Faba Bean : an Alternative to Soybean in Nova Scotia, Canada

Une alternative au Soja pour la Nouvelle-Ecosse, Canada: la Fêverolle

Ackerbohne: eine Alternative zur Sojabohne in Neu-Schottland, Kanada

David G. Patriquin and D. Burton

Abstract

For farmers in Nova Scotia who wish to be self-sufficient in animal feed, and in N fertilizer, the faba bean offers a number of advantages over soybean:

1. no special processing is required;
2. nodulation is generally spontaneous in N.S. soils (no inoculation required);
3. nitrogen fixation is roughly double that of soybean;
4. faba bean is better adapted than soybean for growth on low nitrate soils.

Nitrogen fixation (ca 140 kg N/ha) is sufficient to allow the N balance in a rotation system to be maintained or augmented when manures are returned to the field. The main problem is to ensure that the N from animal and green manures is available to plants when required. This problem must be approached at the local level. In addition, selection of suitable varieties and appropriate management strategies are essential in combatting Chocolate Spot, its major disease.

Résumé

Pour les agriculteurs de la Nouvelle-Ecosse qui veulent assurer leur autosuffisance en alimentation du bétail et en fertilisation azotée, la culture de la fèverolle est plus avantageuse que celle du soja car :

- Aucun traitement de transformation n'est nécessaire
- Aucune innoculation n'est nécessaire (innoculation spontanée)
- La fixation azotée est pratiquement double
- La fèverolle s'adapte mieux aux sols pauvres en nitrate.

La fixation azotée (environ 140 kg N/ha) est suffisante pour équilibrer les bilans azotés ou pour les améliorer si les fumiers sont systématiquement recyclés. Le problème principal est celui de la minéralisation de l'azote provenant des fumiers et des engrais verts au moment où les plantes en ont besoin. De plus, la sélection de variétés appropriées, combinée à un système de culture adéquat, est primordiale pour la lutte contre son principal parasite, le botrytis.

Zusammenfassung

Für solche Landwirte in Neu-Schottland, die Selbstversorger hinsichtlich ihrer Futtermittel und auch der N-Dünger sein möchten, kann die Ackerbohne eine Vielzahl von Vorteilen bringen im Vergleich zu Sojabohnen:

1. Es ist keine spezielle Verarbeitung notwendig,
2. Normalerweise setzt in den Böden von Neu-Schottland die Knöllchenbildung spontan ein (keine Beimpfung notwendig),
3. Die Stickstoffixierung liegt ungefähr doppelt so hoch wie diejenige von Sojabohnen,
4. Ackerbohnen wachsen wesentlich besser in Böden mit geringem Nitratgehalt im Vergleich zur Sojabohne.

Eine Stickstoffixierung von etwa 140 kg N/ha ist ausreichend für eine ausgeglichene Stickstoff-Bilanz in einem Fruchtfolgesystem, bei dem auch Hofdünger wieder aufs Feld gebracht werden. Das Hauptproblem besteht darin, dass der Stickstoff von tierischen Ausscheidungen und Gründüngung dann zur Verfügung steht, wenn die Kulturen den Nährstoff benötigen. Die Lösung dieses Problems kann aber nur auf lokaler Basis angestrebt werden. Zusätzlich bedarf es selbstverständlich der Auswahl angepasster Sorten und entsprechender Anbaustrategien, um mit der Schockoladen-Fleck-Krankheit, der hauptsächlichen Krankheit von Ackerbohnen, fertig zu werden.

Introduction

Recently efforts have been made to establish the faba bean (*Vicia faba* L. var *minor*) in Western Canada as a home grown alternative to imported soybean meal. However, they have not been as successful as had been anticipated. In this paper we will examine some of the reasons for this and report on our more hopeful experiences with this crop in Nova Scotia (N.S.). The faba bean is one of the oldest cultivated plants. It requires cool to warm, moist growing conditions, and is tolerant of late spring frosts. The crop has been grown in Europe, North Africa, South and Central America and in Asia for food, animal feed, hay, silage and green manure (Presber 1972, Canada Grains Council 1977).

Presber (1972) of the Canada Grains Council lists the following advantages of faba bean: -

a) a tall, erect legume, with a high protein content of grain and leaf, able to fix N in soil, and be harvested in a wet climate;
b) can be mechanically threshed, as pods do not shatter easily;
c) not being a row crop it can, in general, be worked with the same machinery as wheat;
d) highly frost resistant;
e) early sowing often allows a complete leaf canopy to develop before arrival of the longest days - a great advantage for energy absorption;
f) somewhat resistant to most diseases, though may need to improve through breeding;
g) largely self-pollinating, thus partly independent of insect pollinators, which might not be too reliable;
h) greatly benefits companion crops; e.g., oats have higher protein content than when grown in pure stand; yields of the mixed stand may also be higher;
i) small faba bean is useful as a "break crop" in a crop rotation program for cereal;
j) its protein has a high lysine content (significantly higher than barley).

In some studies the faba bean has been found to be sensitive to unfavorable weather, pests and disease. Despite early successes (Evans *et al.* 1972, Seitzer and Evans 1976), Keatinge and Shaykewich (1977) observed that "the Manitoban prairie yields are likely to be depressed by interactions between suboptimal ambient temperature, soil heat and moisture stress. Field beans could not therefore be considered as a feasible substitute for imported soybean meal at the present time".

Soil moisture is a critical limiting factor both in Manitoba and in the U.K. where it has been noted that "water supply may be a more important factor controlling yield than either solar radiation or plant competition, with the period following pod setting being especially critical" (Sprent *et al.* 1977).

Preliminary Observations on Faba Bean Yields in Nova Scotia

Faba beans might be expected to fare well in the relatively moist, moderate climate of N.S. In our studies we found that yields achieved under commercial conditions on two farms compared well with those obtained in England (Table 1).

Table 1. Seed yields for faba beans at various locales

Locale	Yield (t/ha)	Combine (C) or hand (H) harvest	Ref.
Lawrencetown, Anna. Co., Nova Scotia			
1973	3.0	C d)	Cox 1974
1974; 3 var.	3.5 - 4.1	H	Cox 1974
	2.6 - 3.4	C	
1978	4.6	H	e)
Belle Isle, N.S. (dykeland)			
1978*	7.2 a) 3.2 b) 0 c)	H	e)
Kentville, N.S.			
1972-5	1.4 - 5.6	H	f)
Scotland, 1972-5 (experimental)	5 - 9	H	Sprent *et al.* 1977
England, National avg.	2 - 3	C, H	g)
Manitoba			
1971-3	4.4	H	Seitzer and Evans 1976
1974-5	0.6 - 1.9	H	Keatinge and Shaykewich 1977

a) not including plants heavily infested by Chocolate Spot;
b) all plants;
c) in a few sharply delineated low lying areas (no nodulation);
d) combine yields may be 20 - 30% lower than hand yields;
e) yields calculated from counts of plant density in 20 one sq. meter quadrats, and dry weights of seeds from 15 plants; observations Aug. 31 - Sept. 11, 1978;
f) Summary Cereal Work Western Nova Scotia 1954-1975. Canada Dept. Agr. Res. Stn., Kentville, Nova Scotia;
g) quoted in Ishag, H.M. J. Agr. Sci. Cambridge 80, 181; 1973.

On these farms, faba beans have been grown on silty dykeland soil (Rob Warren's farm) and on sandy loam upland soil (Basil Aldhouse's farm) in rotation with grain crops since 1967, and are used as vegetable protein supplement for dairy cattle and poultry respectively.

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* Post conference note: In 1978 Warren was of the opinion that the Maris Bead variety he had grown in the past was more resistant to Chocolate Spot than the higher yielding Minden variety planted in 1978; this is confirmed by formal analysis of varietal resistance in the U.K. (J.E.M. Elliot and W.J. Whittington. 1979. J. Agr. Sci. Camb. 93, 411-417). Warren planted

In early August 1978 the dykeland crop experienced a severe infestation of Chocolate Spot (*Botrytis fabae*) that reduced the high potential yield by about 50% (Table I). This is the most common disease of faba bean in England. Concern for this fungal disease is an important deterrent to the more widespread use of faba bean in N.S. As spread of the disease is stimulated by high moisture, the frequent occurrence of fog at the dykeland site may have been responsible for the severity of the outbreak there. Both dykeland and upland (Lawrencetown) crops were infected to a similar degree early in the season, and both farmers report that low levels of infection are routine. Other factors that may have been responsible for differences in the development of the disease were the higher planting density at the dykeland site (35 plants per m^2 versus 26 at the upland site), and use of different varieties (Table I). A number of cultural practices are recommended to minimize losses from Chocolate Spot, including use of inspected seed, rotation, selection of fields with good air circulation, weed control and modest seeding rates (Presber 1972, C.G.C. 1977). Chocolate Spot not withstanding, this crop provides an economically viable alternative to imported soybean meal.

Experimental Observations on Nitrogenase and Nitrate Reductase Activities in Faba Bean: An Aid to Appropriate Management

An additional, but unevaluated (in N.S.) benefit of faba bean, is the contribution of this legume to soil N fertility. To understand its role in soil N processes, we examined the seasonal patterns of nodule nitrogenase activity and leaf nitrate reductase activity, two enzymatic processes involved in incorporation of atmospheric N_2 and soil nitrate respectively.

Nitrogenase activity (NA) was measured by the acetylene reduction technique (Hardy *et al.* 1968), and leaf nitrate reductase activity (NRA) by an *in vivo* method (Brunetti and Hageman 1976). The patterns observed are quite different from those reported for soybean (Fig. 1).

For soybean, leaf NRA is high during vegetative growth, and declines following the onset of NA in early bloom stage (ARA in Fig. 1). NA in turn reaches a maximum at early pod filling. Pod filling creates a strong photosynthetic "sink", resulting in less energy being available to roots and nodules, and NA declines rapidly without a concomitant increase in leaf NRA. Most of the N for developing seeds then comes from redistribution of N from vegetative parts, which in turn senesce. Thus, there are successively three more or less distinct phases in N utilization: utilization of soil nitrate, utilization of atmospheric N_2, and finally, movement of N from vegetative parts into seeds. Total N_2 fixed by soybean is generally in the range 50-100 kg N/ha and supplies 25 - 35% of total plant N (Burns and Hardy 1975, Hardy and Hevelka 1976). Incorporation of straw residues has been reported to enhance N_2 fixation by immobilizing soil N (which otherwise may supress N_2 fixation) and by providing CO_2 enrichment (Shivashankar and Vlassak 1978). Development of plants with delayed senescence (Abu-Shakra *et al.* 1978), earlier nodulation, or more efficient *Rhizobia* (Maier and Brill 1978), may alter the N_2 fixation pattern in the future, but currently, a restricted mid-season period of N_2 fixation is typical (Thibodeau and Jaworski 1975, cf. Weber *et al.* 1971, Hardy and Hevelka 1976).

Maris Bead again in 1979, and the crop suffered only low level Chocolate Spot infestation in spite of an excessively wet summer; yields were about 3 t/ha. Yields of all crops were low in 1979 because of unfavorable weather. Aldhouse grows the Akerperle variety (Lawrencetown farm).

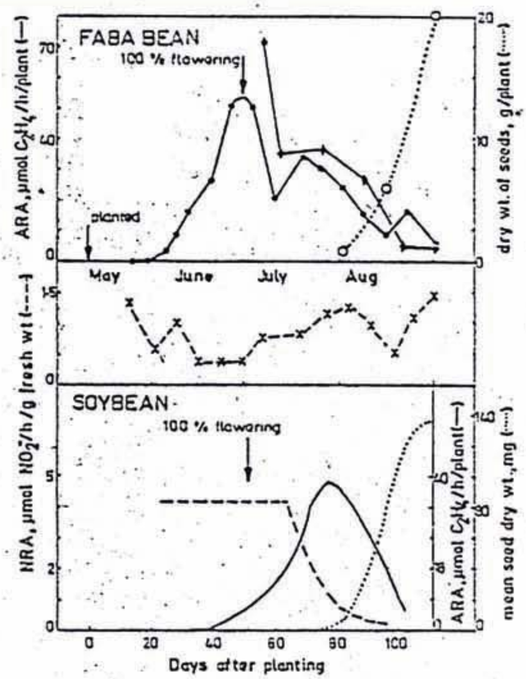

Figure 1. Seasonal patterns of nodule nitrogenase activity (NA) measured by the acetylene reduction technique (ARA = acetylene-reducing activity), and of leaf nitrate reductase activity (NRA) in faba bean and soybean. In the top figure, closed circles give ARA data for the dykeland crop, and diamonds the data for the upland crop. Seed dry weight data (top) and leaf NRA (middle) are for the dykeland crop. Soybean data from Thibodeau and Jaworski (1975).

ARA data points are means of six samples, each sample consisting of root plus nodules of an individual plant in 450 or 900 ml Mason Jar with 10% acetylene; incubation time 30 min., bottle buried in soil.

NRA data points are means for three plants. Twenty leaf discs, 7 mm diameter, were taken from the youngest two fully expanded leaves. Incubation temperature 30°C; incubation time, one hour.

For faba bean, the most significant differences from these patterns were:

i) much earlier development of nodules and initiation of NA, and occurrence of high NA during vegetative growth;
ii) a gradual (rather than abrupt) decline in NA following the maximum at the early bloom stage;
iii) a trend of increasing leaf NRA during the period of declining NA (Fig. 1).

There are four important consequences of these differences.

1. <u>Higher total N_2 fixation.</u> Because NA occurred over a more extended period than in soybean, the total N_2 fixed was greater. For the dykeland crop,

we estimated that total N_2 fixation was about 140 kg N/ha[1], and that of the upland crop was probably of similar magnitude. Equivalent or higher values are reported for faba beans in the U.K. (Sprent *et al.* 1977, Rothamsted Experimental Station 1977), while lower values seem to be characteristic of prairie environments (Candlish and Clark 1975, Dean and Clark 1977).

2. Vegetative growth is less dependent on soil nitrate. Because NA was initiated early in the season, vegetative growth was not highly dependent on soil nitrate, as is vegetative growth of soybean (Hatfield *et al.* 1974).

   The dependence of faba bean at low levels of soil nitrate (3-5 ppm NO_3-N in May and June) on N_2, as opposed to soil nitrate, for vegetative growth was dramatically illustrated by the cessation of growth in early June of non-nodulated plants. These plants occurred in a few low-lying areas of the dykeland where salt intrusions apparently interfered in some way with nodulation. Soil nitrate level was similar to that in normal stands. The plants developed flowers, and in some cases even pods and seeds, but they were chlorotic and did not grow to more than about 15 cm in height. Larger, normally green plants in these areas possessed a few lateral root nodules, but they were still much shorter (approx. 30 cm) than plants (50-90 cm in early July) exhibiting normal development of nodules on tap roots.

3. Faba bean is an efficient scavenger of nitrate late in the season.

   While the plants seem to be unable to grow on soil nitrate (at low nitrate levels) during vegetative growth, only about 40% of the total N accumulated in plants (approx. 350 kg/ha) could be accounted for by N_2 fixation, suggesting that about 60% of the N, equivalent to 210 kg N/ha, must have come from the soil.

Table 2. Rates of incorporation of soil nitrate and atmospheric N_2 per faba bean plant.

Date 1978	rates of incorporation[1] of	
	soil NO_3^-	atm N_2
	(ug N/plant/h)	
June 21	34.1	252
July 7	201	326
August 3	383	222
August 31	94.6	58.5

[1] Estimated from whole plant leaf nitrate reductase activity, and nodule nitrogenase activity. Measurements were made between 0930 and 1200 h at the dykeland farm. NO_3^- incorporation values are based on mean NRA values for three plants (all leaves sampled; specific activities were multiplied by total leaf biomass). N_2 incorporation values are based on measurements of acetylene-reducing activities of six plants.

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[1] N_2 fixation estimated from acetylene-reducing activities assuming a 3:1 molar ratio of C_2H_2 reduced to N_2 fixed. Diurnal variation was taken into account.

Most of the uptake of soil N, as indicated by total leaf NRA (Table 2). occurred in July and August during reproductive growth. Soil nitrate levels during this period were between 3.8 and 6.6 ppm. Thus, the early growth on N_2 seems to enable the plant to take up nitrate from low levels of soil nitrate later in the season. This is in contrast to soybean, which is an efficient scavenger (Johnson *et al.* 1975) of soil nitrate early in the season. For both plants, the ability to extract large quantities of N from low nitrate soils is a property of considerable importance in a region of high rainfall and shallow soils, as high soil nitrate levels will lead to large losses through leaching and denitrification (Patriquin *et al.* 1978) We monitored soil denitrification in the dykeland soils using the acetylene blockage technique (Yoshinari *et al.* 1977) but never observed significant rates.

4. Soybean and faba bean will differ in their responses to N fertilizer or manure. The early development of NA, and the high NRA during grain filling (in contrast to soybean) suggest that faba bean will differ from soybean in its response to added N. On two other farms, where N fertilizer (17-45 kg/ha) was applied at planting, nodule weights at the time of sampling (July 26) were lower than those of plants on the dykelands, but the specific NA's (per unit weight of nodule) were higher. These characteristics indicate that N fertilizer resulted in delayed nodulation. Recommendations for applying small amounts of "starter" N to faba bean[1] are likely to be based on experience with soybean. For faba bean such a practice may reduce N_2 fixation without enhancing final yield. On the other hand, faba bean could be expected to respond to N fertilization during grain-filling when NRA and N demand are both high. For soybean, NRA is low during grain-filling, and N fertilization does not alter N use patterns (Egli *et al.* 1978). Dry beans exhibit patterns of NA and NRA similar to those of faba bean and respond well to late fertilization. The late applied fertilizer-N is much more efficiently used than N applied at planting because the early N_2 fixation phase is not supressed, and losses from leaching and denitrification are minimal (Franco *et al.* 1979). Incorporation of incompletely composted manure at seeding might be a means of increasing both N_2 fixation (by immobilizing soil N initially and by-producing CO_2 (Shivashankar and Vlassak 1978)) and use of soil N (by increasing the release of mineral N later in the season).

Nodulation in Nova Scotian Soils is Generally Spontaneous

The different species of legumes require different strains of *Rhizobium* for effective nodulation. For soybeans, inoculation is generally essential for effective nodulation, although it is often either ineffective or short-lived in its effectiveness (Weber *et al.* 1971). In western Canada inoculation is reported to be essential for nodulation of faba beans (Candlish and Clark 1975, Dean and Clark 1977). Both of the faba bean crops represented in Fig. 1 were grown from uninoculated seed in fields where faba beans had not previously been grown. Nodulation and NA developed rapidly, and were similar to those observed for beans grown in fields that had previously supported faba beans. Thus, the indigenous rhizobia populations were of the appropriate sort and magnitude to effectively nodulate plants. Faba beans grown for the first time on three farms were also found to be effectively nodulated (effective meaning that nodules were active).

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[1] Fababean production in the Atlantic Provinces. Cereal Subcommittee of Atlantic Fields Crop Committee, Publ. 125, Agdex No. 141.

On only one farm of six examined was there evidence that appropriate rhizobia might be lacking. At this farm, faba beans were planted on two experimental plots. One of the plots was inoculated with soil from a dykeland faba bean field. The inoculated plants developed normally, with tap root nodules, while the uninoculated were only about one half the size of inoculated plants, and had only a few lateral root nodules. The absence of tap root nodules could have been due to the absence of appropriate rhizobia, or due to insufficient numbers of these rhizobia. The experiment demonstrated that simple inoculation techniques are feasible, that such experiments should be carried out before planting a large area without inoculation, and that low yields observed in field trials that do not include such observations[1] do not necessarily indicate low potential yields. As an extension of this simple experiment, it would be appropriate to see if beans planted a second time on the uninoculated plot developed normal nodules, as after one generation of plants, the rhizobia population would have increased. If the results were positive, it would indicate that the indigenous rhizobia population could be built up by a light planting (possibly immediately following another crop) the year before a normal crop was to be sown.

Nitrogen Must be Recycled

Our estimates of the relative inputs of N from the atmosphere and soil (40 and 60% respectively) indicate there will be a large net removal of N from the soil when seeds, which contain 70-80% of the final plant N, are harvested[2]. It has recently been recognized that the same is true of soybean (Johnson *et al.* 1975). However, return of plant residues and manure to the field should result in maintenance or enhancement of the soil N status.

For the upland farm, no insecticide or NPK fertilizer has been used since 1975. Poultry manure is returned to the fields, and vegetative residues are worked into the soil. Ten hectares are planted in faba beans, and 20 in oats, wheat, barley, forage grasses and occasionally some clover or alfalfa. For this farm we estimate that the annual inputs of N through N_2 fixation (approx. 1600 kg N) roughly balance the annual losses due to export of eggs (380 kg N) and birds (40 kg N) and due to volatilization of N during recycling of feed N (1240 kg N)[3]. Thus, growing of faba beans on 1/3 of the cultivated land, as well as providing an alternative to imported soybean meal, should enable soil fertility to be maintained. Reduction of volatilization losses by composting techniques (Rodale 1975) could result in a healthy positive N balance and enrichment of soil N. With 1/3 of the arable land planted in soybean instead of faba bean, the input from N_2 fixation would be less. However, the important point is not really how much N is fixed, but how it is managed after it is fixed. It is apparent that as many advantages will accrue from reducing volatilization losses as from increasing N_2 fixation, be this for faba bean or soybean. For both plants, failure to recycle N will result in a drain on soil N equivalent to that for corn (Johnson *et al.* 1975).

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[1] Summary Cereal Work Western Nova Scotia 1954-1975. Canada Dept. Agr. Res. Stn., Kentville, Nova Scotia.

[2] For the dykeland, net N removal calculated as in Johnson *et al.* 1975, is approx. 120 kg N/ha per year.

[3] 91 m.t. of 17% protein (approx. 2.48 t N) is processed each year; volatilization loss of N from uncomposted manures is commonly about 50% of initial N (lit. reviewed in Nitrates, An Environmental Assessment, Nat. Acad. Sci., Washington, D.C. 1978).

Management of Manure and Plant Residues: The Key to N Self Sufficiency

Although total input of N into the system appears to be adequate, the grain crops exhibited approximately 50% reductions in yields from those attained when N fertilizer and pesticides were applied. Pests have not been a problem

We (including the farmer, Basil Aldhouse) believe the problem to be one of management of the organic N. Without chemical- or bio-assays, there is no way to tell *a priori* if a particular scheme of managing plant residues and manure will result in conservation of N and its release at the desired time. Given information on C/N ratios, rates of mineralization of C and N according to different climatic and edaphic conditions, and on the time at which mineralization begins, it should be possible to develop a system in which inorganic N can be immobilized, and organic N mineralized as desired. This requires a high degree of farmer competence, i.e., ability to diagnose his/her own system. While this may not have been possible 20 or 30 years ago, technological developments have greatly reduced the costs and complexity of soil tests and it is possible today.

Unfortunately, local soil testing services do not conduct routine analyses of organic and inorganic N, which would be required on a routine basis for diagnostic purposes. Fertilizer N recommendations are made on the basis of what crop is to be grown, allowing a large insurance factor to cover losses. Currently we are examining C and N mineralization processes on this farm with the emphasis on developing simple models relating these to climatic factors and on simple and rapid means of diagnosis, i.e., on concepts and methods that can be readily applied at the local level.

Conclusions

In Nova Scotia faba bean offers a number of potential advantages over soybean for farmers attempting to be self sufficient in animal feed and in nitrogen:

1) no special processing of seeds is required (for soybean, cooking and oil extraction may be necessary);
2) nodulation is generally spontaneous (no inoculation required);
3) N_2 fixation by a faba bean crop is roughly double that of a soybean crop;
4) faba bean is better adapted for growth on low nitrate soils.

Cultural control of weeds is effective. Special attention may have to be given to control of Chocolate Spot in excessively humid areas. N_2 fixation by the faba bean crop appears to be adequate to maintain soil fertility in a rotation system in which 1/3 of the land is planted in beans, and in which animal manures and vegetative residues are returned to the fields. With appropriate management, it may be possible to increase faba bean N_2 fixation and seed yields. The principal problem is one of conserving soil N and ensuring that this is available when it is required. The solutions must be sought at the local level.

The comparison between faba bean and soybean illustrates a more general point. While soybean is number one in terms of food quality, it may not be with respect to N_2-fixing ability or yield. This appears to be true not only of temperate and subtropical pulses, as illustrated by faba bean, but also of tropical pulses (Dobereiner and Campelo 1977). When used with cereal proteins, the food value of these alternative pulses is equivalent to that of soybean. Thus, where N_2 fixation is an important consideration, and the crop is to be grown as an "in house" food source (as opposed to a cash crop), soybean may not be the best choice. Whatever the choice, for the soil N status to be benefited, N must be recycled.

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