WHY USE LEGUMES IN INTENSIVE FORAGE CROP PRODUCTION SYSTEMS

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ABSTRACT

Newer legume ley systems being tested in the Northland, Auckland, Waikato region are discussed.

Both red clover and cool season active annual legumes are likely to fix the bulk of their own nitrogen when used as short term leys between periods of cereal or maize cropping. This biological nitrogen fixation should be above 200 kg N/ha/annum and could be as high as 600kg N/ha/annum. There is no good evidence to show how much of this nitrogen is available to succeeding crops, particularly if the legumes are grazed. The use of legumes in place of cool season cereals would at least remove the need to apply 60-120kg N/ha as fertilizer, but may require higher phosphate inputs.

Legume leys to break pest or disease cycles in maize do not appear to be required in New Zealand. No progressive buildup of these problems has been identified in either maize grain/winter fallow or maize silage/winter cereal production systems.

Linear programme modelling has predicted optimal factory supply dairy systems for Northland that contain 20 to 40% of farm area in crop with substantial use of legumes in these cropping rotations. Legumes appear to be selected because they provide good quality, grazeable feed during Sept/October (cool season annuals) or during summer (red clover). If the margin of returns over costs increases, increased stocking rates become economic and higher yielding cereals for silage are introduced. Forage cropping systems, with or without legumes are less likely to have this impact in the Waikato, where there is a better match between seasonal patterns of pasture growth and the requirements of spring calved dairy cows.

In other countries, legume leys have maintained a substantial role in cropping systems operated under low fertility conditions. This is not a feature of New Zealand agriculture and is unlikely to become so in the future. However, maize grain systems normally leave the soil fallow during winter. It may be possible to grow a self regenerating, cool season annual legume during this normally fallow period in warmer climatic areas and this would be a useful advance.

INTRODUCTION

In New Zealand, many maize and cereal crops have been grown after ryegrass/white clover pasture, and in the South Island, cereals are often grown after pure white clover leys. It is well recognised that biological nitrogen fixation by clover reduces the fertilizer cost of growing subsequent crops. Many legumes have been used for this purpose overseas. Maize for grain or silage is grown on significant areas of the Waikato, South Auckland and Northland regions but rarely in an integrated ley system with a legume. Recent trials have studied the possibility of operating such systems, particularly those involving red clover (Taylor *et al.,* 1979) or mediterranean type cool season annual legumes (Taylor *et al.,* 1979; Piggot and Cooper, 1980; Thom, 1980). This paper is a current assessment of the advantages and disadvantages of these forage legumes when grown as integrated leys with maize or related crops in these warmer zones of the North Island.

Possible crop rotations are first described and overseas experience with related systems discussed. Systems incorporating these legumes are then compared to a summer maize/winter cereal rotation as regards fertilizer requirements; weed and pest problems; yield and general ease of crop management, and desirability in agricultural production systems from the point of view of animal nutrition.

FORAGE CROP SYSTEMS

There appear to be at least four different ways of integrating the growing of maize (or sorghum) and legumes.

Firstly, a 3 to 4 year period of continuous maize cropping could alternate with a similar period of some legume ley "pasture". The semiperennials red clover and lucerne have been used in this way in Europe and the United States respectively, though in Europe, small grain cereals rather than maize are more normally grown. A similar length of legume ley is also used extensively in Australia (Webber, 1975) but once again in alternation with small grain cereals and the legumes used are mediterranean type cool-season active annuals such as subterranean clover or species of *Medicago.* In this paper a red clover ley is used as an example of this type of system, because lucerne is grown more in central areas of the North Island rather than the north, and its management is generally integrated with that of pasture rather than crops. Red clover is relatively easily established, persists for 2 to 4 years, is reasonably tolerant of different soil types and yields well under North Island conditions (Anderson, 1973).

Second, and somewhat related to the above is the possibility of alternating periods of maize cropping with the cropping of soybeans. This is practiced extensively in the United States, where the advantages given for such a rotation are said to be;

"The possibility of improved overall weed control; better distribution of labour; the possibility of breaking cycles of some pests and diseases, particularly those that are soil borne and the addition by soybeans of 50 to 70 kg/ha of organic nitrogen to the soil from its straw and roots" (Tanner and Hume, 1978).

Because this rotation is well proven and documented in the United States it will not be considered further. Soybeans will be grown more extensively for grain in New Zealand when they become profitable in their own right. The proposed construction of soybean processing facilities at Whangarei and the incorporation of genes for improved pod development at low temperatures (Hume and Jackson, 1981) into high yielding, locally adapted cultivars will improve the possibility of this occurring.

Thirdly, there is the option of a tightly integrated 2 crop a year rotation, with a warm-season crop of maize (or sorghum) followed in the cool-season by one of the many mediterranean type annual legumes. Such systems have been used overseas. In the Southern United States for example, winter-grown vetch and crimson clover crops are ploughed down to provide green manure for succeeding maize crops (Mitchell and Teel, 1977). A similar system but with subterranean clover under grazing as the cool season legume has been proposed for the Lockyer Valley in Australia. In New Zealand rather cool winters and the tightly constrained period between maize harvesting and the optimal time for resowing maize (McCormick, 1974) could cause problems in operating such systems. However, substantial yields (> 6 t DM/ha) have been obtained from several *Medicago* spp. and *Ornithopus sativus* in warmer areas of the North Island (Taylor *et al.*, 1978) within the allowable time span so these will be used as a theoretical example in alternation with maize for silage. There is also the possibility of extending the growing period available to the legume by using it with a later sown sorghum crop. This has been successfully accomplished using subterranean clover as the legume (Jurlina, 1978), so this system will also be considered.

Lastly there is the possibility of intercropping. This is being practiced increasingly in tropical agriculture where chickpeas etc. are interplanted with maize or sorghum to increase overall grain yields and provide more balanced human rations. Growing these mixtures is possible because labour is available to hand weed and pick the crops. Herbicidal weed control and mechanical management of crops as practiced in this country may make the use of such mixtures difficult in New Zealand.

NITROGEN AND PHOSPHOROUS INPUTS

Levels of biological nitrogen fixation in established lowland pastures in New Zealand are around 180 kg N/ha/annum (Hoglund *et al.*, 1979) and in these swards clovers are thought to use variable but sometimes significant amounts of mineralised nitrogen from the soil. On nitrogen impoverished soils, however, very high rates of biological nitrogen fixation (600-700 kg N/ha/annum) have been measured by Sears *et al.* (1965) from mown swards of red and white clovers. Under these soil conditions, biological fixation should supply the bulk of nitrogen present in these legumes. Low levels of available soil nitrogen will also develop during periods of intensive maize cropping, so pure swards of red clover grown after maize are likely to have high rates of biological nitrogen fixation. Short term leys of red clover are likely to produce annual yields of around 10 t DM/ha at an average protein content of 16% (Taylor *et al.*, 1979) so the minimum annual turnover from tops and roots would be around 350 kg N/ha under grazing and may be much higher (Ball *et al.*, 1978). Available nitrogen for succeeding crops would be substantially less than annual turnover however because of volatilization and leaching losses (Ball, 1980) and the need for mineralisation to occur.

Estimates of biological nitrogen fixation by several cool season annual legumes have been made on crops grown at Palmerston North (de Ruiter, pers. comm.). Fixation rates were highest in late August-September, relatively early in crop development and well before maximum dry matter accumulation. Removal of these crops in mid spring to plant maize should not seriously reduce the biological nitrogen fixation of which they are capable. Measured biological fixation levels were also close to estimates of total crop nitrogen content at around 200-300 kg N/ha so these legumes may not use much mineralised nitrogen from the soil or they at least "replace" the nitrogen they do use.

The problem is to estimate how much of the largely organic nitrogen in these legumes, or in dung and urine returns from grazing animals, is available to succeeding crops. Rates of nitrogen buildup in the soil under subterranean clover based pastures in temperate regions of Australia have been estimated at 45-80 kg N/ha/annum (Williams, 1970), while Dahmane and Graham (1975) measured an annual increase in soil nitrogen of 110 kg/ha under medic pastures in South Australia. But the climate of Southern Australia is not the same as New Zealand's, and differences in rainfall could substantially alter leaching and volatilization losses. Direct measurements of the benefit of such recently contributed organic nitrogen in soils to the production of succeeding crops have been few. Mitchell and Teel (1977) found that corn grain yields following hairy vetch and crimson clover cover crop mixtures were comparable to those obtained with rye or oat covers fertilized with 112 kg N/ha. Approximately one-third of the total nitrogen from these mulch covers was released to the corn in a single season. Cycling much of this nitrogen through grazing animals is a different situation and there is increasing evidence that volatilization losses from urine patches can be high (Ball, 1980).

When attempting to assess the advantages or otherwise of using a cool season legume in a double cropping system, comparison could be made to a similar system with a cereal as the cool season crop (Taylor and Hughes, 1978). The cereal would probably require from 60 to 120 kg N/ha as fertilizer to ensure a good yield in a continuous cropping situation and may or may not contribute as much mineralisable soil nitrogen as the legume. Using the legume should therefore save a minimum of around 60 kg N/ha of fertilizer. Taking a more optimistic view, the legume may contribute a nett soil input 50 kg N/ha greater than a grass or cereal (Dahmane and Graham, 1975) through nodule turnover and higher overall protein content and a fertilizer saving of over 100 kg N/ha from not using the cereal.

The situation regarding relative phosphate fertilizer inputs into the two systems may be different. Jackman and Mouat (1972), for example, have shown that the legume white clover has a higher phosphorus requirement for maximum growth than does ryegrass, and one might speculate that the phosphorus requirements of a cereal would be more similar to those of the grass. However, other workers have demonstrated substantial differences among both grasses (Asher and Loneragan, 1967) and legumes (Blair and Cordero, 1978) in phosphorus levels necessary for optimal growth; so the relative phosphorus requirements of the two systems may depend on the species used. For example, species of the legume genus *Ornithopus* yield well at relatively low inputs of fertilizer phosphorus.

CROP MANAGEMENT

A forage crop that would naturally re-establish should reduce costs and suit minimum or zero cultivation systems. Many mediterranean type annual legumes have this ability because they produce seed with an initially impermeable, "hard", seedcoat (Rossiter, 1966). At least two double-cropping systems incorporating this feature of natural re-establishment have been proposed. One involving subterranean clover followed by a warm season maize crop grown at wide plant spacings has been suggested for the Lockyer Valley in Australia (Schroder, 1959); the other follows subterranean clover with a greenfeed sorghum and has been operated successfully in Northland (Jurlina, 1978). These concepts have not been sufficiently developed to clarify their potential, but the establishment of crops by full cultivation is expensive. Cereals or short rotation ryegrass can be direct drilled into maize stubble in autumn however but a self regenerating legume would at least save the cost of seed and one pass with a drill.

Legumes may also be useful in controlling the buildup of pests and diseases in maize and cereal crops. In the United States for example, periods of soybean cropping alternated with maize cropping are considered beneficial in reducing the incidence of soil borne diseases and some insect pests (Tanner and Hume, 1978). In New Zealand medium to long term monocropping of maize does not appear to have increased pest or disease problems. Fears that reduced yields a year or so ago in the Waikato may have been caused by soil fungal problems seem unfounded since McCormick (1979) has explained them in terms of spring temperatures. In fact, insect damage in particular, is often worse in maize crops directly following pasture. In long term agronomy trials at Palmerston North with a maize/oats double forage cropping system for example, first year maize established by cultivation out of pasture was severely damaged by Argentine stem weevil while that established by direct drilling was damaged both by stem weevil and slugs. Subsequent maize crops grown after oats by either establishment technique showed progressively less insect damage until little was evident after 3 years (K.A. Hughes, pers.comm.). Winter cereals do not appear to host insect pests of maize to any damaging level. We have no comparable information on insect damage to maize when grown after legumes though we have observed substantial numbers of slugs under legume swards in some of our cultivar assessment trials.

Deterioration of soil structure by repeated cultivations rather than any buildup of pests or diseases seems a bigger constraint to the long term monoculture of maize in this country. Short term leys using red clover, for example, should be useful in improving the structure and natural drainage of some heavily cultivated soils, but the developing crop establishment techniques of minimum cultivation and direct drilling may themselves adequately retain natural soil structure under prolonged cropping.

CROP YIELD

The yield and persistence of red clover will depend on the variety used (Anderson, 1973) but a 3 year ley under good management should average around 10 to 12 t DM/ha/annum (Taylor *et al.*, 1979). This yield is probably more than would be produced by a conventional ryegrass/white clover pasture during an equivalent establishment phase under low soil nitrogen conditions but less than this same pasture would produce when fully established. Of greater contrast is the postulated 31 t DM/ha/annum yield of a maize/oats double forage cropping system (Taylor and Hughes, 1978), which is almost three times that of red clover.

The yield of a range of mediterranean type cool season annuals has been measured at sites in Northland, Palmerston North (Taylor *et al.*, 1978) and the Waikato (Thom, 1980). At Kaitaia, better yielding species of the genera *Trifolium, Medicago, Vicia* and *Ornithopus* produced between 5 and 10 t DM/ha when harvested as one cut, falling to 4 to 6 t DM/ha when harvested by multiple cutting. Adequate yields in cooler climates depend on obtaining early, weed free establishment and an accumulation of over 500 degree days above 10°C (Hughes and Taylor, 1979). In contrast, rust resistant oats produce single cut yields of 12 to 16 t DM/ha from Kaitaia to much cooler winter climates (Taylor and Hughes, 1979), but their protein content and digestibility fall rapidly after flag leaf emergence (Eagles *et al.*, 1979) and this lowers animal performance (McDonald and Wilson, 1980).

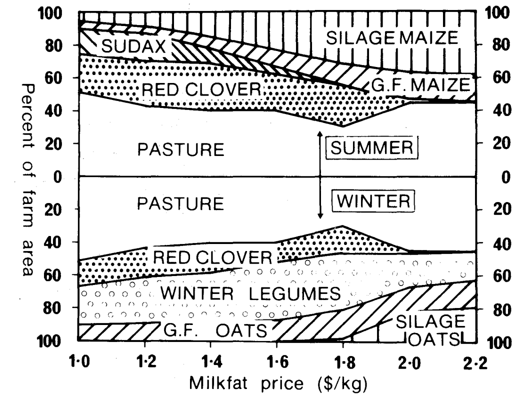
It is probably unrealistic to expect any legume to grow as rapidly as cereals under the poor photosynthetic conditions of winter because of the energy legumes divert into nitrogen fixation. *Lupinus albus,* for example, respires between 4-6.2 g C per g N fixed (Pate and Herridge, 1978), while the cereal is supplied with nitrogen.

ANIMAL PRODUCTION SYSTEMS

If legumes are to be used in forage crop systems, it is important that they can be incorporated into those involving maize, because of the high yield potential of this crop in New Zealand. In current New Zealand agriculture, maize silage is used to intensify dairy production and modify its seasonality for town milk supply or to assist the finishing of beef cattle. Beef cattle rations in United States feedlots are based largely on maize silage or maize grain, both of which are supplemented with protein concentrates or lucerne haylage. Lucerne has been used in this way on one local feedlot (Marshall, 1975), but at R. & W. Hellaby's feedlot at Ruawai, maize silage has been supplemented with urea and substantial quantities of expensive meat and bone meal. Any forage legume grown as a protein supplement for this type of feedlot operation would need to be stored and this would require partial (haylage) or extensive (hay) wilting. Only legumes that can be harvested in summer seem capable of providing this type of high protein conserved feed. No cost/benefit analysis has been made of the possible importance of legumes to New Zealand feedlots or "out of season" beef finishing systems.

In dairying, the protein content of feed assumes more importance because lactating animals require a minimum feed protein content of around 12%, while dry stock require less than 8%. Dairy farmers attempt to feed high protein pasture with low protein maize silage to achieve a balanced ration, but the greater the amount of maize silage fed or the poorer the quality of pasture (i.e. during drought) the less practical this becomes. Miller (1980a) of Massey University has used linear programme modelling to predict optimal dairy farming systems for the drought prone Northland area. The feed option used in the model was based on conventionally managed ryegrass/white clover pasture with the possibility of using fertilizer nitrogen and of pasture conservation as wilted silage. In addition, any proportion of the theoretical property could be used to grow maize, greenfeed sorghum, red clover, cool-season cereal or a cool-season legume. Given 1978 costs and returns, the model predicted a gross margin optimized system with 40% of the farm area in pasture, 20% in red clover and most of the remainder in a maize/cool-season legume rotation (Fig. 1). Cool-season legumes appear to be preferred to cereals because of the high quality feed they provide during early lactation. Red clover is included because of the quality feed it provides from early summer to mid autumn and because it can be grazed rather than incur the substantial cost of conservation. If the ratio of returns of costs falls, the legumes are retained but more pasture and less maize are included. If overall returns rise, higher stocking rates become economic and the model achieves this by increased use of the high yielding maize/oats conservation system at the expense of red clover.

Figure 1: The effect of milk fat price on optimal system structure (Miller, 1980a) for factory supply dairying in Northland.



In these model solutions, no allowance was made for any nitrogen contribution by the legumes so they may be more valuable than the solutions indicate. Miller (1980a) tested how important this nitrogen contribution might need to be by forcing red clover into an otherwise optimal system to the extent of 18% of farm area. This reduced gross margin on the theoretical 50 ha property by $328 or $36.44/ha of red clover. At a nitrogen value of 60c/kg, the red clover would need to contribute the equivalent of 62 kg N/ha/year to make its presence economic.

It should be noted, however, that theoretical systems comprising 80% pasture and 20% of a maize/oats rotation for silage, or all pasture with optimal conservation, produced only $31/ha and $93/ha less gross margin than the complex 'optimal' system containing the legumes. The more complex the system the more time there is required to plan and implement it. The time available to the present day New Zealand dairy farmer is already heavily committed, and often increasingly so as herd sizes continue to increase to maintain profitability under the pressure of rapidly increasing production costs. This is not a good environment to accommodate further complexities within the forage production system and this is a serious constraint to their implementation. Furthermore, linear programme analysis of factory supply dairy systems for the Waikato showed that forage crop systems have much less effect on farm gross margins than in Northland because of the better match between seasonal pasture growth and cow requirements in this area (Miller, 1980b). Neither does the winter climate of the Hamilton area provide ideal growing conditions for cool-season annual legumes (Thom, 1980). The possibility of the forage legumes under discussion finding substantial use in present dairying systems in the Waikato seems remote.

THE FUTURE

It may be possible to predict the future use of legume leys in New Zealand agriculture from past and present overseas trends. Use of red clover leys in the United Kingdom dropped sharply in the 1930's with the advent of cheap fertilizer nitrogen and has continued at only a low level until the present time (Fergus and Hollowell, 1960). Recent and rapid rises in the cost of fertilizer nitrogen have caused a resurgence of scientific interest in legumes, but whether this will lead to a substantial resurgence in use of red clover leys is yet to be seen. Legume leys have consistently held their importance in less fertile, less productive cereal growing areas like Australia. In these situations, crop returns are less and yields more variable, so little use has been made of fertilizer nitrogen because of the risks involved. So present indications are that legumes are likely to have their biggest impact in low fertility situations unless, like soybeans, they can be grown for profit in their own right. Intensive cropping systems of the future for forage, grain or biomass production in New Zealand are unlikely to be operated under low fertility conditions where greatest benefits from the use of legumes seem apparent.

Cropping systems for any purpose in New Zealand are in a sense competing against the profitability of animal based products from pasture. Fertiliser inputs into pasture are largely phosphatic while cropping systems use more nitrogen. The relative costs of these two fertilizer elements have varied considerably over the last few years, due partly to Government subsidies and the rising cost of oil. However, recent sharp rises in the cost of phosphatic fertilizers have brought the price relativity of nitrogen and phosphorus back to approximately where it was 10 years ago although these fertilizers now form a higher percentage of overall farm costs. It is not easy to predict what the real or relative prices of these two basic fertilizers will be in the future though it seems unlikely that the very rapid price escalations of the past few years will continue. Complicating the issue is the probable local production of both fertilizers within the next decade and the ability that this would give the New Zealand Government to artifically set prices. In rather general terms, an increase in the price of nitrogen relative to phosphorus would favour the incorporation of legumes into cropping systems.

Of the various legume ley systems discussed, the greenfeed sorghum/subterranean clover option is technically ideal because of the way the management and utilization of the two components fit together. Unfortunately, only a few thousand hectares of greenfeed sorghums are grown annually in this country. Currently, by far the largest crop grown in the Waikato to Northland area is maize for grain. Substantial further growth in the maize industry is also possible if this grain were to be used for energy production. A system similar to that of sorghum and subterranean clover but involving grain maize and a self-regenerating legume would be a real advance. The benefit of such a system is that legume growth could commence as the maize canopy began to open up during April; well before harvesting of the grain. Doubtless some awkward agronomy problems will arise in trying to develop a system, but the legume would not need to be high yielding to be very useful.

Soybeans have not been specifically discussed in this paper, but American experience has shown that they integrate well with maize. Better adapted varieties and local bean processing facilities are likely to increase local production of soybeans and the chance of operating this type of maize/legume rotation.

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