota conditions.

Rotations - Grain legumes appear to fit best into 4 to 5 year rotations where grain legumes do not follow each other in the cropping sequence. The data in table 6 of Crookston (1987) illustrates the benefit of multiple non-legume crops preceding soybeans under Minnesota conditions. Across locations, 4 years of corn before soybeans produced 131% of continuous soybeans compared to 112% for corn-soybean rotation.

How grain legumes might fit into cropping systems is best determined by examining table 7, illustrating normal planting dates, maturities and growth season requirements under central Minnesota conditions. Faba bean, lentils, lupin, and peas are cool season species which will compete for labor with spring small grains. Adzuki, chickpea, cowpea, lima, mung and peanut compete with corn and soybeans for time of planting.

NITROGEN FIXATION.

Grain legumes may be provided nitrogen through symbiotic nitrogen fixation by Rhizobia inhabiting the host plant roots. The amount of nitrogen fixed by grain legumes is less than forage legumes and the amount of nitrogen returned to the soil is substantially less as is illustrated in table 8. Recent studies on soybeans and drybeans clearly demonstrate that they are soil nitrogen extracting and not soil nitrogen building, Heichel and Robertson et al. (1978). Handling legume crops for grain as opposed to forage reduces the symbiotically fixed nitrogen returned to the soil as is illustrated for lupine by data in tables 9 and 10.

Summary

- Grain legumes are excellent "break crops" for soil borne diseases in cereal crop based systems.
- Some intensively cropped grain legumes are effective in altering weed populations and species for subsequent crops.
- General evidence for smaller stable soil aggregates after an annual grain legume crop, which make most soils more susceptible to wind and water erosion.
- Grain legumes produce less crop residue after harvest causing greater soil losses under conventional tillage management practice.
- Among grain legumes are species and cultivars adapted to Minnesota and compatible with various cropping systems.
- Grain legumes are generally less competitive with weeds than most cereals crops.
- Grain legumes differ in their production of alleopathic compounds and in their sensitivity to alleopathic compounds produced by other crops. Alleopathic reactions are not a problem under conventional tillage systems.
- Grain legumes do not restore nitrogen status of the soil. Nitrogen balance studies generally show grain legumes to be net soil nitrogen depleters even with effective nodules present.

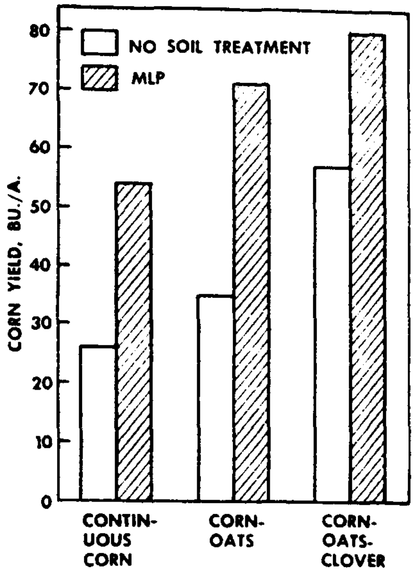

Figure 1. Effect of soil treatment and crop rotation on corn yields, 1904-1955, Morrow plots. L.F. Welch, et al. 1976.

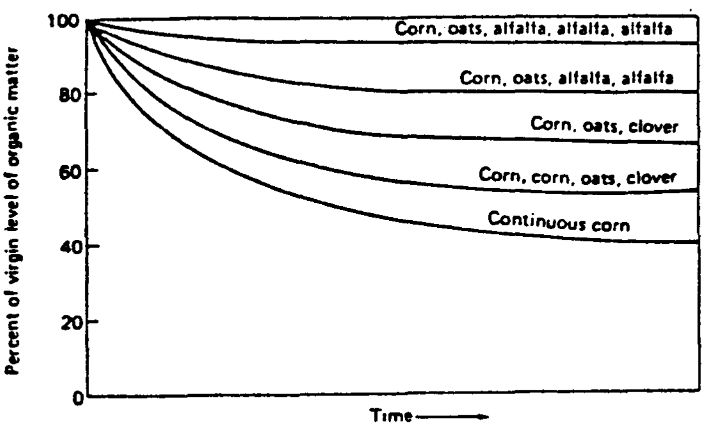

Figure 2. A schematic diagram showing the effect of different cropping systems on soil organic matter, assuming use of enough mineral fertilizers for maintenance of mineral nutrients.

Table 1. Pulse crops as companion crops and their competitive ability with weeds.

Companion crop	Weed control (%)	Forage rank*			
		Alfalfa	Red Clover	Brome	Timothy
Oats	89	3.0	3.2	4.1	4.4
Flax	64	2.3	2.4	3.1	3.7
Horsebean	38	3.2	3.3	2.1	2.5
Field pea	48	4.8	4.5	4.8	4.8
LSD .05	13	0.8	1.0	0.8	0.8

R.G. Robinson 1975.
* 1 = most forage, 5 = least.

Table 2. Effect of crop sequence on weed seedlings in sugar beet fields.

Crop Sequence	Weed seedlings per 400 g soil				
	Kochia	pigweed	grasses	Lambs quarter	Total weeds
Barley-beets	42.9	31.6	14.5	18.2	109.4
Corn-beets	66.6	43.6	48.2	6.6	165.7
Beans-beets	15.7	7.1	11.4	8.6	44.2

Dotzenko et al. 1969

Table 3. Diseases affecting grain legumes crops.

Disease	1. Adzuki	2. Chickpeas	3. Cowpeas	4. Faba bean	5. Field bean	6. Lentils	7. Lima	8. Lupin	9. Mung bean	10. Peanut	11. Peas	12. Soybean
Sowing-emergence												
Pythium sp. (water rot)				X	X	X	XX	XX	X			
Rhizoctonia sp.		X	XX	X	X	X	XX	XX	X		XX	
Thielaviopsis							XX				XX	
Fusarium		XX		X	XX	X	XX	XX	X		XX	
Aphonomyces root rot											XX	
Vegetative period												
Ascochyta sp. (blight)		XXX		XX		XX		X			XX	
Botrytis (Grey mould)		XX		X				X			XX	
Colletotrichum (Anthracnose)			XX		XX		X	XXX	X			X
Cercospora			X		X				X	XXX		
Erysiphe (Powdery mildew)			X					XX	XX		X	
Pleiochaeta								XXX				
Pseudomonas/Xanthomonas			X		XX		X		XX		X	
Scleortinia		X			X	X		X		X		
Virus												
Mosaic			X		X	X	X	X	XX	X		
Flowering-Harvest												
Fusarium								XX				
Phomopsis								X				
Phytophthora												XX
Stemphilium								XXX				
Uromycetes (rust)			X	X	XX	XX		X	X	X		
Nematodes												
Meloidogyne (Root Knot)		X					X					

X = disease occurs
XX = frequent occurrence of disease
XXX = serious production constrait

Table 4. Magnitude of potential sheet erosion losses from agricultural cropping systems in southern Ontario during 1974 growing season.

Crop	Mean soil loss T/A/yr	Range T/A/yr	No. of watersheds
Beans (soybeans & white)	3.4	2.5-4.4	6
Continuous corn	3.0	1.3-5.3	9
Corn in rotation	1.7	0.4-3.1	13
Small grains	1.5	0.6-3.1	13
Meadow in rotation	1.2	0.4-2.3	11

Van Vliet et al. 1976.

Table 5. Average annual soil and water losses for corn/soybean cropping systems.

System	Soil Loss	Water Loss
	T/ha	cm
Soybeans after corn	6.45 a	5.42 a
Corn after soybeans	9.57 b	7.26 b
Corn after corn	6.97 a	6.41 b

McCracken 1984.

Table 6. Long Term Rotation Study - Soybean (Hodgson) Yields 1986.

Rotation Sequence	Lamberton Bu/Acre	1986 % of SSSSS	Waseca Bu/Acre	1986 % of SSSSS	Mean of Locations Bu/Acre	% of SSSSS
SSSSS	37.4c	100	35.2cd	100	36.3	100
SSSSS*	36.5*	98	32.4d	93	34.4	95
CSSSS	34.8c	93	31.7d	90	33.3	92
CCSSS	37.4c	100	41.0b	116	39.2	108
CCCSS	38.7bc	104	38.8bc	110	38.8	107
CCCCS	47.7a	128	47.31a	134	47.5	131
SCSCS	43.0ab	115	38.6bc	110	40.8	112
$\bar{X}$	39.4		37.9		38.7	
LSD	10.3		12.5			

*Alternate varieties: At Lamberton the alternate variety, Corsoy, was grown in 1986.

Yields followed by same letters are not significantly different by anova over same site and year.
Crookston 1987.

Table 7. Planting dates, maturity dates and approximate days to maturity for grain legumes, corn and wheat for Central Minnesota. (Data compiled from various sources)

Crop	Planting Date Normal	Planting Date Range	Maturity date Normal	Approximate days planting to maturity
Adzuki	25 May	20 May-10 June	25 Sept.	110
Corn	5 May	25 Apr-1 June	25 Sept.	140
Cowpeas	1 June	25 May-25 June	25 Sept.	116
Faba bean[1/]	5-15 Apr	22 Mar-15 May	25 July-14 Aug.	116
Field bean	25 May	10 May-10 July	1-10 Sept.	
Lentils[1/]	5-15 Apr	22 May-25 Apr	19 July-3 Aug.	110-119
Lima	25 May	20 May-25 June	25 Sept.	121
Lupin[1/]	5-15 Apr	22 Mar-25 Apr	1-10 Aug	123
Mung	25 May	20 May-10 June	28 Sept.	120
Peanut	5 May	29 May-1 June	3 Oct.	151
Peas[1/]	5-15 Apr	22 Mar-25 Apr	25 July	97-106
Soybean	15 May	1 May-20 June	20 Sept.	100-138
Wheat[1/]	15 April	15 Mar-15 May	24 July	94-101

[1/]Cool season species

Table 8. Nitrogen fixation by leguminous crops and their influence on the following cereal crop.

Legume crop	Est. N fixed	N Harvested in legume crop	Gain or loss of soil N	Yield cereal grain
	(lbs/A)	(lbs/A)	(lbs/A)	(cwt/A)
Alfalfa	450	299	122	23.2
Clover	260	125	115	19.4
Sweet clover	270	170	84	18.9
Soybeans	160	176	-8	11.8
Field bean	70	103	-20	10.6
Cereal every year	--	--	-10	8.7

T.L. Lyon 1936.

Table 9. Nitrogen fertilizer value of grazed and harvested lupin on subsequent cereal crop compared to barley and fallow.

Treatment	N fertilizer value
Lupin (Low population)	
Grazed early	53
Grazed late	86
Harvested	0
Lupin (high population)	
Grazed early	73
Grazed late	79
Harvested	7
Barley	-115
Fallow	0

B.A. McKenzie & G.D. Hill 1984.

Table 11. Effect of preceding grain legume on grain yield of spring wheat at 4 locations in Minnesota.

Preceding crop	Crookston	Grand Rapids	Elk River	Rose mount	Average
	bu/A				
Lupin	17[1/]	-2	0	7	5.5
Faba bean	21	2	-1	4	6.5
Field pea	21	7	0	5	7.8
Lentil	23	-7	-2	3	4.2
Field bean, navy	22	16	-2	5	10.2
Soybean	23	12	-1	10	11.0

[1/] Yield of wheat after the grain legume minus the yield of wheat after oats or oilseed rape.

R.G. Robinson et al. 1984.

Table 10. Influence of different utilization of lupin on subsequent wheat crop grain yield.

Management of prior lupin crop[1/]	Grain yield of subsequent wheat crop T/ha	(lbs/A)
Cut and removed	0.76	677
Plowed in	1.01	900
Cut and Left	1.02	908
Harvested for grain	0.72	641

[1/] Mid pod fill.
T.G. Reeves 1984.

Christenson, D.R., L.S. Robertson, and D.L. Mokma. Systems of cropping. In. Robertson, L.S. and R.D. Frazier (ed). 1978. Dry bean production, principles and practices. Michigan State University, Ext. Bul. E-1251.

Crookston, R.K. 1987. Personal Communication.

Dotzenko, A.D., M. Ozkan and K.R. Stover. 1969. Influence of crop sequence, nitrogen fertilizer and herbicides on weed see populations in sugar beet fields. Agron. J. 61:34-37.

Lopez-Bellido, L. and M. Fuentes. 1986. Lupin crop as an alternative source of protein. Advances in Agronomy 40:239-295.

Lyon, T.L. 1936. The residual effects of some leguminous crops. Cornell University, Agr. Exp. St. Bul. 645.

McCracken, D.V., W.C. Moldenhauer and J.M. Loflen. 1984. The impact of soybeans on soil physical properties and soil erodibility. p. 988-994. In. R. Shibles (ed). World Soybean Research Conference III: Proceedings. Westview Press, Boulder, CO.

McKenzie, B.A. and G.D. Hill. 1984. Cited by L. Lopez-Bellido and M. Fuertis. 1986. Lupin crops as an alternative source of protein. Advances in Agronomy 40, p. 270.

Reeves, T.G. 1984. Cited by Lopez-Bellido and M. Fuertis. 1986. Lupin crops as an alternative source of protein. Advances in Agronomy 40, p. 270.

Robertson, L.S., R.L. Cook and J.F. Davis. 1976. The Ferden Farm Report: Part IV. Soil Management for navy beans. Michigan State University, Agr. Exp. Sta. Rep. 350.

Robinson, R.G. 1968. Faba beans. University of Minnesota Agr. Exp. Sta., Misc. Rep. 83.

Robinson, R.G. 1975. Pulse or grain legume crops for Minnesota. University of Minnesota Agr. Exp. Sta., Sta. Bul. 513.

Robinson, R.G. 1984. Peanut: A food crop for Minnesota. University of Minnesota Agr. Exp. Sta., Sta. Bul. AD-SB-2478.

Robinson, R.G., D.L. Rabas, and L.J. Smith. 1984. Crop sequence effects of pulse crops and agronomic research on lupine. University of Minnesota Agr. Exp. Sta., report AD-MR-2339.

Slife, F.W. and L.M. Wax. 1976. Weed and herbicide management. In L.D. Hill (ed). World Soybean Research. 1976. p. 397-403. Interstate Printers and Publishers, Inc. Danville, IL.

Summerfield, R.J. and E.H. Roberts. 1985. Grain Legume Crops. Collins, London.

Van Vliet, L.J.P., G.J. Wall, and W.T. Dickson. 1976. "Effects of Agricultural and Use on Potential Sheet Erosion Losses in Southern Ontario". Canadian J. Soil Science 56:443-451.

Welch, L.F. 1984. Rotational benefits to soybeans and following crops. 1054-1060. In R. Shibles (ed) World Soybeans Research Conference III: Proceedings. Westview Press, Boulder, CO.

Welch, L.F., S.W. Melsted and M.G. Oldham. 1976. Lessons from the Morrow plots. Ill. Res. 18(1):3-4.