



Adaptation of Australian ley farming to Montana dryland cereal production
by Saidou Koala

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in SOILS

Montana State University

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Abstract:

Sixteen annual legume/cereal rotations plus an alternate crop-fallow control were arranged in a randomized complete block design on an eroded field of Amsterdam var. of silt loam at Bozeman, Montana.

Results obtained during the legume phase (1979-1980) of the rotations showed that high dry matter yielding cultivars were Nungarin, 5268 Kg/ha, Geralton, 4960 Kg/ha, Northam, 4641 Kg/ha, Maral Schaftal, 4406 Kg/ha, Clare, 4353 Kg/ha and Jemalong, 4208 Kg/ha. The lupines were failures and these plots were considered to be double summer fallow treatments. Grain yields of faba bean were encouraging.

During the cereal phase of the rotations (1981), wheat grain yields, protein yields and N uptake were higher in all legume treatments compared to the alternate crop-fallow treatment and are attributed to the residual effect of the legumes. Medicago lupulina L., black medic was the most successful legume treatment.

Total water use and water use efficiency were higher for the legume treatments and support the hypothesis of their superiority over crop-fallow in terms of increased soil fertility and productivity.

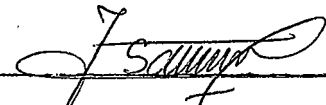
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These data have shown beyond any doubt that the Australian Ley system of farming is adaptable to Montana, can increase soil fertility and has some potential use for saline-seep control.

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ABSTRACT

Sixteen annual legume/cereal rotations plus an alternate crop-fallow control were arranged in a randomized complete block design on an eroded field of Amsterdam var. of silt loam at Bozeman, Montana.

Results obtained during the legume phase (1979-1980) of the rotations showed that high dry matter yielding cultivars were Nungarin, 5268 Kg/ha, Geralton, 4960 Kg/ha, Northam, 4641 Kg/ha, Maral Schaftal, 4406 Kg/ha, Clare, 4353 Kg/ha and Jemalong, 4208 Kg/ha. The lupines were failures and these plots were considered to be double summer fallow treatments. Grain yields of faba bean were encouraging.

During the cereal phase of the rotations (1981), wheat grain yields, protein yields and N uptake were higher in all legume treatments compared to the alternate crop-fallow treatment and are attributed to the residual effect of the legumes. *Medicago lupulina* L., black medic was the most successful legume treatment.

Total water use and water use efficiency were higher for the legume treatments and support the hypothesis of their superiority over crop-fallow in terms of increased soil fertility and productivity.

$\text{NO}_3\text{-N}$ values obtained after the legume phase and just before planting the spring wheat and total $\text{NO}_3\text{-N}$ used by the wheat crop were all significantly higher in the legume treatment.

These data have shown beyond any doubt that the Australian Ley system of farming is adaptable to Montana, can increase soil fertility and has some potential use for saline-seep control.

Chapter 1

INTRODUCTION

The fertility of Montana soils has become a major constraint to the production of small grains and other crops. The increased needs for fertilizer N to achieve maximum yields compared to 30 to 50 years ago reflects a substantial decline in soil organic matter and available N content. Secondary adverse effects of the declining soil fertility are the inefficient use of water resources, leaching of nutrients (especially nitrate - N), formation of saline seeps, and increased susceptibility to both wind and water erosion. Additionally, some areas such as the Sudan Savanna zone of Africa are experiencing a general decline in soil fertility, especially organic matter.

The primary objectives of this study were to test the adaptability of the Australian ley system of farming to Montana and its potential to alleviate the declining fertility and productivity of these soils.

A secondary objective was to develop an understanding of the ley system in order to test it in the Sudan Savanna of Africa.

Chapter 2

REVIEW OF LITERATURE

Dryland Rotations in Montana and the Great Plains

There has been little research on dryland legume-cereal rotations in Montana since the early 1950's.

As early as 1917, Pieters reviewed American experiment station literature relative to the value of legumes as measured by yields of succeeding crops. Data from 28 states and Canada showed that the legume value as green manures decreased from the southeastern to northwestern United States. In South Dakota and North Dakota and in the Canadian Northwest, the use of leguminous green-manure crops was not profitable. Green-manure crops were found to use the moisture needed for the main crops.

Chilcott (1931), Mathews and Cole (1938) stated that the use of biennial and perennial hay and forage crops in rotation was not of major importance in the Great Plains. Maintenance or increase of the organic-matter content of the soil through the application of manures or green manures did not pay for the cost where crops are grown for grain.

In 1955, Duley and Coyle discussed dryland farming problems in the U.S. They reported that the use of green manures was not effective in improving growth of the succeeding crops.

In Montana, green-manure experiments were started at Moccasin in 1909, Huntley in 1913, and Havre 1917 (Hansen et al. 1933, Bell 1937, Army and Hide 1959 and Brown 1964).

Bell reported in 1937 that winter rye, pea and sweetclover green manures had a depressing effect on small grain yields the following year as compared to ordinary fallow. Army and Hide (1959) also found a decrease in yields of spring wheat at Havre, Huntley, and Moccasin of 3.2, 3.6, and 3.8 bushels per acre, respectively. However, at Moccasin winter wheat following a green manure crop out-yielded wheat following ordinary fallow 50 percent of the time from 1914 to 1951 (Army and Hide 1959, Krall, et al. 1965).

These conclusions on the negative response of cereal yields following a green manure crop partially resulted from failure to consider that it required two years to grow a crop using the alternate crop-fallow rotations. Other factors leading to these conclusions were probably inefficient storage of winter precipitation and a poor management of the legume. Often the green-manure legume was plowed down too early in the season (Krall et al. 1965). They reported that the green manure crops actually were grown during the latter part of June or early July. An example of mismanagement was also pointed out by Bell (1937) who stated that "when green-manure crops were not established, there was invariably a good crop of Russian thistle (*Salsola kali* L.) to plow under." Possible other factors were poor selection of legume

species, a lack of nodulation for a variety of reasons, and sufficient release of nitrogen from soil organic matter.

It appears then that summer-fallow has given good results in Montana. The State has been known for producing high quality hard red spring and winter wheats (Sims and Jackson 1974). Even if the recent increases in per acre yields have been the result of improved varieties and increased use of fertilizer, it is also the result of efficient summer-fallowing. However, the increased needs for fertilizer N to achieve maximum yields and appropriate protein levels of dryland cereals as compared to 30 to 50 years ago reflect the substantial decline in organic matter and available N contents of these soils (Sims and Jackson 1974, Jackson and Sims 1977).

Additionally, improvements in cultural practices, more timely tillage and seeding operations, and the availability of high yielding disease-resistant varieties have greatly increased crop yields in recent years. These and other factors have resulted in a greater need for fertilizer N for dryland crop production (Jackson and Sims 1974). The same authors estimated that fertilizer use on Montana wheat appeared to be just sufficient to boost per acre yields enough to result in dilution of protein content and hence lower wheat protein percentages.

These data point out an increased need for fertilizers for Montana agriculture. However, the cost of fossil-fuel derived energy and fertilizers, particularly N fertilizer, has risen sharply in recent

years. An alternative to chemical fertilizer N to supply these needs would be advantageous.

Secondary adverse effects of declining fertility are the inefficient use of water resource, leaching of nutrients (especially nitrate-N), formation of saline seeps, and increased susceptibility to both wind and water erosion.

Salinity is on the increase in the states and provinces of the Great Plains (Miller et al. 1976). Bahls and Miller (1973) estimated that about 590,000 square kilometers of the Northern Great Plains of the United States and Canada are favorable for saline seep development. Unpublished statistics at the Montana State Soil Testing Laboratory operated by Montana Agricultural Experiment Station indicate that approximately 15 percent of the samples from irrigated soils east of the Continental Divide express some degree of salinization. Doering and Sandoval (1976) consider that saline seeps are recent ground water discharges on hillside locations in semiarid regions. Their principal visible characteristics are:

1. Intermittent or continual surface wetness sometimes accompanied by flow of free water down the slope,
2. reduced plant growth, and
3. quite often the development of a salt crust.

The premises that seeps are caused by a combination of geologic, climatic, and cultural conditions (Doering et al. 1976) and that

seeps are sustained by local recharge have also been widely accepted (Ferguson et al. 1972, Halvorson et al. 1974, Brun and Worcester 1976 and 1975, Doering et al. 1976).

Excessive nitrate-N leaching below the root zone has also been associated with saline seep (Custer 1976). Summer fallow plays a great role in soil salinity. It aggravates the salinity problem (Miller et al. 1976) and appears to be the major contributor to saline seep development. Fallowing the soil facilitates percolation of water and leaching of salts below the root zone. Eventually, much of the salts resurface downslope as saline seep spots.

Thus a system that can replace summer fallow while improving the soil fertility level would be desirable.

Agriculture in West Africa

In many parts of the semi-arid tropics, arable land is fast becoming a limiting agricultural resource due to the ever increasing socio-economic pressures (Lombi 1981). Consequently, the traditional bush-fallowing system is being replaced by semi-intensive and continuous cultivation. This system lowers the equilibrium level of soil organic matter and fertility and invariably necessitates continuous fertilization to sustain good crop yields.

This problem has acquired considerable urgency in the heavily populated Sudan Savanna zone of West Africa (north of latitude 11°30'

N) where low annual rainfall (800 to 900 mm, restricted to 3 to 4 months annually) has further compounded the fertility problem of these light, sandy, poorly buffered soils (Kadeba 1977, Lombi 1981).

One approach is increased use of fertilizers. Even though farmers and authorities may recognize this need for fertilizers in sustaining the fertility of continuously cultivated soils, an inefficient distributive system, poor communication, and especially lack of capital and other socio-economic factors severely limit the consumption of fertilizers. It is imperative that cheaper means of improving soil fertility and productivity be explored in order to supplement the use of mineral fertilizers.

Many researchers (Birch et al. 1956, Jones 1971, Kabdiba 1977) recognize the importance of organic matter as a buffering agent and suggest that management practices in future intensive agricultural operations take account of the need to conserve and increase its level in these soils. However, under the climatic conditions of the Sudan Savanna zone of high temperature, an intensive dry season and of low topsoil clay content (Jones 1971), levels of soil organic matter can never be very high (Kabeda 1977). Jones (1971) estimated the maximum practicable topsoil organic-matter content to be 1 percent. This can be maintained either by an annual application of 7 - 8 tons of farmyard manure per hectare or by using grass fallow three years out of every six. However, the supply of farmyard manure under

the actual cropping system will never be sufficient for more than a small fraction of the cultivated land. The proposed grass fallow system, although an effective restorer of soil organic matter, is unproductive. Economic pressures seem bound to tell against a practice which effectively produces a crop only once in two years. Jones (1971) suggested that some form of productive fallow or ley may be the eventual answer.

Ley Farming System

In areas of declining soil fertility, increased soil erosion and increased saline seep, an alternative to chemical fertilizer nitrogen would be advantageous. Legume-cereal rotations may offer such an alternative. The few instances of success with such rotations in central Montana in the first one-half of this century (Brown 1964) and the success of these rotations in other parts of the world such as Australian "Ley farming" (Webber et al. 1976, Webber et al. 1977, Ellington 1977) suggest that legume-cereal rotations should be reevaluated for Montana.

Also in semiarid areas such as the Sudan Savanna zones of low annual rainfall and decreasing soil organic matter, legume-cereal rotations may offer some possibilities.

Ley farming is a system in which crops and pasture are alternated on the same field (Doolette 1977). It may be considered a type of

fallow system in which small grains are alternated with a short-season annual legume grown for pasture during the fallow year (Oram 1977).

Ley farming, a legume pasture-cereal crop rotation has revolutionized agricultural production in the cereal zone of South Australia since the late 1930s (Webber et al. 1977). It is based on growing annual legumes including forage and grain species between cereal crops.

In South Australia, soil fertility was depleted by continuous cropping of the initially fertile soils (Cornish 1949, Woodroffe 1949) and the introduction of fallowing and fertilizer gave only temporary relief. When the legume based pasture was introduced, however, the improvement in soil fertility was so marked that wheat yields were raised above the yield obtained on the virgin soils (Webber et al. 1976, Webber et al. 1977, Ellington 1977).

Measurements taken in the wheat belt of South Australia indicate that an average medic stand increases soil nitrogen by at least 60 to 70 kg/ha in one season. This is the equivalent of about 300 kg/ha of sulphate of ammonium (Webber et al. 1976). An increase of 200 Kg N/ha per year has been recorded on a sandy soil after a vigorous sward of Harbinger medic (*Medicago Littoralis* L.) and Subterranean clover (*Trifolium subterraneum* L.) pastures have also been shown to build up soil fertility on a light textured soil (Watson 1963).

Elliott et al. (1972) studied the influence of rotation systems on long-term trends in wheat yields over a 29 year period. All the rotation systems examined showed positive, almost linear, yield increases over the first 19 years (1940-1958). Over the final ten years (1959-1968) those systems including a pasture phase continued to show a linear yield increase; other three-course systems (fallow, wheat, stubble crops) showed a less than linear increase while the two-course system (fallow-wheat) showed a 22 percent yield decline.

In general, ley farming in South Australia has given best results on the alkaline soils (the solonized brown soils and black earth) and has been less successful on the neutral to slightly acid soils (solodized solonetz and solodic soils).

The key to successful ley farming lies in the pasture phase of the rotation (Webber et al. 1976, Webber et al, 1976, Ellington 1977). A legume is needed which increases soil fertility, improves soil structure, and regenerates naturally after a crop. Some legumes can do this.

In South Australia, the main medics used are:

- Barrel medic (*Medicago truncatula* Gaertn) cv. Jemalong, Hannaford, Cyprus, and Borung.
- Strand medic (*Medicago littoralis* L.) cv. Harbinger
- Gama medic (*Medicago rugosa* L.) cv. Paragosa
- Snail medic (*Medicago scutellata* Mill.)

- Disc medic (*Medicago tornata* L.)

and the main subterranean clovers include the following cultivars: Clare, GERALTON, Woogenelup and Daliak. The reason for their success is that they produce many hard seeds. Hard seeds are seeds with seed coats resistant to the entry of water, thus retarding germination (Doolette 1977). Where the medics are well adapted, most of their seeds are hard after seed-set at the end of the growing season. This means that in the following summer, they can resist germination after rains. During summer, extreme heat cracks the coats of some seeds so that by autumn they have become "soft", water can now penetrate allowing germination to begin.

Most seeds remain hard for longer than one summer and do not germinate with the first rains. Their seed coats remain hard for maybe a year or more. This means that the species can survive for years when it sets no seed, such as when a cereal crop is grown.

Clearly, the presence of hard seeds has important implications in ley farming.

Effects of Nitrogen

Legumes can derive N from the soil, applied fertilizers, and through symbiotic N_2 -fixation. Each of these three sources can presumably supply the N requirements of the legumes.

As early as 1924, Perkins (1924) reported a study conducted in

the greenhouse of the effect upon nodulation of the four essential elements most likely to be limiting factors. His results indicated that small applications of mineral N increased nodulation to a slight degree. However mineral N was not essential for good nodulation and that high applications inhibited nodulation of the host.

Fred, Baldwin and McCoy (1932) demonstrated that nodulation and thus fixation can be inhibited by a concentration of available inorganic N.

Burk and Lineweaver (1930) and later Wilson, Hull and Burris (1943), showed that fixation by azobacter could be prevented by the presence of sufficient inorganic N.

More recently, utilizing ^{15}N as a tracer, studies have been performed to evaluate the influence of varying quantities of available N on the fixation process in legumes. Norman and Krampitz (1946) reported investigations with soybeans (*Glycine max* L.) and lespedeza (*Lespedeza* sp), and Thornton and Broadbent (1948) worked with peanuts (*Arachis hypogaea* L.). Allos and Bartholomew (1955) reported studies with soybeans, peanuts, alfalfa (*Medicago sativa* L.), lespedeza, ladino clover (*Trifolium repens* L.) and birdsfoot trefoil (*Lotus corniculatus* L.). In all cases, negative effects of the presence of available inorganic N on N_2 -fixation was noted. The effects varied among the legumes studied and among other experimental conditions, including the soil or substrate in which the legumes were grown. Other physical and

environmental conditions also had an influence on the inhibition of fixation by inorganic N.

Allos and Bartholomew (1959) reported on the influence of increasing increments of available inorganic N on N_2 -fixation by a number of legumes. Plants were grown in gravel culture in the greenhouse and supplied at weekly intervals with varying amounts of tracer nitrogen. Subsequent analyses of plant N permitted calculations of the N coming from the fertilizer and symbiotic fixation. All legumes responded in growth and in N uptake to the addition of inorganic N. In some instances, the increased growth resulting from fertilization caused increases in fixation of N. When N was applied in excess for growth, it tended to replace the fixation process. They found that fixation processes never supplied sufficient N for maximum growth under the conditions of their experiment. Each species exhibited an apparent capacity to fix about one-half to three-fourths of the total N which could be used by the plant.

The discrepancies in the results of Allos-Bartholomew (1959) and Thornton (1948) may be due to differences between nutrient solution and soil cultures, initial soil N level, and availability of the N.

Most of the data in the literature support a reduction in nodulation from any application of mineral N. Weber (1966) found that nodule numbers were reduced by about 33 percent, nodule fresh weight

by 50 percent, and nodule size by 25 percent when 168 Kg N/ha was applied. A stronger reduction occurred when 672 Kg N/ha was applied on soil that had part of its available N immobilized by incorporation of corn cobs.

More recently, the acetylene reduction assay (Hardy et al. 1968) has been developed as a reliable measurement of N_2 -fixation. The assay makes possible the rapid evaluation of the effects of cultural practices and environmental factors on N_2 -fixation. Following this, reliable *in situ* methods for sample preparation and assay of nitrogenase activity were developed as described by Lockerman (1974).

Using these new techniques, Johnson and Hume (1972) reported the results conducted on low fertility soils in Ontario, Canada, with soybeans in newly introduced areas. N_2 -fixation was progressively increased by treatments:

- 1) M_1 (88 T/ha of liquid cattle manure),
- 2) M_2 (176 T/ha of liquid cattle manure) + O.M (1.4 T/ha (dry weight) of ground corn cobs as an organic matter source),
- 3) M_1 + O.M. and
- 4) O.M.

Addition of 14 T (dry weight)/ha of ground corn cobs increased N_2 -fixation seven times as much as the control.

The soybean plant has been extensively studied since the acetylene reduction assay. It has been reported that soybean is generally

capable of growth and seed production with symbiotic N_2 -fixation as the only N source. However, a marked decrease in seed yields has been observed and strongly suggests that the soybean plant must have an N source other than atmospheric N for optimum yield production. Harper (1972) reported maximum nitrate utilization at the full-bloom growth stage, with symbiotic N_2 (C_2H_2) fixation peaking three weeks later during pod fill. Seed yield of plants totally dependent on atmospheric N was less than one-half the yield of plants utilizing both nitrate and atmospheric N under hydroponic growth conditions. He concluded that both symbiotic N_2 -fixation and nitrate utilization are essential for maximum yield of soybean.

Semu and Hume (1979), however, reported different results. They found that fertilizer N applications at planting time did not increase yields in areas where soybean had been grown several times, indicating that N_2 -fixation may support maximum yields. Nodule number and mass, and N_2 (C_2H_2) fixation rates were decreased by fertilizer N. Yield responses to N fertilizer applied at planting will usually indicate that N_2 -fixation is less than optimal.

In cases where inhibition has been obtained, nitrate has been reported to be the causal factor. Wong (1980) reported that lentils grown in a nutrient solution containing 15 mM nitrate had 84 percent fewer nodules than lentils grown in nitrate free nutrient solution. Nodules weighed 71 percent less and N_2 -fixation was reduced. Addition

of sugars alleviated the inhibitory effects of nitrate on symbiotic N_2 -fixation. This not only increased the carbohydrate supply so lentils could support both N_2 -fixation and nitrate reduction but also inhibited the accumulation of nitrate.

Obviously different results from supplying inorganic N to legumes have been reported. Many of them supporting that N fertilizer is beneficial to the plant at early stage with later inhibition of nodulation and N_2 -fixation. Some reports indicated that N fertilizer is either beneficial or detrimental at all growth stages. Most of these discrepancies are probably due to differences in procedure. *Rhizobium* strain effectiveness, species and cultivar differences, nutrient solution versus soil cultures, initial soil N levels and availability of the N.

Chapter 3

METHODS AND MATERIALS

Description of site

Field plots were established May 22 and 23, 1979 on an eroded field of Amsterdam var. of silt loam (fine-silty, mixed family of Typic Haploborolls) located at the Montana State University Arthur H. Post Field Research Laboratory and which had been fallowed the previous season (Appendix Table 1).

Cultivars

Seed of sixteen annual legumes were utilized. Fourteen accessions were from the South Australia Department of Agriculture, including:

Five *Medicago* sp; annual medics,

- *Medicago truncatula* Gaertn. cv. Ghor (barrel medic)
- *M. truncatula* Gaertn. cv. Jemalong (barrel medic)
- *M. littoralis* L. cv. Harbinger (strand medic)
- *M. scutellata* Mill. cv. Robinson (snail medic)
- *M. truncatula* Gaertn. cv. Cyprus (barrel medic)

Seven *trifolium* sp.

- *Trifolium subterraneum* L. cv. Nangeela (subterranean clover)
- *T. subterraneum* L. cv. Clare (subterranean clover)
- *T. subterraneum* L. cv. Nungarin (subterranean clover)
- *T. subterraneum* L. cv. Northam (subterranean clover)

- *T. subterraneum* L. cv. Geralton (subterranean clover)
- *T. subterraneum* L. cv. Daliak (subterranean clover)
- *T. resupinatum* L. cv. Maral Schaftal.

Two *Lupinus* sp. sweet lupines

- *Lupinus angustifolius*, L. cv. Unicrop (narrow-leafed lupine)
- *L. albus*, L. cv. Ultra (white lupine).

One faba bean cultivar from the Egyptian Ministry of Agriculture

- Giza III,

and one *Medicago* species from Montana

- *Medicago lupulina* L. Montana common, Black medic.

Conventional alternate crop-fallow (spring wheat/summer fallow) plots were included as the control.

Experimental design

These sixteen annual legumes plus the conventional alternate crop-fallow were arranged in a randomized complete block design. The plots were 4 x 7 m wide with each cultivar replicated three times.

In the spring of 1979, the plots were seeded with a "Planet Jr." hand seeder at the rate of 10 Kg/ha for forage legumes, 100 Kg/ha for grain legumes and 60 Kg/ha for the Newana spring wheat control plots. Row spacings were 45 cm for forage legumes, 80 cm for grain legumes and 30 cm for spring wheat. For the first year, no fertilizer treatments were applied. In 1979, soil samples were taken at 0-15 cm and 15-30 cm from plots 1-17 on 15 May, 18 to 34 cm on 16 May and

35 to 51 on May 17.

Observation on growth pattern of legumes

Seed were planted on May 22 and 23 and the first observation on percent ground cover was recorded August 30. Flowering was recorded July 6, 12 and 24. In 1979, the mature crops were harvested 25 September.

Dry matter and seed production were measured by harvesting 1 m² areas in each plot except for seed yields of the grain legumes for which the grain from each entire plot was harvested. The control plot wheat yields were determined by harvesting a 10 m² swath down the middle of each plot with a small-plot combine.

Dry material were analyzed for total nitrogen and the seeds from faba bean were analyzed for total protein and amino-acids by the amino acid analyzer.

During the 1980 season, the annual forage legumes except Nangeela subclover were allowed to re-establish themselves from residual hard seeds and from seeds produced during the 1979 season. The Nangeela subclover which did not flower well in 1979, the Maral Schaffal clover and the grain legumes were reseeded and the control plots were summer fallowed. All dry matter produced during the 1980 season was incorporated into the surface 10 cm of soil by rototilling during late September. The faba bean plots were harvested for grain yield.

Observation on growth pattern of spring wheat

All plots were seeded to Pondera spring wheat on 5 May 1981 after soil samples were taken in each plot to a depth of 120 cm for total N, percent O.M., $\text{NO}_3\text{-N}$, P and soil water determinations. Phosphorus fertilizer at a rate of 100 Kg/ha was uniformly spread over all plots.

During the growing season, the plots were kept weed free by spraying with a chemical herbicide, Bromate, at 0.5 kg a. i per ha and by hand weeding. Growth stages based on Feekes scale adapted by Large (1954) were recorded on July 2 and 3. Plant heights were recorded using a meter stick and plant canopy color was estimated by visual observations.

Wheat samples, based on the entire plant cut at crown level were taken on July 15 for yield estimation and total N analysis. In each plot, three (3) sub-samples were taken on 30 cm x 15 cm and oven-dried at 80° C with forced air for 48 hours. Prior to harvesting, average tiller numbers and tiller density were also recorded.

On September 11, grain yields were determined after harvesting with a small plot combine as described above. Again soil samples were taken on each plot to a depth of 120 cm with a hydraulic soil sampler for total N, O.M., $\text{NO}_3\text{-N}$ and soil water determinations. Following the soil sampling, the stubble was incorporated by cultivation to a depth of 10 cm with an off-set disc.

During the 1982 season, the annual forage legumes were allowed to re-establish from residual seed produced in 1979 and 1980. The Nangeela subclover, Maral Schaffal clover, and the grain legumes were reseeded as in 1980. The control plots were summer fallowed as in 1980. In early summer, percent ground cover and density were recorded to evaluate the degree of re-establishment.

Laboratory analysis

Laboratory analysis of soil samples and stored soil moisture obtained prior to fertilization include pH (2:1 water:soil), electrical conductivity (EC in mmhos/cm), NH_4OA_c extractable Ca, Mg, Na and K as described by Chapman (1965) and as used by the Montana State University Soil Testing Laboratory and P by the modified Bray and Olsen tests (Smith, et al., 1957; Olsen and Dean, 1965).

Soil $\text{NO}_3\text{-N}$ was determined by the "chromotropic acid" procedure as developed by Sims and Jackson (1971) and as modified by Haby and Larson (1976) and soil organic matter was measured by the colorimetric method of Sims and Haby (1971). Grain, straw and soil samples were analyzed for total N by a semi-micro Kjeldahl method (Bremner 1965). Wheat grain samples were analyzed for total protein using a near-infrared analyzer.

Faba bean grain samples were analyzed for total protein and amino acids with an amino acid analyzer. Available soil water was estimated

by drying the samples at 105° C for 48 hours in a forced-air oven.

Meteorological observations

Precipitation, evaporation and average temperatures were recorded daily approximately 300 m from the plots by the Weather Service Climatological Station and are summarized in Appendix Tables 2 and 3.

Statistical methods

Statistical analyses were performed on the Montana State University Honeywell Computer, GP6. Analyses of variance and correlation were calculated using MSUSTAT developed by Dr. Richard E. Lund. Multiple regression analyses were performed by the SPSS stepwise regression analysis program (Nie, et al., 1975). The stepwise forward procedure was used to select the first best five variables that entered the equation. This approach inserts variable in turn until the regression equation is satisfactory. The order of insertion is determined by using the partial correlation coefficient as a measure of the importance of variables not yet in the equation.

Chapter 4

RESULTS AND DISCUSSION

Legume phase, 1979-1980

Legume dry matter yields

Legume dry matter yields for the 1979 season are reported in Table 1 and Figure 1. Yield differences were statistically significant ($p = 0.01$). The highest dry matter yield was obtained with *Trifolium subterraneum* L. cv. Nungarin with 5268 Kg/ha compared to an average yield of 3113 Kg/ha. This represents a 69 percent yield increase over the average yield.

An average yield of 2254 Kg/ha of dry matter (straw) was produced on the cereal-fallow control plots planted with Newana spring wheat. This yield represents only 42.7 percent of the yield of Nungarin and 72 percent of the average yield.

Treatments which resulted in significantly high dry matter yield ($p = 0.05$) compared to the control plot and their percent yield increases include:

Nungarin	133.7 percent
Geralton	120.1 percent
Northam	105.9 percent
Maral Schaftal	95.5 percent
Clare	93.1 percent

Table 1. Mean dry matter yields, seed or seed pod yields, total N (%) and total N uptake for the 1979 season legume crops.

Crop	Dry Matter Kg/ha	Seed Kg/ha	N Content %	N Uptake Kg/ha
Nangeela	3329	16.0	2.40	79.46
Jemalong	4208	1964.0	1.77	74.49
Northam	4641	154.6	1.77	83.35
Cyprus	2792	1171.0	2.06	58.43
Clare	4353	110.8	1.80	76.73
Harbinger	3455	1846.0	2.21	72.96
Grain-fallow/Control	2254	2041.0 ^{1/}	- ^{2/}	-
Daliak	3800	43.8	2.00	76.14
Black medic	811	225.3 ^{1/}	2.58	19.30
Geralton	4960	342.6	1.51	74.65
Ghor	1067	745.1	1.87	20.31
Nungarin	5268	304.7	1.91	100.09
Unicrop	451	0.0	2.96	14.13
Robinson	3447	1934.0	1.82	63.21
Giza III	2131	283.5 ^{1/}	3.10	67.37
Maral Schaftal	4406	114.5 ^{1/}	3.04	131.42
Ultra	1554	920.1 ^{1/}	2.65	44.15
Level of significance	0.01	0.01	0.01	0.01
LSD p = 0.05	1554 Kg/ha	553.5 Kg/ha	0.60	31.63 Kg/ha
Cv	29.8	46.2	16.2	28.7

^{1/}Yield data are for seed only, all others are for intact seed pods.

^{2/}Not determined.

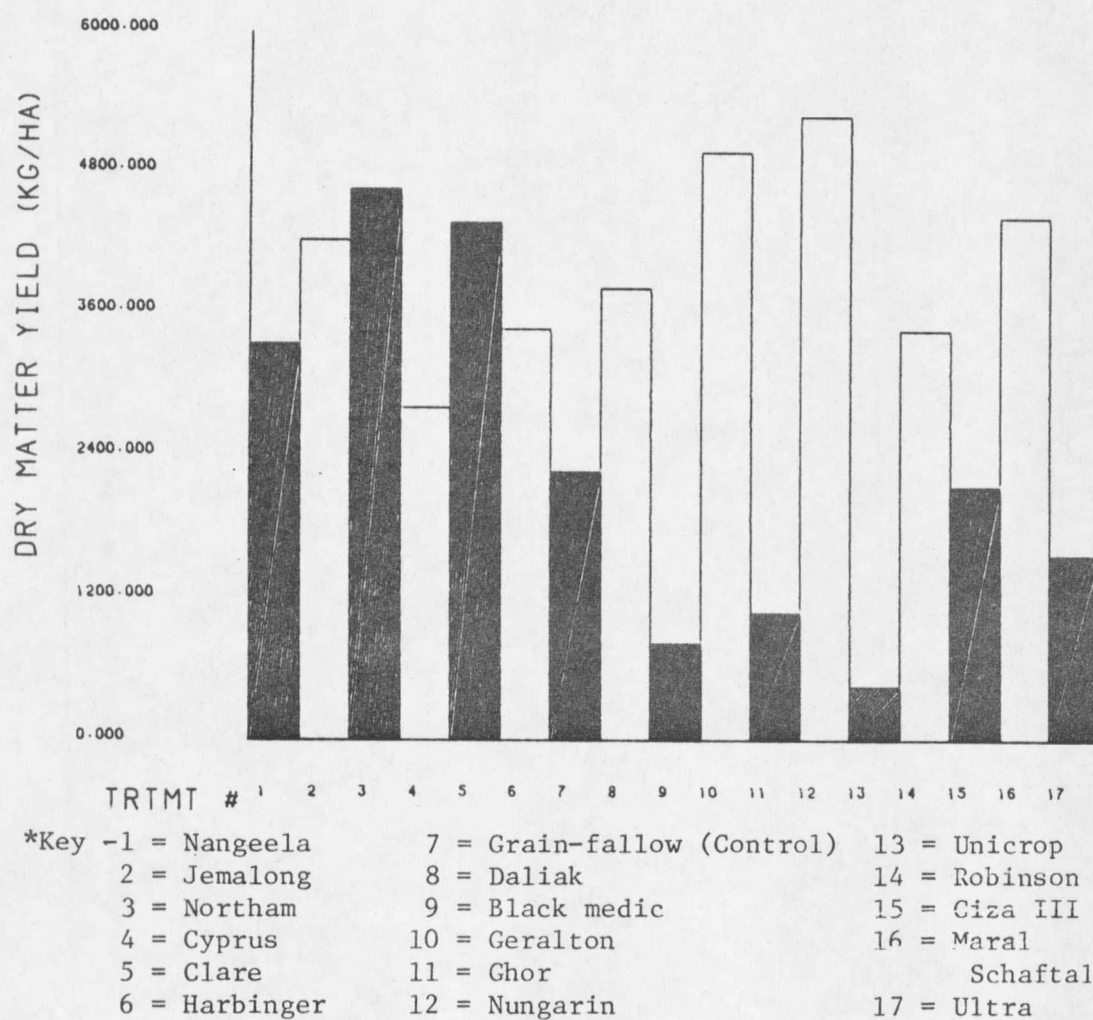


Figure 1. Dry matter yield from annual-legume/cereal rotation plots at Bozeman, Montana, 1979.

*Key is same for all figures.

Jemalong	86.7 percent
Daliak	68.6 percent

On the average, the Australian medics (2994 Kg/ha) yielded less than the clovers (4394 Kg/ha).

The lupines, *Lupinus angustifolius* L. cv. Unicrop and *Lupinus albus* L. cv. Ultra, did not perform well in 1979 season with an average yield of 451 Kg/ha and 1554 Kg/ha respectively. This might be the result of a poor adaptability of these crops to the test site soil, the climate or to residual herbicides.

Medicago lupulina L. black medic resulted in a poor yield the first year (811.4 Kg/ha). This was apparently due to its high hard seed content that resulted in the poor establishment of the crop. A very good stand was achieved the second year after the seeds had softened in the soil.

The Egyptian faba beans, *Vicia faba* L., cultivar Giza III yielded a dry matter of 2131 Kg/ha.

Seed or seed pod yields

Seed or seed pod yields are reported in Table 1 and Figure 2. In the ley system of farming, it is important that the legume sets enough seeds for the succeeding years when a legume crop is desirable.

Seed yields were statistically significant ($p = 0.01$). An average yield of 719 Kg/ha was obtained but great variation was

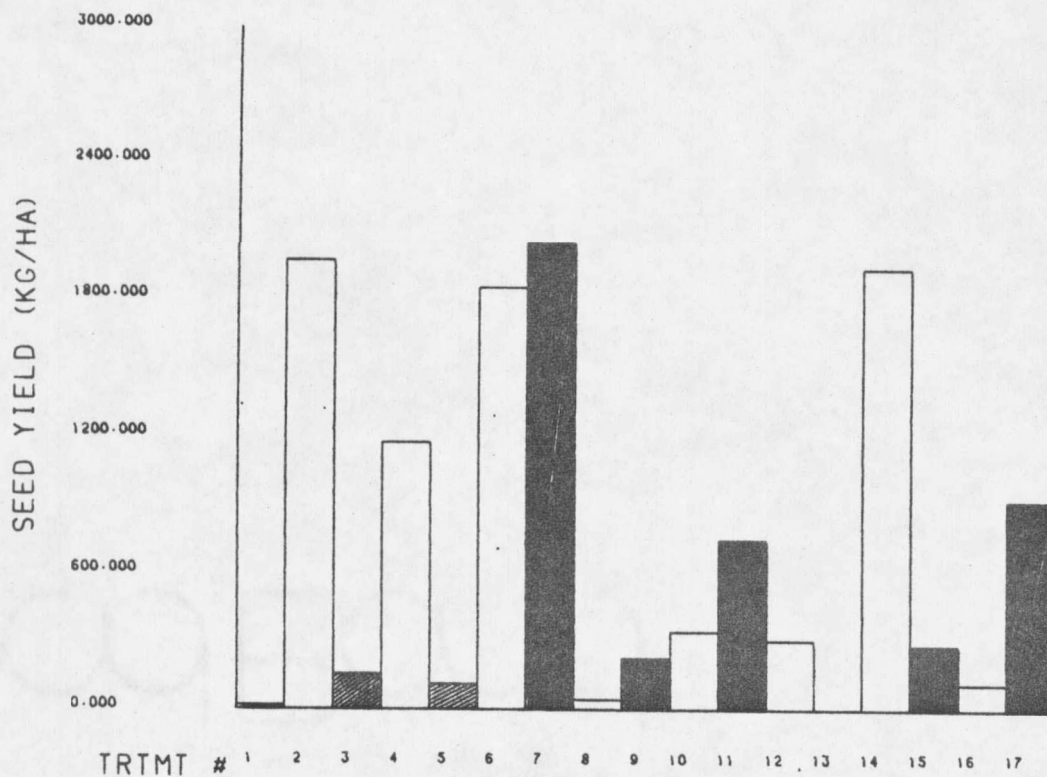


Figure 2. Seed or seed pod yields from annual-legume/cereal rotation plots at Bozeman, Montana, 1979.

observed.

Seed yields varied from a high value of 2041 Kg/ha for the Newana spring wheat control plots to no yield at all for *lupinus angustifolius* L. cv. Unicrop.

Among the subterranean clovers, the greatest seed yield response was observed for GERALTON with 343 Kg/ha, followed by Nungarin (305 Kg/ha), Northam (155 Kg/ha), and Clare 111 Kg/ha).

Nangeela produced the lowest seed yield of 16.03 Kg/ha. This variety was late in flowering and produced no seed in two of the plots and very little in the third plot.

The highest seed yield response among the Australian medics was noted with *Medicago scutellata* Mill. cv. Ghor with 745 Kg/ha.

The seed yield of *Medicago lupulina* L. black medic was good considering its poor establishment the first year.

The Australian medics (1532 Kg/ha) outyielded the clovers (155 Kg/ha). Considering a seeding rate of 10 Kg/ha, all medic cultivars produced an optimum seed yield for the regeneration of the species in a ley farming system. The two lupine cultivars did not perform well. Unicrop did not produce any seed and Ultra gave a low yield of 920 Kg/ha. This might be related to poor vegetative performance and support the view of poor adaptability to these soils or to this climatic zone.

The cereal-fallow control plot, which was planted to Newana spring

wheat, resulted in a grain yield of 2041 Kg/ha.

A yield of 2131 Kg/ha was obtained with the Egyptian faba bean. Faba bean is a cool season crop and requires more than 100 days growing season for maximum production. Inadequate rainfall or soil moisture in the root zone will induce wilting and reduce seed set. Considering then the 20.1 cm of precipitation for the 1979 season (Appendix Table 2) and the fact that the crop was planted late (23 May), the faba bean grain yield is encouraging. It also appears from observations taken during the growing season that this cultivar seems to be earlier than the North American cultivars tested in Montana (Jackson et al. 1979).

Faba bean grain samples were analyzed for protein and amino acids (Table 2). Grain protein percentage averaged 30 percent and this combined with an averaged grain yield of 2131 Kg/ha, resulted in a protein yield of 639 Kg/ha. However, animals require specific amino acids rather than protein per se, and since they cannot synthesize all amino acids, they depend on plants or microorganisms for those they cannot synthesize. Therefore the relative concentration of each of the amino acids is rather important.

The concentration of glutamic acid, aspartic acid, arginine and leucine was greater than 2 percent; alanine, glycine, histidine, lysine, phenylalanine, proline, serine, threonine and valine concentration ranged between 2 and 1 percent, and methionine, tyrosine, and taurine were present in amount less than 1 percent. Tryptophan

Table 2. Protein content and amino acid analysis of faba bean seeds for 1979 Harvest

		Protein (N x 6.25)
Rep. 1		30.0
Rep. 2		30.7
Rep. 3		29.7
Amino Acid Analyses		% (W/W)
A.A.	Means	
Alanine	1.17	
Arginine	2.68	
Aspartic acid	3.64	
Cysteine		
Glutamic acid	6.29	
Glycine	1.03	
Histidine	1.22	
Leucine	2.06	
Lysine	1.61	
Methionine	.266	
Phenylalanine	1.29	
Proline	1.55	
Serine	1.69	
Threonine	1.15	
Tryptophan		
Tyrosine	.869	
Valine	1.36	
Taruvine	.58	
Total	28.97	
Kjeldahl N	30.1	

N.D. = Not determined.

and cysteine contents were not determined. Compared to wheat and barley, the faba bean grain was higher in lysine.

The yield levels of both dry matter and seed for the forage legumes are, in general, encouraging in terms of adapting the Australian ley system of farming to Montana. Several of the annual legumes have a good potential as annual hay or pasture crops having produced from 4000 to over 5000 Kg/ha (2 to 2.5 tons/A) of forage. These include Nungaring (5268 Kg/ha), Geraldton (4960 Kg/ha), Northam (4641 Kg/ha) and Clare subclover, (4353 Kg/ha) Maral Schaftal clover (4406 Kg/ha), and Jemalong medic (4308 Kg/ha). There were some exceptions. Nangeela subclover was very late in flowering and produced virtually no seed. This could be an advantage if a producer desired only one year of a legume as a green-manure or annual pasture crop and no residual buried seed for succeeding years. The hard seed content of the black medic was apparently too high to establish a good stand the first year. This suggests that the producer would have to seed black medic at the time he seeded the last cereal crop, scarify the seed or wait for the second legume cycle to realize the full benefit of the black medic.

The faba bean protein, compared to cereals, is high in lysine 1.61 percent, an essential amino acid for humans as well as for swine and poultry. In Montana, faba bean has a potential as an export crop, a protein supplement or high protein silage. Canadian feeding studies

have shown faba bean to be excellent protein source for poultry, if supplemental methionine is added (Jackson et al. 1979). It can also replace soybean meal in rations for pigs weighing over 80 pounds, for lactating dairy cows, calves and beef cattle. Thus, based on the data from this experiment, faba bean could be produced in Montana in rotation with cereals utilizing the faba bean for animal feed and plowing down the stover for soil enrichment.

Total N content and total N uptake in leaves

The total N percent and total N uptake by the legume are shown in Table 1. A statistical difference between treatments ($p = 0.01$) was observed for the two variables.

The greatest N concentration was measured with the Egyptian faba bean (3.10 percent) followed by Maral Schaftal clover (3.04 percent).

The lowest response, 1.5 percent, was obtained with Geralton subclover. Most cultivars had more than 2 percent N in their leaves. The few cultivars which resulted in N concentration of less than 2 percent include Jemalong barrel medic (1.77 percent), Northam subclover (1.77 percent), Ghor barrel medic (1.51 percent), Nungarin subclover (1.91 percent) and Robinson snail medic (1.82 percent). There was correlation between low N content and high dry matter yield.

Legume N uptake includes both N from atmospheric fixation and soil N. It is a function of total dry matter yield and N concentration.

Maral Schaftal, due to a high dry matter yield, combined with a high N content had the highest N uptake of 131.42 Kg/ha. This cultivar, however, was not statistically different ($p = 0.05$) from Nungarin subclover for total N uptake but both cultivars had significantly greater N uptake ($p = 0.05$) than the others.

The low N uptake was observed for Ghor barrel medic (20.31 Kg/ha), a result of its poor dry matter yield.

In general, the clovers outyielded the medics by 32 Kg/ha. This probably results from thinner stands of the medics due to high hard seed contents and, hence, lower dry matter yields. The clovers may also be better nitrogen fixers or are more efficient in utilizing the available soil nitrogen or both. Also, the Australian medics and local *Rhizobium* strains in the inoculum and/or indigenous in the soil may have been an inefficient combination.

The N uptake of the lupines and faba bean were very low, 29 Kg/ha and 67.37 Kg/ha respectively. This is not surprising for the lupines which were failures or for the faba bean crop since most of its N is translocated to the seed at maturity.

Cereal Phase, 1981

Wheat grain yield

In 1981, all plots were seeded to Pondera spring wheat and yield results are summarized in Table 3 and Figure 3.

Table 3. Mean grain yields, dry matter yields, grain protein and protein yields of Pondera spring wheat at Bozeman, Montana in 1981 following various 1980 legume crops.

1980 crop	Yields, Kg/ha		Protein %	Protein yield
	Wheat grain	Dry matter	Wheat grain	Kg/ha
Nangeela	2626	6217	13.40	350.64
Jemalong	2371	4766	13.77	326.71
Northam	2103	4913	14.60	309.68
Cyprus	2276	4736	14.87	336.48
Clare	2245	4640	13.70	307.76
Harbinger	2581	5859	15.13	392.44
Grain-fallow	1824	4430	14.83	271.80
Daliak	2703	4967	14.00	378.06
Black medic	3501	5644	15.17	529.12
Geralton	2307	5565	13.93	321.85
Ghor	2393	4925	15.37	367.75
Nungarin	2447	4896	13.60	332.96
Unicrop	2644	5493	15.83	418.57
Robinson	2124	4524	15.47	328.09
Giza III	2746	5961	15.23	418.24
Maral Schaftal	2862	5950	14.40	412.13
Ultra	2513	4667	15.97	402.27
Level of significance	0.005	N.S. ^a	0.01	0.01
Lsd p = 0.05	680 Kg/ha		0.85	103.5 Kg/ha
Cv %	16.4	23.0	3.5	17.0

^aNS = non significant.

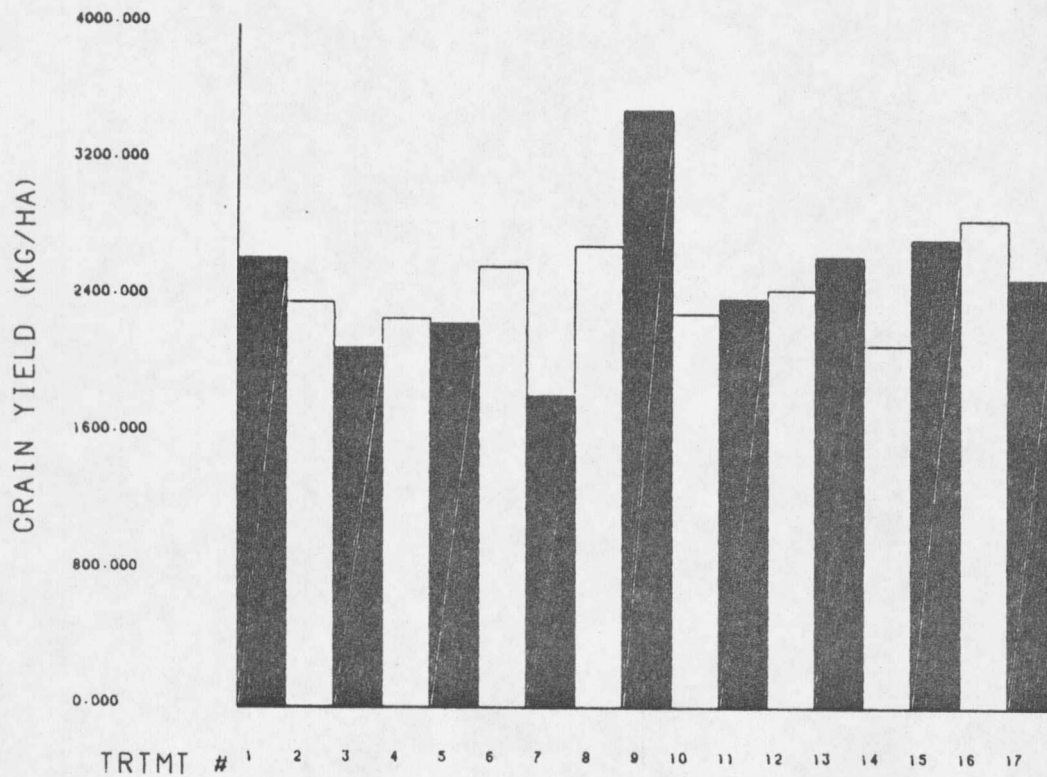


Figure 3. Wheat grain yield from annual-legume/cereal rotation plots at Bozeman, Montana, 1981.

Grain yields averaged 2486 Kg/ha. All of the annual legume treatments resulted in grain yields greater than that of the summer fallow control treatment. Analysis of variance indicates that differences in grain yields were statistically significant at the 5 percent level (Appendix Table 6).

The grain fallow plots had an average yield of 1824 Kg/ha. This is 73 percent of the overall average yield and only 52 percent of the yield of black medic treatment.

The greatest yield response was obtained with black medic treatment, 3501 Kg/ha.

Maral Schaftal clover treatment gave the highest yield among the clovers and Harbinger medic treatment the highest among the Australian medics with 2862 Kg/ha and 2581 Kg/ha respectively.

In general, the subclover treatments outyielded the Australian medics by 160 Kg/ha. The difference between the grain-fallow control treatment and the highest yielding clover and medic treatments were 1038 Kg/ha and 757 Kg/ha respectively.

Annual legume treatments which produced significantly higher yields ($p = 0.05$) compared to the summer fallow control treatment and their percent yield increases are as follows:

Black medic	92 percent
Maral Schaftal	56.9 percent
Faba beans	50.5 percent

Daliak subclover	48.2 percent
Unicrop lupines	45.0 percent
Nangeela subclover	44.0 percent
Harbinger medic	41.5 percent
Ultra lupines	37.8 percent

The lupines failed to produce in 1979 and 1980 seasons and their plots are considered as double summer fallow which resulted in their high wheat yields. The soil relatively high nitrate-N levels in these plots resulted from the double summer fallow.

The Egyptian faba bean treatment yielded 2746 Kg/ha which represents 922 Kg/ha more than grain fallow treatment.

Considering the fact that differences in initial, 1979, soil nitrogen were statistically non-significant in all the plots, this indicates that the differences in yield between the legume treatments and the grain fallow control treatment can be attributed to the residual effect of the legumes. Also the differences among the legume treatments themselves are the result of a differential nitrogen fixation during the 1979 and 1980 seasons. These differences are discussed further in the section on effects on soil properties.

The average maximum temperature during the 1981 season was 20.7° C and precipitation from seeding until harvest totalled 27.29 cm and was not evenly distributed (Appendix Tables 2 and 3). Under these

conditions, some moisture stress was placed on the crop and may have partly influenced the wheat grain yields from all plots.

Wheat total dry matter yields and percent N

Total dry matter yields include the straw and the grain at stages 11.1 (milky-ripe) and 11.2 (mealy-ripe) of the Feekes scale modified by Large (1954). There was no significant difference between the treatments (Table 3). However, all legume plots yielded more than the control plots with the greatest yield noted for Nangeela sub-clover, 6217 Kg/ha, followed by Giza III faba bean plots, 5961 Kg/ha, Maral Schaftal clover, 5950 Kg/ha and Harbinger medic 5859 Kg/ha. Correlation coefficients, r , should show if there is a relation between dry matter yields and grain yields. These data are presented in a later section.

The percent N in the wheat dry matter taken at ripening stages 11.1 and 11.2 (Large 1954) did not show any statistically significant difference between the treatments (Table 3). This suggests that the differences in the protein concentration, protein yield and total N uptake observed at final harvest were due to late N uptake from the soil followed by a rapid translocation to the seeds. Also the N concentrations in the wheat straw at harvest were not significantly different ($p = 0.05$) supporting the view of late uptake and rapid translocation into the grain.

Wheat grain protein concentration and protein yield

Grain protein concentration between the treatments was statistically significant ($p = 0.01$) (Table 3, Figure 4). Protein concentration in grain depends on the crop specie and variety, but also reflect the soil nitrogen level. A low N fertility soil will generally result in low protein percentage in the grain for a particular crop. Exceptions may result when grain yields are low due to other growth promoting or limiting factors such as available water.

Only five legume treatments - Nangeela subclover, Nungarin, Clare and GERALTON subclovers, and Jemalong medic, resulted in significantly lower ($p = 0.05$) protein content compared to the grain fallow treatment. This might then suggest that these low values are the result of a low soil nitrogen content. However, these lower protein levels more likely reflect a dilution effect resulting from the higher yields of these treatments compared to the summer fallow control rather than reflecting lower nitrogen fertility in these treatments.

The greatest protein concentrates were obtained with Ultra and Unicrop lupines. Since the lupines failed, this further substantiates that these plots represent a double summer fallow treatment. Soil chemical test results should help elucidate the hypotheses of double summer fallow effect and the dilution effect on grain protein.

A slightly lower response of 15.2 percent protein content was observed with faba bean plots but was not significantly different from

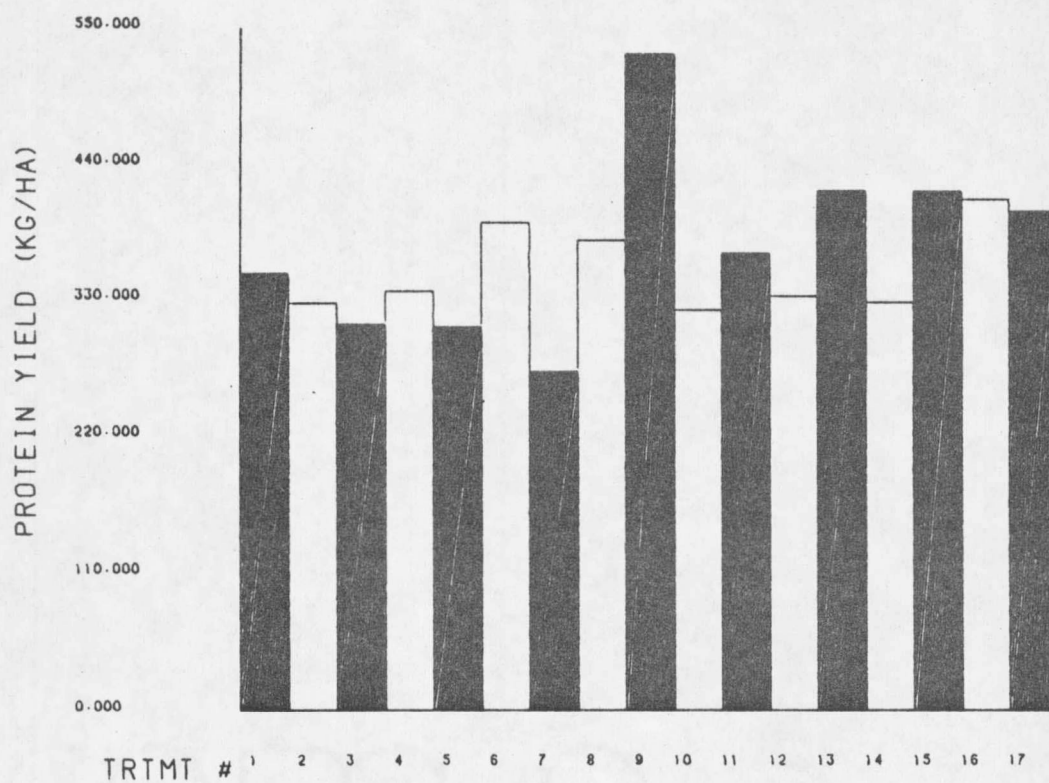


Figure 4. Wheat protein yield from annual-legume/cereal rotation plots at Bozeman, Montana, 1981.

the greatest response. A protein concentration difference of 1.0 percent was noted between the Australian medics (14.3 percent) and the subterranean clovers (13.9 percent). This also illustrates the dilution effect as the subterranean clover treatments produced higher grain yields.

Protein yields varied from a low of 271.80 Kg/ha for the summer fallow control treatment up to 529.12 Kg/ha for black medic treatment and were found to be significantly different ($p = 0.01$) (Table 3).

Seven legume treatments resulted in protein yields significantly higher than the summer fallow control treatment: Harbinger medic due to its high wheat grain yield (2581 Kg/ha) coupled with a high grain protein concentration (15.13 percent), black medic treatment due to both high wheat grain yield and high protein percentage (15.17 percent), faba bean treatment due to a high wheat grain of 2746 Kg/ha and a protein concentration of 15.23 percent, Maral Schaftal clover due mainly to a high wheat grain yield, and the lupine treatments as a result of high grain protein concentration. The high protein yields of the lupine treatments are attributed to the double summer fallow which these treatments, in effect, provided.

On the average, the Australian medics yielded more protein than the clovers but the difference was negligible (5.6 Kg/ha).

The protein yields data also substantiate the hypothesis of dilution effect on some of the legume treatments. In effect, the

five legume treatments, Nangeela, Nungarin, Clare and GERALTON sub-clovers, and Jemalong medic which have been shown to have a low protein concentration, resulted in total protein yields of 29 percent, 22.5 percent, 13.2 percent, 20.2 percent and 18.4 percent greater than the control plots respectively.

Grain total nitrogen (percent N) and total N uptake

Grain total nitrogen (percent) and total N uptake are shown in Table 4. There is consistency between the percent N measured by the semimicro Keldhal method and the percent protein measured by the infrared analyzer. However, a higher protein percentage would result if total nitrogen (percent) was converted to protein using the conversion factor $\text{Percent N} \times 6.7 = \text{Percent protein}$.

Unlike grain protein concentration, the total N (percent) was not significantly different ($p = 0.05$). Ten of the legume treatments plus the fallow control treatment resulted in total wheat N greater than 3 percent and only six legume treatments resulted in total wheat N of less than 3 percent.

Total N uptake in grain showed a significant difference ($p = 0.05$). The lowest total N uptake resulted from the summer fallow control treatment which is indicative of the low availability of this element in the plot.

The greatest total N uptake was obtained with black medic

Table 4. Grain total N, wheat straw total N, and total N uptake of Pondera spring wheat at Bozeman, Montana in 1981 following various 1980 legume crops.

1980 Crop	Wheat grain total N %	Wheat straw total N %	Total N up- take Kg/ha
Nangeela	2.84	0.39	74.62
Jemalong	2.98	0.42	70.76
Northam	3.47	0.43	73.11
Cyprus	3.15	0.44	70.90
Clare	2.78	0.49	62.00
Harbinger	2.70	0.46	70.20
Grain-fallow	3.16	0.49	58.47
Daliak	2.83	0.39	76.67
Black medic	3.32	0.50	116.98
Geralton	2.94	0.40	68.77
Ghor	3.08	0.51	75.50
Nungarin	3.03	0.42	74.17
Unicrop	3.26	0.50	86.05
Robinson	3.18	0.54	67.61
Giza III	3.14	0.46	86.67
Maral Schaftal	3.11	0.39	88.90
Ultra	3.33	0.47	84.64
Level of significance	N.S.	N.S.	0.05
Lsd p = 0.05			27.08 Kg/ha
Cv %		17.5	21.1

treatment. The N uptake of the Australian medics and the clover was similar (71 versus 74 Kg/ha).

All legume treatments outyielded the control plots and thus demonstrate again that the low total N percentage obtained in some of the legume treatments do not reflect low N fertility in those plots but rather a dilution effect.

Wheat tillers, tiller density and plant height

Wheat tillers/plant, density and height data are reported in Table 5. In general the number of tillers per plant was low but showed a significant difference ($p = 0.05$). Low tillering was observed with the control treatment 2.26 tillers/plant and high tillering was noted with Ultra lupine (3.45 tillers/plant), black medic (3.01 tillers per plant) and Cyprus medic (3 tillers per plant).

Contrary to tillers/plant, plant density (tillers/m²) was not significantly different. This indicates that tillering was mainly a compensatory mechanism in this experiment. Low plant stand was compensated by more tillering so that plant density was kept uniform.

Plant height differences were visible in the field as shown in Plates I and II and were statistically significant ($p = 0.01$). Values varied from 56 cm for the control treatment to 73 cm for black medic treatment. All legume treatments were taller than the control treatment. In Plate I, the noticeable dip in plant height of the middle

Table 5. Mean average tillers/plant, density and height of spring wheat grown following various legume crops at Bozeman, Montana, 1981.

1980 crop	Tillers/plant	Density Tillers/M ²	Height cm
Nangeela	2.97	330.0	70.17
Jemalong	2.63	284.5	67.83
Northam	2.43	387.8	64.50
Cyprus	3.00	315.5	66.00
Clare	2.53	315.5	67.50
Harbinger	2.68	281.1	69.67
Grain-fallow	2.26	255.6	57.50
Daliak	2.87	337.8	68.33
Black medic	3.01	326.7	72.50
Geralton	2.60	280.0	67.33
Ghor	2.80	323.4	65.33
Nungarin	2.29	275.6	67.83
Unicrop	2.51	282.2	66.00
Robinson	2.31	281.1	66.67
Giza III	2.84	336.7	69.33
Maral Schaftal	2.86	308.9	68.67
Ultra	3.45	352.9	62.83
Level of significance	0.05	N.S.	0.01
Lsd p = 0.05	0.54		7.01
Cv %	12.0	13.4	6.28



Plate 1. Pondera spring wheat growing in plots previously cropped to annual legumes at Bozeman, Montana, 1981.

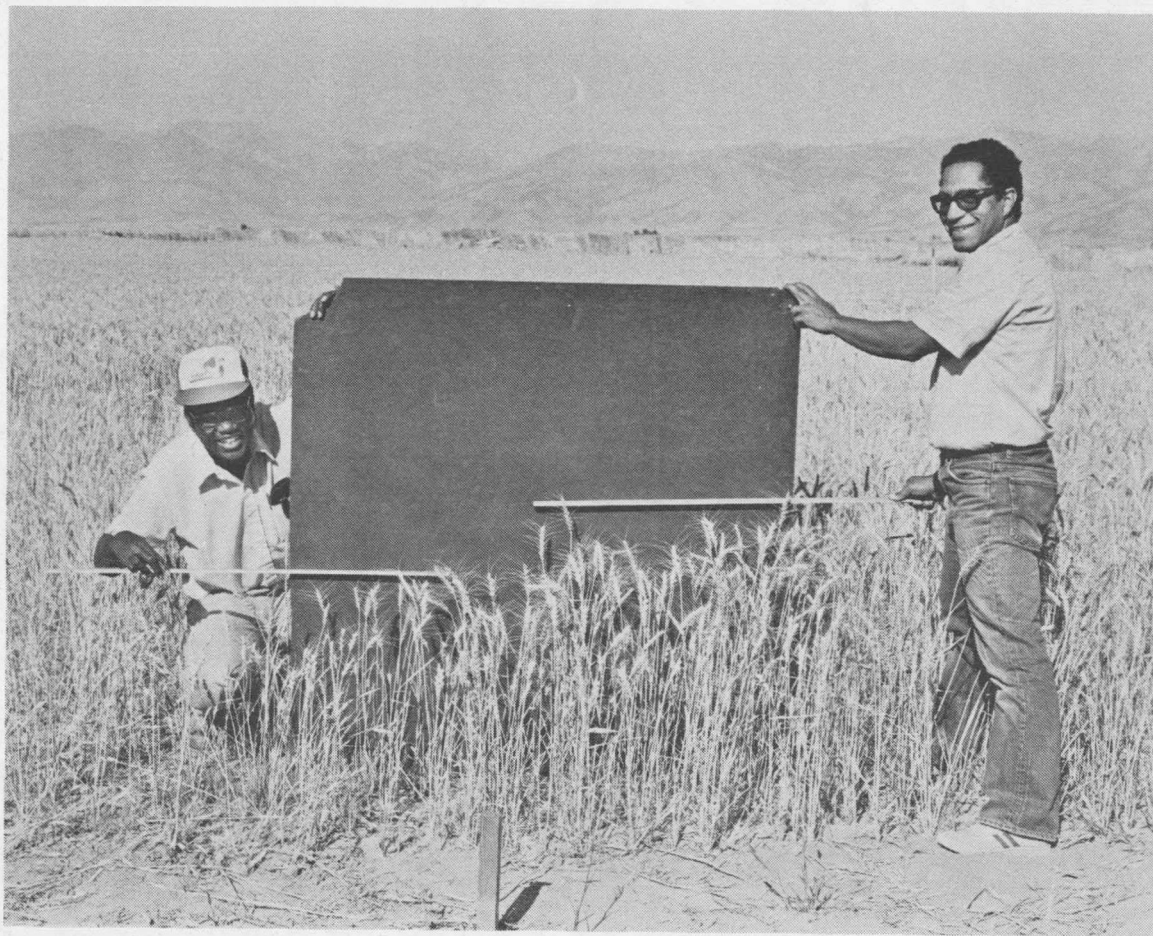


Plate 2. Pondera spring wheat, after summer fallow on left, after Maral Schaftal clover on right at Bozeman, Montana, 1981.

replication denotes the location of the summer fallow control treatment. Plate II shows the specific difference between the summer fallow control (left and the Maral Schaftal clover (right) treatments.

Effect on soil water relations

Water relations in the soil at wheat planting time, 1981

Total stored water in the soil for the following depths, 0 - 30 cm, 0 - 60 cm, 0 - 120 cm, 30 - 120 cm. and 60 - 120 cm, are reported in Table 6 and Figure 5 for total stored water in 0 - 120 cm soil depth.

None of the different soil depths showed significant differences in their water content at planting time. These results would indicate that stored soil water was the same irrespective of the treatment. Average values were 7.0 cm, 13.6 cm, 25.17 cm, 18.15 cm, and 11.57 cm for the 0 - 30, 0 - 60 cm, 0 - 120, 30 - 120, and 60 - 120 cm depth of soil respectively. However, the control plot which was summer fallowed the previous year had more stored water than any of the legume treatments, but that difference was not enough to influence the test of significance. Thus, yield differences in the 1981 wheat crop cannot be attributed to differences in stored soil water.

Water relations in the soil at harvest time

The stored water at harvest time was significantly different

Table 6. Pre-plant total soil water content of cereal/legume rotation plots at Bozeman, Montana, 17 April, 1981.

1980 crop	Depths, cm.				
	0-30	0-60	0-120	30-130	60-120
Nangeela	7.33	13.97	24.78	17.45	10.81
Jemalong	7.17	13.83	25.47	18.30	11.64
Northam	7.15	13.76	25.44	18.29	11.68
Cyprus	7.11	13.57	24.43	17.32	10.86
Clare	7.10	13.82	26.21	19.11	12.39
Harbinger	6.79	13.29	24.96	18.16	11.66
Grain-fallow (control)	6.95	13.99	26.29	19.34	12.30
Daliak	7.32	13.88	25.35	18.03	11.47
Black medic	6.96	13.24	24.88	17.92	11.64
Geralton	7.12	13.49	24.42	17.25	10.92
Ghor	7.09	13.84	25.61	18.52	11.76
Nungarin	6.83	13.58	25.94	19.10	12.35
Unicrop	6.93	13.54	25.59	18.66	12.05
Robinson	6.86	13.26	24.65	17.79	11.39
Giza III	6.68	13.26	24.10	17.42	10.84
Maral Schaftal	7.13	13.54	24.29	17.15	10.75
Ultra	6.79	13.38	25.47	18.68	12.09
Level of significance	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	5.5	3.7	3.9	5.0	7.4

N.S. = Non significant

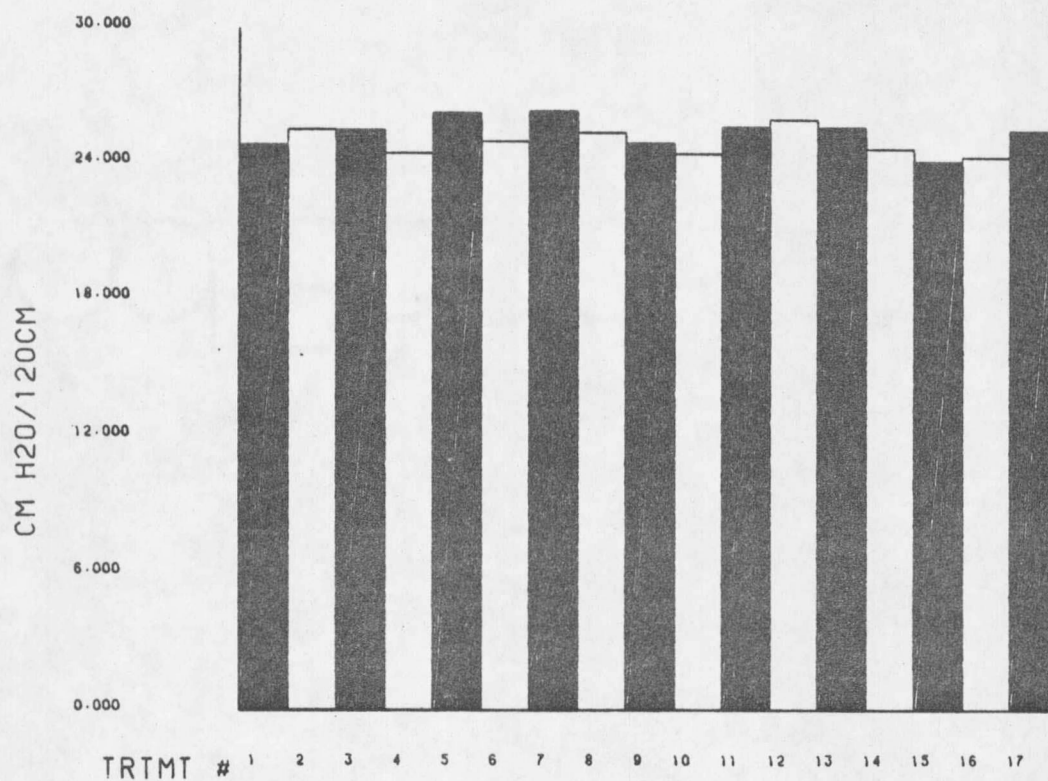


Figure 5. Spring cm of water to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

($p = 0.01$) at all depths measured (Table 7 and Figure 6). In the 0 - 30 cm soil depth, the summer fallow control treatment had 3.75 cm of water. Compared to the control, ten legume treatments contained significantly lower water to a 30 cm depth at harvest. Only two legume treatments, Geralton (3.86 cm) and Nungarin (3.93 cm) subclovers had more water left in the surface 30 cm than the control plots but these differences were not statistically significant. The data show that the control treatment had, in general, more water remaining in its profile than did most of the legume treatments. This suggests that cereal/legume rotations such as these may be preferable to the alternate crop/fallow rotation in areas susceptible to saline-seep problems.

In the 0 - 60 cm soil depth, the greatest amount of water remaining in the profile was that of the control treatment, 8.78 cm, compared to the lowest water content of 7.10 cm for the Robinson medic treatment. Only three legume treatments did not show a significant lower value, Unicrop 8.13 cm, Nungarin subclover, 8.24 cm, and Ghor medic, 8.09 cm.

In the 0 - 90 cm, the control plot resulted in the greatest amount of water remaining in the profile with 14.03 cm. The lowest value was noted for black medic with 11.27 cm. The Australian medics had an average water content of 12.40 cm and the clovers 12.56 cm. The Egyptian faba bean treatment was left with 12.24 cm of water.

Table 7. Post-harvest total soil water content of cereal/legume rotation plots at Bozeman, Montana, 24 September 1981.

1980 crop	Depths, cm				
	0-30	0-60	0-120	30-120	60-120
Nangeela	3.49	7.60	18.09	14.61	10.49
Jemalong	3.70	7.99	17.93	14.23	9.943
Northam	3.63	7.55	17.18	13.54	9.627
Cyprus	3.64	7.88	17.86	14.22	9.980
Clare	3.68	7.89	17.56	13.87	9.667
Harbinger	3.73	7.76	16.81	13.08	9.053
Grain-fallow	3.75	7.78	19.64	15.89	10.85
Daliak	3.52	7.63	17.45	13.93	9.820
Black medic	3.44	7.25	15.97	12.53	8.717
Geralton	3.86	8.01	17.61	13.75	9.600
Ghor	3.75	8.09	18.27	14.52	10.18
Nungarin	3.93	8.24	18.36	14.43	10.12
Unicrop	3.65	8.13	18.16	14.51	10.03
Robinson	3.36	7.10	16.73	13.37	9.630
Giza III	3.65	7.69	17.32	13.67	9.633
Maral Schaftal	3.40	7.23	16.21	12.81	8.980
Ultra	3.50	7.62	17.37	13.87	9.750
Level of significance	0.01	0.01	0.01	0.01	0.01
Lsd 0.05	0.25cm	0.56cm	1.21cm	1.13cm	0.36cm
0.01	0.34cm	0.75cm	1.63cm	1.52cm	0.48cm
Cv%	4.15	4.31	4.14	4.84	5.24

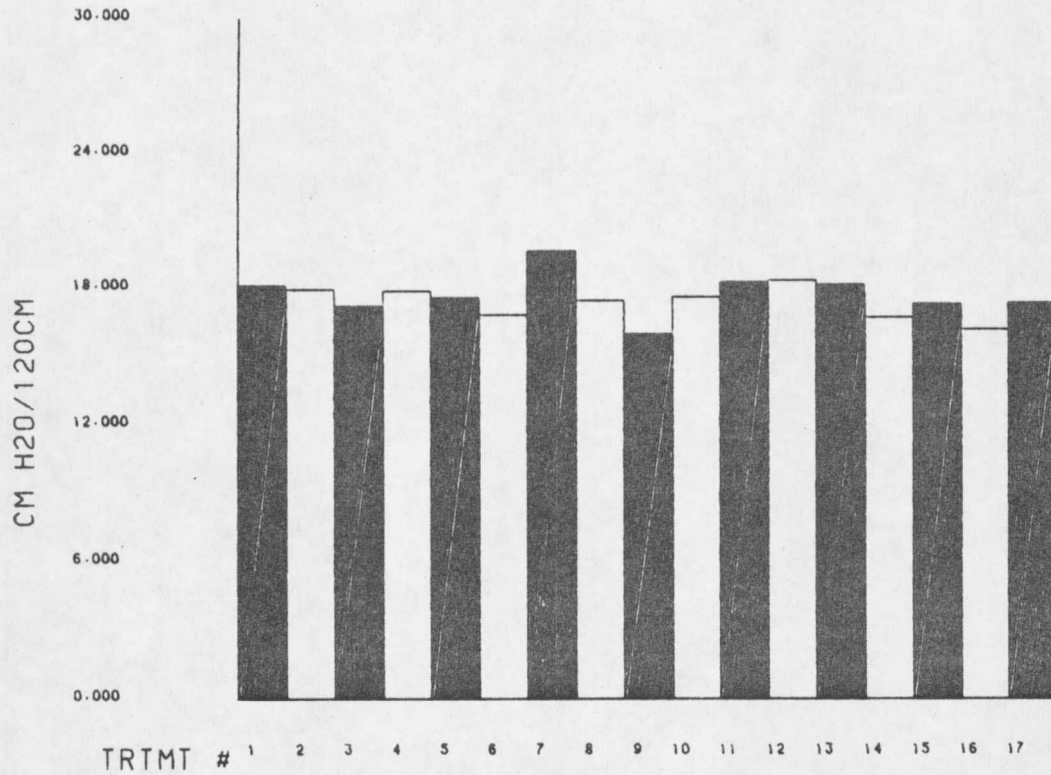


Figure 6. Fall cm of water to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

In the 0 - 120 cm. depth, values varied from a low of 15.97 cm for the black medic treatment to a high value of 19.64 cm for the control plots. All legume treatments were significantly lower ($p = 0.05$) compared to the control treatment.

The greatest amount of water content in the 30 - 120 cm soil depth was obtained with the control treatment, 15.89 cm and the lowest value was noted with the black medic treatment, 12.53 cm, followed by Maral Schaftal clover, 12.81 cm, and Harbinger medic, 13.08 cm. The same trend was also observed with the 60 - 120 cm depth water content data.

Total water used and water use efficiency

Total water used includes both the difference between the stored water at planting and harvest time plus the growing season precipitation. Theoretically this includes the water used for transpiration, evaporation and probably a small fraction moving below the root zone.

On the average, 34.0 cm of water was used during the growing season (Table 8). There was no significant difference between the treatments. However, the control treatment used less water (non significant) than all the legume treatments except the Cyprus medic treatment (see Figure 7).

Water use efficiency is the amount of harvested crop dry matter that can be produced from a given quantity of water. It was calculated

Table 8. Stored soil water use, total water use and water use efficiency for Pondera spring wheat following various legume crops at Bozeman, Montana, 1981.

1980 crop	Soil Water used to 120 cm depth cm	Total water used ^{1/} cm	Water use Efficiency ^{2/} Kg/cm
Nangeela	6.69	32.98	79.62
Jemalong	7.54	33.83	70.09
Northam	8.26	34.55	60.87
Cyprus	6.57	32.86	69.26
Clare	8.65	34.94	64.25
Harbinger	8.15	34.44	74.94
Grain-fallow	6.65	32.94	55.37
Daliak	7.90	34.19	79.06
Black medic	8.91	34.98	100.09
Geralton	6.81	33.10	69.70
Ghor	7.34	33.63	71.16
Nungarin	7.58	33.87	72.25
Unicrop	7.43	33.72	78.41
Robinson	8.73	35.02	60.65
Giza III	6.78	33.07	83.04
Maral Schaftal	8.07	34.36	83.29
Ultra	8.10	34.39	73.07
Level of significance	N.S.	N.S.	0.05
Lsd 0.05	-	-	20.4
CV %	17.5	4.0	16.6

^{1/} Sum of soil water used plus 26.29 cm growing season rainfall.

^{2/} Wheat grain produced divided by total water used.

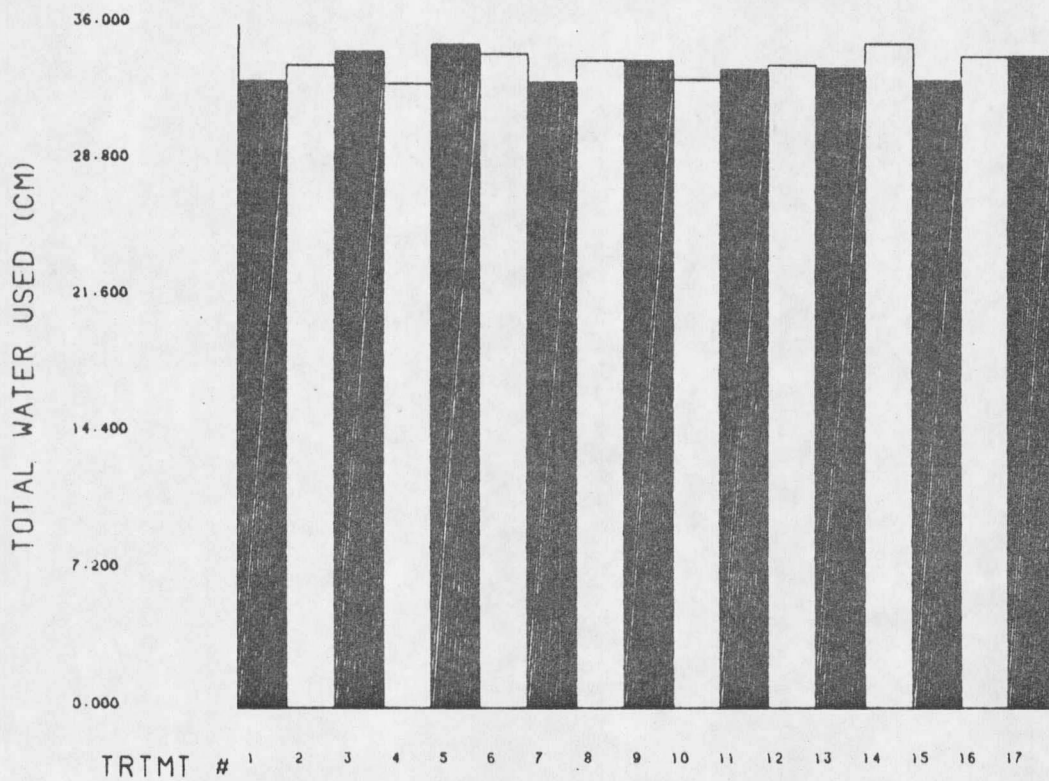


Figure 7. Total water used to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

here as the wheat grain yield in Kg/ha per unit cm of total water used. The treatments showed a significant difference at the 5 percent level (Table 8 and Figure 8). Values varied from as low as 55.37 Kg/cm of water used for the summer fallow control treatment to as high as 100.09 Kg/cm of water used for black medic. Legume treatments which resulted with significantly ($p = 0.05$) higher water use efficiency compared to the control and their percent increases are as follows:

Black medic	81 percent
Maral Schaftal	50 percent
Giza III faba bean	50 percent
Nangeela subclover	44 percent
Daliak subclover	43 percent
Unicrop lupine	42 percent

The Australian medics produced 69.22 Kg/cm and the clovers 72.72 Kg/cm. The responses obtained for the lupines and the faba bean treatments were 75.67 and 83.04 Kg/cm of water used respectively.

Discussion on the soil water relations

No significant differences were observed for soil water content at any depth at planting time. This indicates that all treatments, including the control, had stored the same amount of water. However, at harvest, significant differences were observed. There was more

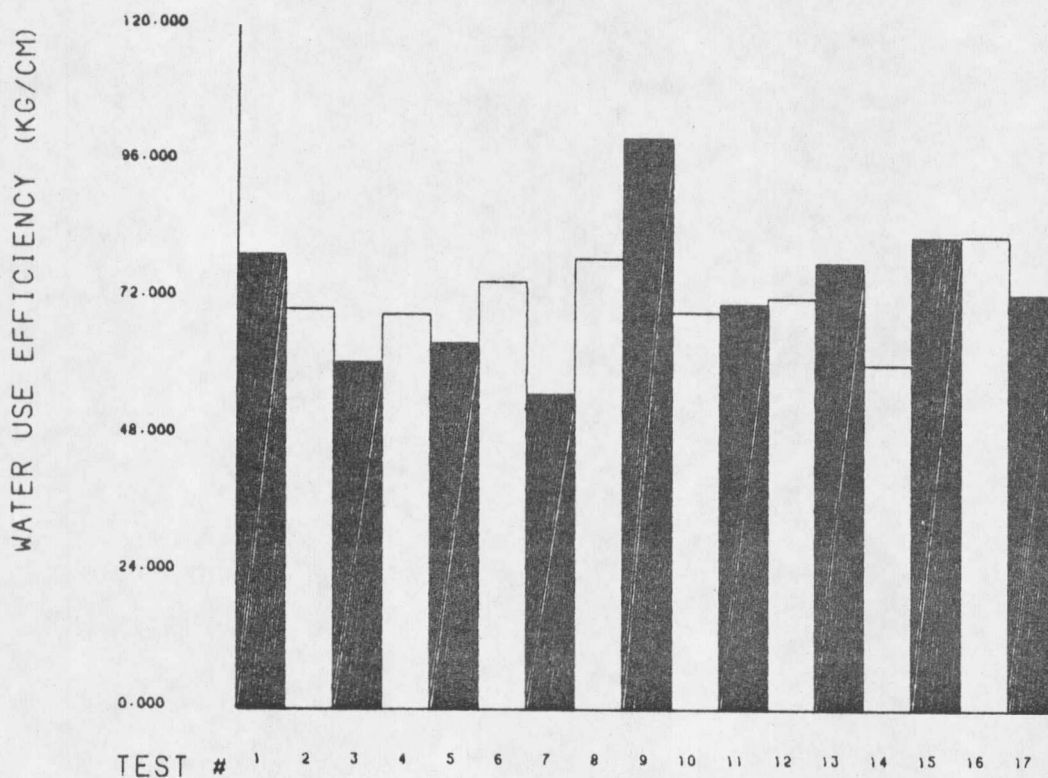


Figure 8. Wheat water use efficiency in kg of wheat grain per cm of water used following various legume crops at Bozeman, Montana, 1981.

available water in the control plots than in any of the legume treatment.

The hypothesis that the wheat grain yield increases, while maintaining respectable protein levels, resulted from increased soil fertility derived from the previous years legume residues is substantiated by these soil water data. The control plots contained more stored water at all depths after harvest than did the legume treatments. This suggests that improved soil fertility in the legume treated plots increased water use, whereas, soil fertility remained a limiting factor in the control plots. From the available water aspect, the cereal-fallow treatment had a slight but statistically insignificant advantage in yield potential.

So, undoubtedly, the legume treated plots had increased in soil fertility as expressed by increased grain yields, N uptake, protein yields, etc.

The total water use data and the water use efficiency data also substantiate the hypothesis of increased soil fertility. As already suggested, a high water use efficiency reflects a high soil fertility level. Plants growing on a high fertility soil tend to exhibit a greater water use efficiency.

The hypothesis of double summer effect on the lupine treatments is also substantiated by those water relations data. These legumes

failed in 1979 and 1980 seasons and could have not contributed much biologically fixed N or other nutrients via crop residues. Since these plots showed a significant higher water use efficiency, this suggests a high N level. This high N level likely comes from the two years of mineralization of soil N.

The water relations data in the 60 - 120 cm soil depth has shown that the cereal-fallow plots still have more stored water at harvest time than any of the legume treatments. This higher water content at this lower depth increases the potential for water movement below the root zone and, hence, the saline-seep hazard. The ability of the annual legume/cereal rotations to decrease the water levels at these lower soil depths demonstrates their potential use for saline-seep control.

Effects on Soil Properties

Initial soil fertility levels

Initial soil analysis results for Bray P, Olsen P, K, Na, Mg, Ca, Boron, sulfur, $\text{NO}_3\text{-N}$, pH, E.C. Zn, Cu, Fe and Mn at the 0 - 15 cm and 15 - 20 cm soil depths are reported in Appendix Table 10 and summarized in Tables 9, 10, 11, 12, and 13.

Except for Fe at the 15 - 30 cm depth, there were no significant differences ($P = 0.05$) in the soil fertility parameters measured.

Table 9.. Mean initial soil analysis data for Bray P, Olsen P and K in ppm

Crop	Bray P		Olsen P		K	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
<i>T. subterraneum</i> (Nangeela)	36.67	21.33	10.67	6.667	281.0	232.0
<i>Medicago truncatula</i> (Jemalong)	42.33	17.67	13.67	7.667	265.3	224.0
<i>T. subterraneum</i> (Northam)	51.67	19.67	14.00	8.000	273.7	229.3
<i>Medicago truncatula</i> (Cyprus)	49.00	20.33	13.00	8.333	275.7	232.0
<i>T. subterraneum</i> (Clare)	45.33	8.667	12.33	7.333	288.7	226.7
<i>Medicago littoralis</i> (Harbinger)	48.00	17.67	15.00	7.333	250.0	216.7
Grain-fallow	50.33	20.67	12.67	8.333	265.7	211.3
<i>T. subterraneum</i> (Daliak)	47.33	19.00	11.33	6.667	268.0	237.0
<i>Medicago lupulina</i> (Black medic)	49.67	15.33	15.00	8.000	255.3	244.7
<i>T. subterraneum</i> (Geraldton)	42.67	24.67	11.67	6.667	283.7	219.0
<i>Medicago truncatula</i> (Ghor)	39.67	17.00	10.00	6.333	273.3	211.0
<i>T. subterraneum</i> (Nungarin)	35.67	13.00	14.00	7.667	276.0	232.0
<i>Lupinus angustifolius</i> (Unicrop)	33.00	10.00	12.67	7.333	273.3	224.3
<i>Medicago scutellata</i> (Robinson)	45.33	20.67	12.00	6.667	268.0	206.0
<i>Vicia faba</i> (Giza III)	37.00	8.667	11.00	7.000	262.7	213.7
<i>T. resupinatum</i> (Maral Schaftal)	51.00	27.33	11.33	7.333	270.3	224.0
<i>Lupinus albus</i> (Ultra)	46.67	12.00	16.00	7.333	255.0	231.7
Means	44.20	17.27	12.73	7.333	269.7	224.4
Level of Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	24.72	63.08	25.70	14.72	7.95	7.70

Table 10. Mean initial soil analysis data for Na, Mg, and Ca in ppm

Crop	Na		Mg		Ca	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
<i>T. subterraneum</i> (Nangeela)	0.000	0.033	2.967	3.033	37.67	38.67
<i>Medicago truncatula</i> (Jemalong)	0.033	0.033	2.800	2.900	37.00	37.67
<i>T. subterraneum</i> (Northam)	0.033	0.000	2.867	3.200	37.67	38.67
<i>Medicago truncatula</i> (Cyprus)	0.000	0.033	2.933	3.033	38.67	38.67
<i>T. subterraneum</i> (Clare)	0.000	0.033	2.900	2.867	36.00	36.67
<i>Medicago littoralis</i> (Harbinger)	0.033	0.033	2.933	2.533	35.33	35.33
Grain-fallow	0.033	0.033	2.633	2.833	35.00	35.67
<i>T. subterraneum</i> (Daliak)	0.033	0.033	2.500	3.000	36.67	38.67
<i>Medicago lupulina</i> (Black medic)	0.000	0.033	2.100	2.533	35.67	36.00
<i>T. subterraneum</i> (Geraldton)	0.000	0.033	2.967	3.033	37.00	36.67
<i>Medicago truncatula</i> (Ghor)	0.033	0.033	2.967	2.900	34.00	38.33
<i>T. subterraneum</i> (Nungarin)	0.000	0.033	3.000	2.867	35.00	36.00
<i>Lupinus angustifolius</i> (Unicrop)	0.000	0.067	2.967	3.200	36.67	38.67
<i>Medicago scutellata</i> (Robinson)	0.033	0.067	2.733	2.933	36.67	36.00
<i>Vicia faba</i> (Giza III)	0.033	0.000	2.700	2.933	38.33	37.00
<i>T. resupinatum</i> (Maral Schaftal)	0.033	0.067	2.733	3.033	38.00	38.67
<i>Lupinus albinus</i> (Ultra)	0.000	0.033	2.833	3.033	36.33	39.00
Means	0.0177	0.0353	2.796	2.933	36.57	37.43
Level of Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	168.3	119.05	11.89	12.11	7.49	10.66

Table 11. Mean initial soil analysis data for Boron, Sulfur and NO₃N in ppm

Crop	Boron		Sulfur		NO ₃ N	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
<i>T. subterraneum</i> (Nangeela)	0.67	0.40	1.53	1.17	8.53	8.73
<i>Medicago truncatula</i> (Jemalong)	0.67	0.53	1.30	0.47	9.03	9.07
<i>T. subterraneum</i> (Northam)	0.53	0.40	1.43	1.70	10.87	11.50
<i>Medicago truncatula</i> (Cyprus)	0.53	0.37	1.83	0.43	8.27	7.20
<i>T. subterraneum</i> (Clare)	0.63	0.53	1.57	1.43	9.47	9.80
<i>Medicago littoralis</i> (Harbinger)	0.67	0.60	1.57	0.80	7.97	8.83
Grain-fallow	0.60	0.60	1.90	2.60	8.20	9.43
<i>T. subterraneum</i> (Daliak)	0.60	0.40	0.30	0.80	7.63	7.33
<i>Medicago lupulina</i> (Black medic)	0.67	0.60	1.70	0.30	8.73	8.20
<i>T. subterraneum</i> (Geraldton)	0.67	0.60	0.57	0.43	8.37	8.27
<i>Medicago truncatula</i> (Ghor)	0.80	0.60	0.30	0.30	6.90	7.77
<i>T. subterraneum</i> (Nungarin)	0.73	0.60	1.27	0.57	9.97	10.17
<i>Lupinus angustifolius</i> (Unicrop)	0.60	0.53	1.83	0.30	10.17	10.10
<i>Medicago scutellata</i> (Robinson)	0.57	0.47	1.27	1.13	8.33	7.40
<i>Vicia faba</i> (Giza III)	0.67	0.47	2.23	1.03	8.03	7.93
<i>T. resupinatum</i> (Maral Schaftal)	0.60	0.53	1.57	1.53	8.97	8.53
<i>Lupinus albinus</i> (Ultra)	0.67	0.53	0.90	0.90	8.50	9.17
Means	0.64	0.52	1.36	0.94	8.70	8.79
Level of significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	25.08	39.35	67.23	118.53	19.12	19.04

Table 12. Mean initial soil analysis data for pH, EC, Zn

Crop	pH		EC		Zn	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
<i>T. subterraneum</i> (Nangeela)	8.33	8.40	0.77	0.77	0.45	0.41
<i>Medicago truncatula</i> (Jemalong)	8.40	8.30	0.77	0.77	0.37	0.30
<i>T. subterraneum</i> (Northam)	8.50	8.47	0.77	0.77	0.37	0.32
<i>Medicago truncatula</i> (Cyprus)	8.40	8.37	0.73	0.77	0.42	0.31
<i>T. subterraneum</i> (Clare)	8.40	8.50	0.77	0.77	0.38	0.27
<i>Medicago littoralis</i> (Harbinger)	8.37	8.43	0.77	0.73	0.37	0.26
Grain-fallow	8.27	8.17	0.80	0.80	0.48	0.37
<i>T. subterraneum</i> (Daliak)	8.37	8.33	0.77	0.77	0.37	0.30
<i>Medicago lupulina</i> (Black medic)	8.33	8.30	0.73	0.77	0.36	0.30
<i>T. subterraneum</i> (Geraldton)	8.37	8.37	0.73	0.77	0.34	0.30
<i>Medicago truncatula</i> (Ghor)	8.40	8.40	0.77	0.77	0.39	0.30
<i>T. subterraneum</i> (Nungarin)	8.43	8.53	0.77	0.77	0.38	0.45
<i>Lupinus angustifolius</i> (Unicrop)	8.37	8.40	0.73	0.77	0.37	0.37
<i>Medicago scutellata</i> (Robinson)	8.27	8.30	0.80	0.80	0.41	0.27
<i>Vicia faba</i> (Giza III)	8.43	8.43	0.77	0.77	0.40	0.31
<i>T. resupinatum</i> (Maral Schaftal)	8.30	8.30	0.80	0.80	0.43	0.35
<i>Lupinus albinus</i> (Ultra)	8.23	8.27	0.80	0.80	0.48	0.37
Means	8.36	8.37	0.77	0.77	0.40	0.33
Level of significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	1.40	1.46	5.33	5.11	14.56	33.77

Table 13. Mean initial soil analysis data for Fe, Cu and Mn in ppm

Crop	Fe		Cu		Mn	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
<i>T. subterraneum</i> (Nangeela)	9.70	9.20	3.00	2.87	18.37	13.70
<i>Medicago truncatula</i> (Jemalong)	8.93	8.53	2.90	2.70	20.60	13.90
<i>T. subterraneum</i> (Northam)	8.10	7.63	2.93	2.83	15.90	12.70
<i>Medicago truncatula</i> (Cyprus)	7.73	7.63	2.70	2.47	15.37	15.80
<i>T. subterraneum</i> (Clare)	7.83	7.27	3.07	2.70	15.57	12.37
<i>Medicago littoralis</i> (Harbinger)	8.57	8.37	2.87	2.70	16.10	12.37
Grain-fallow	8.10	7.53	2.87	2.57	16.10	12.50
<i>T. subterraneum</i> (Daliak)	7.73	8.00	2.60	2.40	17.30	12.90
<i>Medicago lupulina</i> (Black medic)	7.73	7.83	2.57	2.63	20.00	13.30
<i>T. subterraneum</i> (Geraldton)	8.53	9.03	2.67	2.53	15.70	12.57
<i>Medicago truncatula</i> (Ghor)	9.13	8.43	3.00	2.73	16.10	13.83
<i>T. subterraneum</i> (Nungarin)	8.67	8.63	2.77	2.73	17.03	13.23
<i>Lupinus angustifolius</i> (Unicrop)	8.80	8.57	2.90	2.63	16.77	11.70
<i>Medicago scutellata</i> (Robinson)	8.53	7.30	2.90	2.47	20.87	10.97
<i>Vicia faba</i> (Giza III)	8.20	8.30	2.93	2.70	19.00	12.57
<i>T. resupinatum</i> (Maral Schaftal)	8.20	7.53	2.63	2.67	13.30	11.50
<i>Lupinus albinus</i> (Ultra)	7.83	6.80	2.50	2.37	16.63	11.70
Means	8.37	8.04	2.81	2.629	17.10	12.80
Level of significance	N.S.	0.01	N.S.	N.S.	N.S.	N.S.
CV %	9.52	8.67	8.02	7.61	19.77	18.58

Also, the lowest level of Fe measured is considered to be adequate.

It appears from these average values that the soil was uniformly low or bordering on low for the macronutrients and possibly Zn. This is not surprising since the experiment was placed on an eroded soil of low productivity.

Soil $\text{NO}_3\text{-N}$ at planting and harvest time for the 1981 season

Soil $\text{NO}_3\text{-N}$ data at planting and harvest time are reported in Tables 14 and 15.

In the 0 - 15 cm soil depth, $\text{NO}_3\text{-N}$ values were not significantly different at planting time. However, only the Ghor medic treatment with 12.4 ppm contained less $\text{NO}_3\text{-N}$ than the control plot level of 12.8 ppm. High $\text{NO}_3\text{-N}$ levels were observed for black medic, 22.0 ppm, and Clare, 22.3 ppm.

Considering the 0 - 30 cm depth, however, $\text{NO}_3\text{-N}$ levels were significantly different ($p = 0.05$). Values ranged from 3.3 ppm for the control treatment to 8.0 ppm for the Nangeela subclover treatment. The high $\text{NO}_3\text{-N}$ levels for the successful legume treatments presumably resulted from decomposition of the previous years residues while the high levels for the lupine plots resulted from mineralization during two years of summer fallow.

The differences in soil $\text{NO}_3\text{-N}$ at the 30 - 60 cm depth were not statistically significant whereas those at the 60 - 120 cm depth were

Table 14 . Average spring $\text{NO}_3\text{-N}$ at different soil depths following various legume crops at Bozeman, Montana, 1981.

1980 crop	Spring $\text{NO}_3\text{-N}$ in ppm			
	0-15cm	0-30cm	30-60cm	60-120cm
Nangeela	19.1	8.0	3.6	2.4
Jemalong	17.2	5.9	4.0	2.5
Northam	17.4	6.1	4.1	5.7
Cyprus	16.5	6.0	3.5	5.3
Clare	22.3	7.7	3.9	4.5
Harbinger	17.3	6.3	4.1	6.4
Grain-fallow	12.8	3.3	4.0	2.1
Daliak	16.1	7.1	4.3	3.4
Black medic	22.0	5.4	6.4	8.8
Geralton	18.1	7.1	4.0	5.2
Ghor	12.4	5.4	4.8	7.2
Nungarin	14.6	5.9	3.5	2.8
Unicrop	13.7	6.7	6.6	9.1
Robinson	14.8	5.1	3.8	7.3
Giza III	14.1	5.0	5.4	6.3
Maral Schaftal	19.9	7.1	4.6	4.6
Ultra	13.6	8.0	5.6	6.3
Level of significance	N.S.	0.05	N.S.	0.01
Lsd 0.05	--	2.5	--	3.0
CV %	23.7	23.7	30.4	33.7

Table 15. Average fall $\text{NO}_3\text{-N}$ at different soil depths following various legume crops at Bozeman, Montana, 1981

1980 crop	Fall $\text{NO}_3\text{-N}$ in ppm				
	0-15 cm	15-30cm	30-60cm	60-90cm	90-120cm
Nangeela	3.9	2.9	2.5	2.3	2.1
Jamalong	3.4	3.2	2.1	1.9	1.9
Northam	3.0	2.7	2.4	1.9	2.1
Cyprus	4.0	3.3	2.1	2.0	2.3
Clare	4.0	3.2	2.5	2.1	2.0
Harbinger	3.5	3.0	2.5	2.1	2.7
Grain-fallow	3.6	3.0	2.4	1.9	2.1
Daliak	3.6	3.1	1.7	2.0	2.1
Black medic	3.6	2.5	2.2	1.5	3.1
Geralton	3.5	2.7	1.9	1.8	2.2
Ghor	2.9	2.7	2.1	1.9	2.3
Nungarin	3.3	2.8	2.2	1.8	2.1
Unicrop	3.2	2.7	1.6	1.6	3.1
Robinson	3.0	2.0	1.7	1.4	1.7
Giza III	3.5	2.5	1.7	1.6	2.3
Maral Schaftal	4.2	2.5	2.1	1.6	1.9
Ultra	3.4	3.2	2.0	1.6	2.3
Level of significance	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	21.6	20.3	21.4	19.9	38.9

significant ($p = 0.01$). This probably indicated differential decomposition and mineralization of the various residues, denitrification and leaching into the lower profile. Improved physical parameters such as aeration and water infiltration would be an expected result of the legume treatments. Improved aeration would increase decomposition and N mineralization while decreasing denitrification. Increased water infiltration would be expected to move $\text{NO}_3\text{-N}$ to lower soil depths. This interpretation can be reconciled with the spring 1981 uniform soil water levels by assuming that low infiltration rates and/or evaporation losses from the control plots in 1980 was equivalent to evapo-transpiration by the legume crops.

In the entire profile, 0 - 120 cm depth, $\text{NO}_3\text{-N}$ varied from a low value of 51.3 Kg/ha for the control treatment to as high as 137 Kg/ha for the black medic treatment, and 117.5 and 149.8 Kg/ha for the two lupine treatments, which, in effect, were double summer fallow treatments (Table 16, Figure 9). These values were highly statistically significant ($p = 0.01$). The higher N fertility levels (90 to 140 Kg/ha) produced by the more effective legume treatments come very close to meeting the N requirements for maximum dryland wheat and barley production in much of Montana. In most instances only an additional 10 to 15 Kg N/ha drilled with the seed would be required to bring available N to the recommended level.

Table 16. Spring and fall $\text{NO}_3\text{-N}$ and total $\text{NO}_3\text{-N}$ used to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

1980 crop	NO_3N at wheat planting time Kg/ha	NO_3N at harvest Kg/ha	NO_3N used Kg/ha
Nangeela	73.92	46.07	27.85
Jemalong	66.90	41.21	25.69
Northam	97.21	41.22	56.00
Cyprus	90.05	45.47	44.57
Clare	92.14	45.92	46.22
Harbinger	103.93	47.34	56.60
Grain-fallow	51.22	43.38	7.84
Daliak	81.24	41.06	40.18
Black medic	131.71	44.20	87.51
Geralton	96.02	40.32	55.70
Ghor	109.91	40.99	68.92
Nungarin	66.90	40.69	26.21
Unicrop	140.82	41.66	99.16
Robinson	111.70	32.63	79.07
Giza III	98.56	38.31	60.25
Maral Schaftal	93.93	39.87	54.06
Ultra	117.52	41.22	76.31
Level of Significance	0.01	N.S.	0.01
Lsd 0.05	33.86 Kg/ha	--	34.78 Kg/ha
CV %	21.3	--	38.9

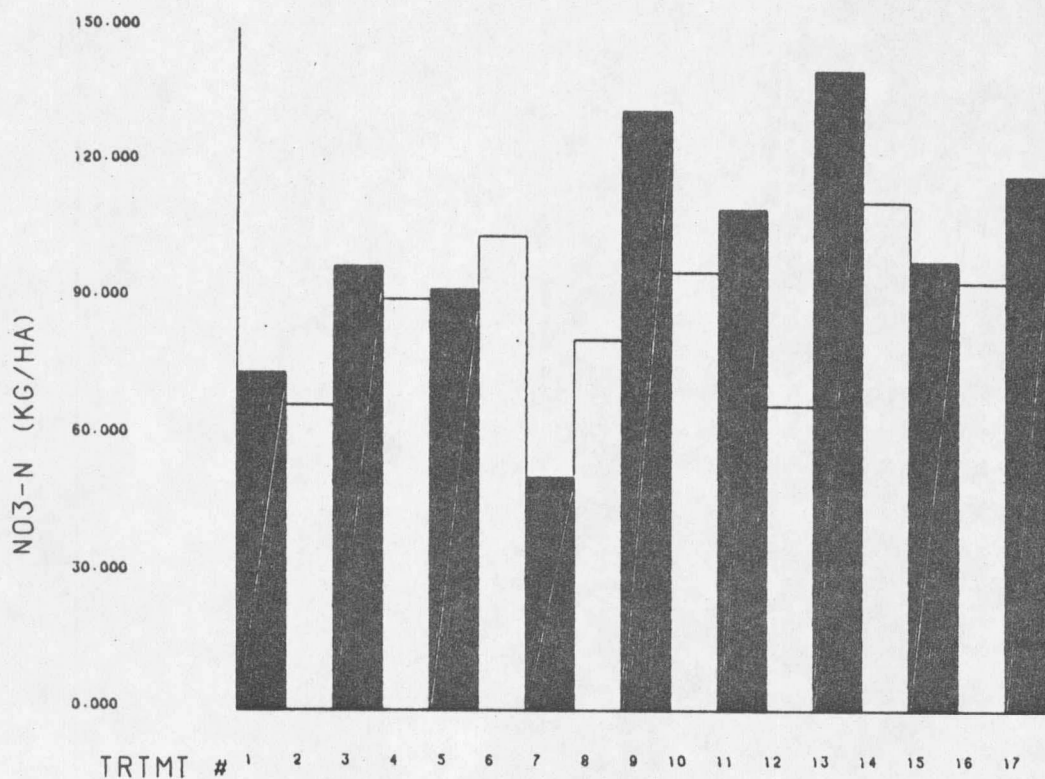


Figure 9. Spring $\text{NO}_3\text{-N}$ to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

NO₃-N at harvest time

At harvest, there were no significant differences in the soil NO₃-N values for the following depth increments: 0 - 15 cm, 15 - 30 cm, 30 - 60 cm, 60 - 90 cm, and 90 - 120 cm (Table 15). These NO₃-N levels at harvest represent what was left in the soil after plant uptake for dry matter and grain production and other fates of soil N such as leaching, immobilization and denitrification (Figure 10). Recropping a soil with these levels of residual available N with a cereal would require supplemental fertilizer N. Also of interest is the total quantity of NO₃-N utilized by each treatment (Table 16, Figure 11). The treatments showed a significant difference ($p = 0.01$). NO₃-N varied from a low value of 7.8 Kg/ha for the control treatment to as high as 87.5 Kg/ha for the black medic, 76.3 and 99.2 Kg/ha for the two lupine treatments. Compared to the spring wheat total N uptake of Table 4, these NO₃-N levels are the evidence that the higher N fertility levels produced by the more effective legume treatments come very close to meeting the N requirements for maximum spring wheat production. Black medic treatment supplied up to 91.3 percent of the N required, Robinson supplied more than required, 117 percent, Geralton 81.4 percent, and Harbinger 80.6 percent. The differences between the NO₃-N levels and the wheat total N uptake must have been compensated by mineralization of soil

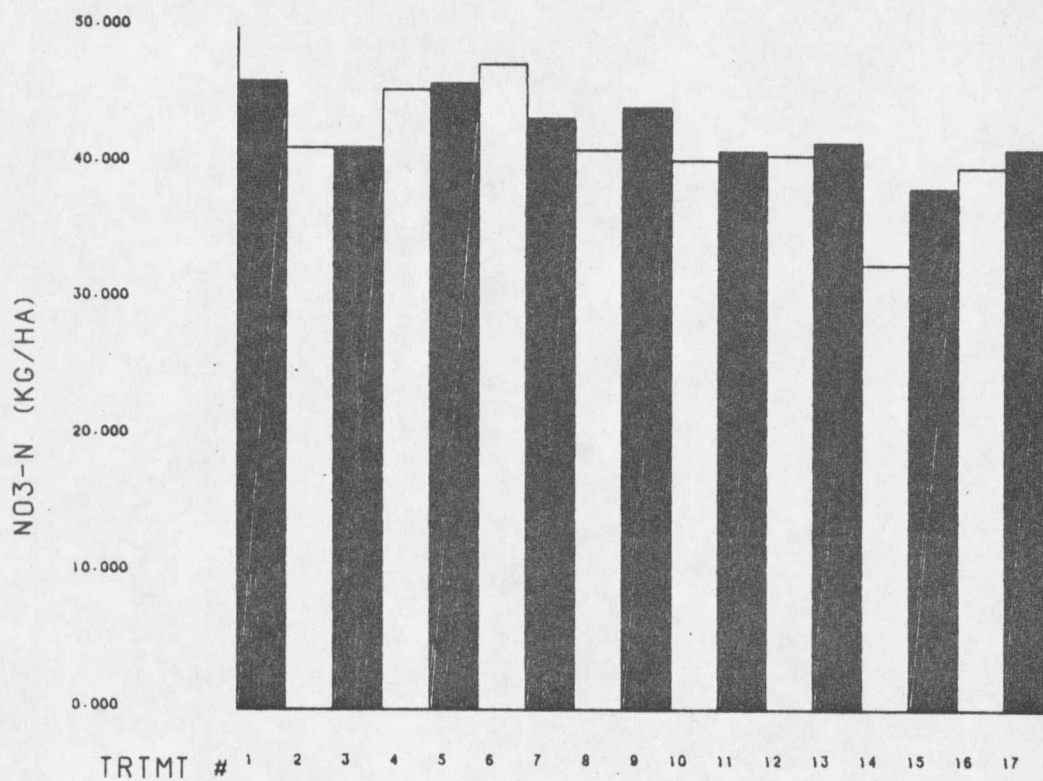


Figure 10. Fall $\text{NO}_3\text{-N}$ to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

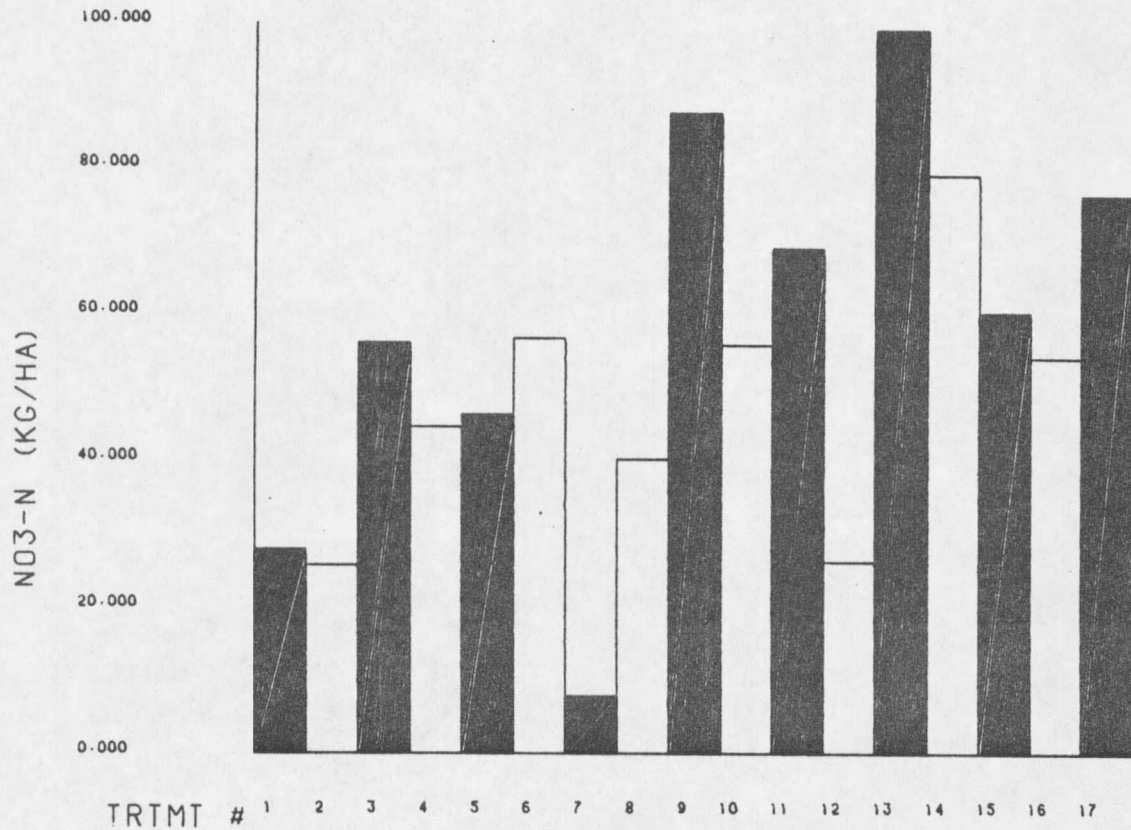


Figure 11. Total $\text{NO}_3\text{-N}$ utilized by the wheat crop to 120 cm soil depth following various legume crops at Bozeman, Montana, 1981.

organic matter during the growing season whereas the excess $\text{NO}_3\text{-N}$ in Robinson medic, 11.5 Kg/ha, and Unicrop, 13.1 Kg/ha, must have been immobilized or leached through the soil profile.

Discussion on $\text{NO}_3\text{-N}$

At planting time, the cereal-fallow control treatment showed a statistically significant lower $\text{NO}_3\text{-N}$ in its profile to 120 cm compared to the legume treatment plots. This is hypothesized as being the result of increased soil N inherited from the previous years legume residues. If this was the case, more crop yields would be expected from the legume treated plots and this was indeed the result. Also, the slightly lower grain protein contents exhibited by some treatments resulted from a dilution effect.

Wheat grown on the legume treated plots utilized more soil N during the growing season than that grown on the control plots. Apparently under these soil conditions, there is a critical minimum soil $\text{NO}_3\text{-N}$ concentration of 2 to 3 ppm below which most of the soil nitrates becomes positionally unavailable to the wheat roots. Except for the surface 15 cm, the soil in the control plots was near this critical minimum level throughout the season. This created an acute N deficiency in the control plants for the duration of the season. Also this substantiates the hypothesis that the observed increased soil fertility was indeed a result of the legume treatments.

The fall $\text{NO}_3\text{-N}$ data were not significantly different. Furthermore, with very few exceptions, the $\text{NO}_3\text{-N}$ concentration was very near the 2 to 3 ppm level which supports the hypothesis of a critical minimum concentration resulting in positional unavailability.

It appears then from the $\text{NO}_3\text{-N}$ data that the Australian ley system of farming is adaptable to Montana in terms of increasing soil fertility and productivity. The significant differences between the legume treatments and the control (cereal-fallow) have demonstrated the ability of the system to improve the N economy of the soil and increase wheat yields.

Soil P, O.M. and total N

P levels are reported in Appendix Tables 11 and 12 and summarized in Tables 17 and 18. Initial available P was low to very low at all soil depths and averaged 44.2 ppm in the 0 - 15 cm and 17.3 ppm in the 15 - 30 cm. In terms of absolute values, the same pattern was observed in all 1981 analyses: highest in the 0 - 15 cm, lowest between 15 - 90 cm and higher again between 90 - 120 cm soil depths. There was no apparent effect of the legume treatments on the availability of soil P. The generally higher available P levels in the 0 to 15 cm soil depth in the 1981 fall versus spring samples reflects the spring 1981 uniform P fertilizer applications.

There were no significant differences in the soil O.M. values

Table 17. Average spring P levels at different soil depths following various legume crops at Bozeman, Montana, 1981

1980 Crop	Spring Bray P in ppm			
	0-15cm	0-30cm	30-60cm	60-120cm
Nangeela	38.0	27.0	2.3	8.0
Jamalong	36.7	31.3	6.0	14.7
Northam	37.3	32.7	1.0	5.7
Cyprus	33.3	26.0	4.0	6.0
Clare	38.7	30.3	1.0	7.3
Harbringer	33.7	25.0	1.0	11.3
Grain-fallow	33.3	12.7	1.0	8.3
Daliak	34.3	31.0	1.7	3.7
Black medic	33.7	22.7	3.3	8.0
Geralton	32.7	29.0	2.7	8.7
Ghor	35.3	22.7	1.3	7.7
Nungarin	35.7	29.3	2.7	13.7
Unicrop	33.3	29.7	2.3	14.3
Robinson	34.0	19.0	2.0	2.3
Giza III	42.0	19.3	1.7	5.3
Maral Schaftal	29.7	29.3	1.0	0.7
Ultra	35.7	28.0	1.0	7.3
Level of significance	N.S.	N.S.	N.S.	N.S.
CV %	15.9	43.4	11.2	72.7

Table 18. Average Fall P levels at different soil depths following various legume crops at Bozeman, Montana, 1981.

1980 Crop	Fall Bray P in ppm				
	0-15cm	15-30cm	30-60cm	60-90cm	90-120cm
Nangeela	43.0	18.0	9.0	12.0	23.3
Jemalong	38.3	17.0	5.7	11.7	24.7
Northam	43.0	17.7	4.7	5.3	14.3
Cyprus	48.7	19.7	7.7	6.0	23.7
Clare	50.3	18.3	4.0	10.7	13.3
Harbinger	40.7	10.0	1.0	8.0	20.3
Grain-fallow	31.0	8.3	2.7	7.0	18.0
Daliak	36.7	16.7	4.7	6.0	18.3
Black medic	44.7	2.0	10.3	7.7	28.3
Geralton	48.0	15.7	4.7	3.7	15.3
Ghor	36.0	7.3	2.3	3.7	13.0
Nungarin	87.3	12.3	5.7	8.7	18.7
Unicrop	57.7	15.3	4.0	9.3	20.3
Robinson	35.0	11.3	4.3	5.7	13.0
Giza III	45.0	15.0	2.7	15.3	20.0
Maral Schaftal	37.3	7.7	3.3	3.3	18.3
Ultra	43.7	13.7	5.0	6.7	18.0
Level of significance	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	35.9	69.1	07.3	80.4	51.4

for 1979, 1980 and 1981 (Table 19). However, some interesting points need to be mentioned. A general increase from the initial soil O.M. in 1979 to the spring of 1981 was observed. Average values go from 1.38 percent O.M. to 1.57 percent O.M. in the 0 - 15 cm. This increase is directly related to the legume crop residues.

The 0.05 percent difference between spring and fall O.M. levels in the cereal-fallow plots is certainly within the range of experimental error.

From spring 1981 to fall 1981, there was a general decrease in soil O.M. This decrease is probably due to soil O.M. mineralization. Overall, from spring 1979 to fall 1981, some legume treatments resulted in an O.M. increase and some showed a decrease. Those with increased O.M. include Nungarin subclover, 0.20 percent, black medic, 0.18 percent, Clare subclover, 0.16 percent and Harbinger medic, 0.15 percent.

Soil N (percent) (Appendix Table 10) behavior was similar to the observations already made on soil O.M. There was a general increase followed by a small decrease by fall 1981. The soil O.M. and percent N data have shown a general increase as a result of the legume treatments compared to the control. These observed differences are small but very important in the sense that they show and/or confirm the superiority of the cereal/legume rotations to crop/fallow

Table 19 . Soil organic matter levels for 1979 and 1981 seasons at Bozeman, Montana.

1980 Crop	% initial O.M.1979		%O.M. Spring 1981		% O.M.Fall 1981	
	0-15cm	15-30cm	0-15cm	0-30cm	0-15cm	15-30cm
Nangeela	1.37	1.00	1.63	1.58	1.43	0.88
Jemalong	1.30	1.00	1.52	1.41	1.40	0.80
Northam	1.40	1.23	1.50	1.33	1.19	1.03
Cyprus	1.20	0.97	1.52	1.19	1.33	1.10
Clare	1.37	1.13	1.62	1.44	1.53	1.22
Harbinger	1.33	1.13	1.62	1.56	1.48	1.16
Grain-fallow	1.50	1.17	1.55	1.37	1.49	0.85
Daliak	1.37	1.07	1.47	1.57	1.30	1.14
Black medic	1.40	1.20	1.65	1.28	1.58	0.85
Geralton	1.33	1.30	1.62	1.28	1.39	0.98
Ghor	1.33	1.07	1.57	1.40	1.38	0.83
Nungarin	1.27	1.03	1.65	1.41	1.47	0.69
Unicrop	1.37	1.07	1.52	1.42	1.47	0.95
Robinson	1.57	1.13	1.60	1.55	1.44	1.02
Giza III	1.33	1.00	1.51	1.26	1.38	0.92
Maral Schaftal	1.60	1.10	1.61	1.34	1.53	0.81
Ultra	1.40	1.07	1.57	1.19	1.27	1.00
Means	1.38	1.10	1.57	1.39	1.42	0.96
Level of significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
CV %	10.18	13.12	7.43	12.41	18.12	27.86

rotations for improving soil fertility and productivity.

Density and Re-establishment Evaluations for Legume Species in 1982

In the ley system of farming, it is important that the legume crops regenerate and establish good stands following the cereal phase of the rotation. On July 2, the actual population of plants present was determined by direct counts on the central row of each plot for each of the three replicates using three quadrats ($1/10 \text{ m}^2$ each). Percent ground cover was evaluated based on published charts for estimating proportions of mottles and coarse fragments used in soil survey. The mean densities and mean ground cover recorded in each species are shown in Table 20. There were no observations on Nangeela subclover, Maral Schaftal, faba bean, the control and the lupine plots. Nangeela subclover, Maral Schaftal, faba bean and the lupine plots were reseeded. The control and the lupine plots were summer-fallowed. No attempt was made to evaluate the percent mixture on each plot. It was observed, however, that some black medic had invaded other plots.

Legume cultivars which resulted in plant density of more than 150 plants m^{-2} include: black medic with 1132 plants m^{-2} , followed by Cyprus, 517 plants m^{-2} , Clare, 378 plants m^{-2} , Daliak, 278 plants m^{-2} , Jemalong, 261 plants m^{-2} , Northam, 246 plants m^{-2} , and Harbinger 229 plants m^{-2} . Those legumes which resulted in plant density of more

Table 20. Plant density and ground cover evaluations of legume crops following the cereal phase of the rotation at Bozeman, Montana 1982.

Crop	Density ₂ Plants/m	Ground Cover %
Jemalong	261	19.0
Northam	246	17.7
Cyprus	517	36.7
Clare	378	25.7
Harbinger	229	15.7
Daliak	278	15.0
Black medic	1132	93.3
Geralton	90	8.3
Ghor	42	3.0
Nungarin	38	4.3
Robinson	139	18.3

than 150 plants m^{-2} include: Robinson, GERALTON, Ghor and Nungarin. Results on ground cover showed that only black medic gave an estimate of more than 50 percent. Cyprus and Clare were between 50 and 25 percent. Low ground cover estimates were given by Jemalong, 19 percent, Robinson, 18.3 percent, Northam, 17.7 percent, Harbinger, 15.7 percent, Daliak, 15 percent, GERALTON, 8.3 percent, Nungarin, 4.3 percent and Ghor, 3.0 percent.

An assessment of the success or the failure of these legume cultivars following the cereal phase of the rotation can be based on the now classic studies of Donald (1951, 1954). He showed that the end-of-season yields of plants such as subterranean clover were independent of sowing density over the range of about 150 - 30,000 plants M^{-2} . He pointed out that only yield in early season was strongly density-dependent. He estimated that at a low density of about 150 plants M^{-2} growth was exponential with time early in the season and subsequently became near-linear. At sowing densities above about 6000 plants m^{-2} , growth was linear over a large part of the growing season. Silsbury et al. (1970) working in Australia, also found that end-of-season yield of *Medicago truncatula* Gaertn. cv. Jemalong at about 10 $t\ ha^{-1}$ was largely independent of sowing time and of sowing density. They also explained this fact by suggesting that dry matter growth in time can usually be interpreted

as comprising three stages: Stage I is characterized by exponential or near-exponential growth and ends as the sward reached complete light interception at LAI of about 3. Stage II is a phase of more or less constant crop growth rate, the stage ending when departure from linearity becomes appreciable. Stage III is a phase of decelerating growth rate associated with seed production and plant maturation and with the onset of moisture stress.

Based on the results of Donald (1951, 1954) and Silsbury et al. (1979), the legume cultivars black medic, Cyprus, Daliak, Jemalong, Northam and Harbinger were successful in reestablishing themselves, having produced more than 150 plants m^{-2} . However, one needs to be cautious on this estimate since no attempt was made to establish the purity of each stand. A more conservative estimate would consider black medic as highly successful, Cyprus, Jemalong, and Northam as successful, Daliak and Harbinger as fair to good and the other cultivars as requiring more testing if they are to be included in the ley system.

Assessment of the Weed Problem

In 1979 and 1980 seasons, during the legume years, the weeds did not pose much of a problem. They were kept to a minimum by hand weeding. Also, it is estimated that when these legumes are used

for pasture, these weeds would represent a minor problem.

During the 1981 season, only a few legume seeds germinated and established plants. However, as the yield data suggest, these few plants offered little competition to the spring wheat which got off to a much earlier start. It is believed that the cereal crop will always have the advantage of germinating earlier than the legume crops and thus offset the weed development.

During the legume season following the cereal crop, weeds and volunteer grain may then cause some problems, mainly in years where the spring temperatures and water content are too low to allow rapid germination of the legumes. In the 1982 season particularly, volunteer wheat was a serious problem requiring chemical control. Chemical herbicide, fusilade, was applied on June 18 at a rate of 3/4 lb./acre active ingredient but was slow, however, in controlling the wheat plants. Also the test site was infested with thistles but these thistles were not specific to the system and have been reduced by the use of Round-Up applied on the growing tips.

In all cases, these weeds would not destroy the efficiency of the ley system if the plots were used for pasture. Also, these cereal/legume rotations offer an opportunity to exercise more control over grassy weeds during the legume phase and over broadleaf weeds during the cereal phase compared to continuous cereal or cereal/

fallow rotations.

Multiple Correlation and Regression

Correlation of legume dry matter yield, seed yield, percent N and N uptake with initial soil fertility levels.

There was no significant correlation between legume dry matter yield and initial soil fertility levels (Table 21). However, high positive correlations (non significant) were observed with Bray P in 15 - 30 cm soil depth ($r = 0.40$), K in 0 - 15 cm ($r = 0.43$) and pH in 15 - 30 cm ($r = 0.35$). The lack of significant correlation of legume dry matter yield with initial soil fertility levels suggest that the differences observed in yields were not influenced by the initial soil status. This would be expected as the soil analysis data (Appendix Tables 10 and 11) indicate that the initial soil conditions were quite uniform.

Seed yield was significantly and negative correlated with K ($r = -.53$) and pH ($r = -.49$) in the 15 - 30 cm depth, both at the 5 percent level. Percent N and N uptake did not show any significant correlations.

Correlation between wheat grain and protein yields and 1981 soil fertility levels.

Wheat grain yield was positively correlated with wheat dry

Table 21. Correlation coefficients, r , relating legume dry matter yield, seed yield, percent N and N uptake with initial soil fertility levels.

Variables	Dry Matter	Seed Yield	% N	N Uptake
Bray P 0 - 15 cm	.16	.28	-.29	.22
Bray P 15 - 30 cm	.40	.18	-.40	.44
Olsen P 0 - 15 cm	-.06	.28	.01	-.14
Olsen P 15 - 30 cm	-.02	.24	-.22	.02
K 0 - 15 cm	.43	-.44	-.24	.25
K 15 - 30 cm	.02	-.53*	.29	.01
Mg 0 - 15 cm	.31	.02	.08	.21
Mg 15 - 30 cm	.13	-.38	.12	.14
Ca 0 - 15 cm	.23	-.24	.41	.37
Ca 15 - 30 cm	-.14	-.43	.40	-.02
Boron 0 - 15 cm	-.17	-.07	.07	-.21
Boron 15 - 30 cm	-.14	.31	-.19	-.20
Sulfur 0 - 15 cm	-.18	.09	.24	.05
Sulfur 15 - 30 cm	.23	.18	-.40	.41
NO ₃ N 0 - 15 cm	.30	-.33	.10	.23
NO ₃ N 15 - 30 cm	.22	.19	-.13	.14
pH 0 - 15 cm	.32	.33	.01	.13
pH 15 - 30 cm	.35	-.49*	.21	.20
Zn 0 - 15 cm	-.24	.27	-.05	.07
Zn 15 - 30 cm	.01	-.29	.09	.17
EC 0 - 15 cm	.19	.36	-.15	.42
Fe 0 - 15 cm	.09	.09	-.10	.10
Fe 15 - 30 cm	.03	.05	.01	.01
Cu 0 - 15 cm	.12	-.22	.04	.01
Cu 15 - 30 cm	.06	.11	-.22	-.04
Mn 0 - 15 cm	.19	-.26	.08	.22
Mn 15 - 30 cm	.20	.28	.04	-.32
O.M. 0 - 15 cm	.01	.03	-.18	-.12
O.M. 15 - 30 cm	.01	.10	.01	.22

* Significant at 0.05 level.

**Significant at 0.01 level.

matter yield ($p = 0.05$, $r = .65$), wheat N uptake ($p = 0.01$, $r = .91$), protein yield ($p = 0.01$, $r = .94$), plant height ($p = 0.01$, $r = .75$), density ($p = 0.05$, $r = .53$), and was negatively correlated with the amount of water remaining in the soil profile at harvest ($p = 0.05$, $r = -.63$) (Table 22). This negative correlation is not surprising since initial soil water was uniform across all plots and low yields have been previously associated with low water use and poor water use efficiency. This also supports the view that high yields obtained from the legume treatments will result in less water to potentially contribute to saline seep development. However, it seems that due to their high water use efficiency, the decreased soil water content should not be a limiting factor in the succeeding year crops.

A positive correlation ($p = 0.05$) was also noted with spring $\text{NO}_3\text{-N}$ ($r = .63$) in the 30 - 60 cm with grain yield. High correlation values which did not reach a significant level ($p = 0.05$) were observed with spring $\text{NO}_3\text{-N}$ in the 0 - 15 cm ($r = .42$) and 60 - 120 cm ($r = .40$) soil depths.

Wheat grain protein concentration was highly correlated ($p = 0.01$) with $\text{NO}_3\text{-N}$ used ($r = .73$) but was negatively related to the spring $\text{NO}_3\text{-N}$ in the 0 - 15 cm.

Wheat protein yield was correlated ($p = 0.05$) with the previous year legume percent N and was negatively (non significant) related

Table 22. Selected correlation coefficients relating wheat grain yield, wheat protein concentration and protein yield.

	Grain Yield	Protein Concentrate	Protein Yield
	----- r -----		
Dry matter yield	.65*	-.09	
N uptake	.91**	.34	
Protein yield	.94**	.44	
% N grain	.03	.58*	.23
% N Legumes 1979	.74**	.31	.77**
Density	.53*	.13	.51*
Height	.75**	-.28	.59*
N uptake legume 1979	-.16	-.65*	-.36
Cm H ₂ O/120 Harvest	-.63	-.18	-.63*
H ₂ O use efficiency	.99**	.08	.92**
Spring NO ₃ N 0-15 cm	-.42	-.50*	.22
Spring NO ₃ N 30-60 cm	.63*	.65*	.80**
Spring NO ₃ N 60-120 cm	.40	.78**	.63*
Fall NO ₃ N 60-90 cm	-.31	-.60	-.49*

* significant at the 5% level.

** significant at the 1% level.

to their total N uptake. Several other variables related to yield and N availability were also correlated with wheat protein yield.

Multiple linear regression equations relating yield components to soil parameters

A total of 27 variables were used in developing the different models (Table 23). The first eleven variables were considered dependent variables and the remaining 16 variables as independent variables.

On building the models, some decision had to be taken regarding the minimum number of variables that can be included without loss of precision and simplicity. Thus, the decision was made to fit a maximum of five variables into each model even though the stepwise procedure would have allowed more. The main reasons for this choice were for simplicity as suggested above and to allow more degrees of freedom for the error term since only 17 observations were available with 16 independent variables. These 17 observations represent averages over the three replicates for each treatment. By doing so the variability among the legume treatments is ignored, but their common behavior in relation to soil fertility factors is emphasized. Also it is noted here that the main objective in constructing these models is to help explain the results obtained in this experiment rather than testing their predictive power.

Table 23. Variables used in developing predictive equations for grain yield, grain protein content and other yield variables of spring wheat.

Variable designation	Variable description	Units of Measurement
X ₁	Grain yield	Kg/ha
X ₂	Grain protein content	%
X ₃	Dry matter yield	Kg/ha
X ₄	N uptake	Kg/ha
X ₅	Protein yeild	Kg/ha
X ₆	% N in grain	%
X ₇	% N in straw	%
X ₈	Tiller/plant	nb/plant
X ₉	Density	
X ₁₀	Plant height	cm
X ₁₁	Water use efficiency	Kg/cm of H ₂ O
X ₁₂	Available H ₂ O in 120 cm of soil at planting	cm
X ₁₃	Available H ₂ O in 120 cm of soil at harvest	cm
X ₁₄	Available H ₂ O used	cm
X ₁₅	Total H ₂ O used (X ₁₄ + precipitation)	cm
X ₁₆	Spring soil NO ₃ -N in 120 cm of soil	Kg/ha
X ₁₇	Soil NO ₃ -N utilized by crop	Kg/ha
X ₁₈	Spring O.M in 15 cm of soil, 1981	%
X ₁₉	Spring O.M in 30 cm of soil, 1981	%
X ₂₀	Spring NO ₃ -N in 15 cm of soil, 1981	ppm
X ₂₁	Spring NO ₃ -N in 30 cm of soil, 1981	ppm
X ₂₂	Spring NO ₃ -N in 30-60 cm of soil, 1981	ppm
X ₂₃	Spring NO ₃ -N in 60-120 cm of soil, 1981	ppm

Table 23, continued.

Variable Designation	Variable description	Units of Measurement
X ₂₄	Spring Bray P in 15 cm of soil, 1981	ppm
X ₂₅	Spring Bray P in 30 cm of soil, 1981	ppm
X ₂₆	Spring Bray P in 30-60 cm of soil, 1981	ppm
X ₂₇	Spring Bray P in 60-120 cm of soil, 1981	ppm

In considering the wheat grain yield models of Table 24, the variable X₂₂, namely the spring NO₃-N in 30 - 60 cm of soil was the first variable to enter the regression equation but with only 40 percent of the variation explained ($R^2 = .40$). The second variable to enter the regression was the spring NO₃-N in 15 cm of soil (X₂₀) which improved the R^2 to 62 percent. However, this variable was only significant at the 5 percent level. The standard error of the estimate (SE) could be still further decreased and the R^2 increased by the incorporation of X₁₂, X₁₉ and X₁₇ in equations 3, 4 and 5 respectively but none were significant ($p = 0.05$). The fact that spring NO₃-N variables (X₂₂ and X₂₀) were incorporated significantly in the wheat grain yield model is not surprising. Yield is highly dependent on soil fertility factors, especially available N parameters when an N deficient soil is involved.

Table 24. Multiple linear regression equations relating grain yield of spring wheat to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 1383.29 + 246.26^{**} X_{22}$	9.98**	297.75	.40	.40
2. $Y = 346.20 + 261.74^{**} X_{22} + 58.36^{*} X_{20}$	11.45**	244.93	.62	.22
3. $Y = 3889.69 + 245.39 X_{22} + 54.65 X_{20}$ $- 135.75 X_{12}$	9.24**	233.20	.68	.06
4. $Y = 3855.05 + 267.44 X_{22} + 52.58 X_{20}$ $- 172.45 X_{12}$	7.68**	227.67	.72	.04
5. $Y = 4948 + 376.15 X_{22} + 52.86 X_{20}$ $+ 230.05 X_{12} + 762.02 X_{19}$ $- 6.26 X_{17}$	7.03**	219.09	.76	.04

^{1/}F ratio due to regression; total df = 16

^{2/}SE = Standard error of the estimate

* Sign. p = .05

** Sign. p = 0.01

In the wheat protein content model of Table 25, the spring $\text{NO}_3\text{-N}$ in 60 - 120 cm (X_{23}) was the first variable to enter the regression with an $R^2 = .62$ and a $\text{SE} = .52$. In equation 2, the spring $\text{NO}_3\text{-N}$ in 15 cm of soil was added to the model and both variables were highly significant ($p = 0.01$). When five variables were incorporated into the model, none was significant. The most useful regression would be equation 2. Again, the entrance of available N parameters as initial and significant variables in this regression analysis is consistent with classical theory relating N availability and grain protein levels.

Wheat N uptake and protein yield models were similar in incorporating the most important variables (Tables 26 and 27). In both cases, equation 2 would be the most useful one with the spring $\text{NO}_3\text{-N}$ in 30 - 60 cm and available water in 120 cm of soil at harvest explaining 75 percent and 81 percent of the variations respectively. The standard error of the estimates were low in both cases. The grain N percent was poorly explained by the variables under consideration (Table 28). The soil O.M in 30 cm of soil at planting time (X_{19}) was the most important variable.

In the water use efficiency of Table 29, the spring $\text{NO}_3\text{-N}$ in 30 - 60 cm of soil was the first variable to enter the regression equation with 38 percent of the variation explained ($R^2 = .38$). The

Table 25. Multiple linear regression equations relating wheat protein content to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 13.11 + .29^{**} X_{23}$	24.07**	.52	.62	.62
2. $Y = 15.19 + .28^{**} X_{23} - .12^{**} X_{20}$	32.00**	.37	.82	.20
3. $Y = 15.67 + .28^{**} X_{23} - .10^{**} X_{20} - .30 X_{25}$	25.40**	.34	.85	.03
4. $Y = 15.31 + .05 X_{23} - .11^{**} X_{20} - .47^{*} X_{25}$ + .24 X_{16}	20.20**	.34	.87	.02
5. $Y = 14.44 - .01 X_{23} - .12 X_{20} - .53 X_{25}$ + .28 X_{16}	17.12**	.33	.89	.02

^{1/} F ratio due to regression; total df = 16

^{2/} SE = Standard error of the estimate

* sign. p. = 0.05

** sign. p = 0.01

Table 26. Multiple linear regression equations relating wheat protein yield to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 136.89 + 50.92^{**} X_{22}$	26.86**	37.53	.64	.64
2. $Y = 697.81 + 23.88^{**} X_{22} - 29.89^{**} X_{13}$	29.94**	28.25	.81	.16
3. $Y = 1046.49 + 43.08^{**} X_{22} - 41.21^{**} X_{13}$ $- 19.73 X_{14}$	23.32**	26.65	.84	.03
4. $Y = 736.39 + 45.25^{**} X_{22} - 38.96^{**} X_{13}$ $- 22.04 X_{14} + 177.12 X_{18}$	19.75**	25.45	.87	.03
5. $Y = 816.21 + 56.78^{**} X_{22} - 44.94^{**} X_{13}$ $- 20.83 X_{14} + 177.84 X_{18} - .76 X_{17}$	17.51**	24.45	.89	.02

^{1/} F ratio due to regression: total df = 16

^{2/} SE = Standard error of the estimate

* sign. p. = 0.05

** sign. p = 0.01

Table 27. Multiple linear regression equations relating wheat N uptake to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 28.10 + 10.87^{**} X_{22}$	22.83**	8.69	.60	.60
2. $Y = 143.70 + 9.22^{**} X_{22} - 6.16^{*} X_{13}$	21.16**	7.12	.75	.15
3. $Y = 179.52 + 13.24^{**} X_{22} - 8.50^{**} X_{13}$ $- .26 X_{17}$	17.62**	6.59	.80	.05
4. $Y = 172.84 + 13.04^{**} X_{22} - 8.35^{**} X_{13}$ $- .24 X_{17} + 1.76 X_{26}$	15.02**	6.30	.83	.03
5. $Y = 102.51 + 13.49^{**} X_{22} - 7.65^{**} X_{13}$ $- .24 X_{17} + 1.89 X_{26} + 34.43 X_{18}$	12.89**	6.15	.85	.02

^{1/}F ratio due to regression: total df = 16

^{2/}SE = Standard error of the estimate

* sign. p. 0.05

** sign. p = 0.01

Table 28. Multiple linear regression equations relating percent N in wheat grain to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 4.50 - 1.03^{**} X_{19}$	8.96**	.17	.37	.37
2. $Y = 4.15 - .89^{*} X_{19} + .32 X_{23}$	6.38*	.16	.48	.11
3. $Y = 4.36 - .86^{*} X_{19} + .32 X_{23} - .42 X_{21}$	4.87*	.15	.54	.06
4. $Y = 4.68 - .80^{*} X_{19} + .12 X_{23} - .99 X_{21}$ + .16 X_{17}	4.87*	.15	.62	.08
5. $Y = 4.58 - .78^{*} X_{19} - .12 X_{23} - .13^{*} X_{21}$ + .16 $X_{17} + .94 X_{25}$	3.94*	.15	.62	.02

^{1/}F ratio due to regression: total df = 16

^{2/}SE = Standard error of the estimate

* sign. p = 0.05

** sign. p = 0.01

Table 29. Multiple linear regression equations relating water use efficiency of spring wheat to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 42.79 + 6.80^{**} X_{22}$	9.17**	8.58	.38	.38
2. $Y = 16.63 + 7.19^{**} X_{22} + 1.47^{*} X_{20}$	8.72**	7.52	.55	.17
3. $Y = 135.37 + 6.64^{**} X_{22} + 1.35^{*} X_{20} - 4.55 X_{12}$	7.66**	7.03	.64	.09
4. $Y = 170.78 + 10.00^{**} X_{22} + 1.37^{*} X_{20} - 6.18^{*} X_{12} - .20 X_{17}$	6.84**	6.72	.70	.06
5. $Y = 175.45 + 11.28^{**} X_{22} - 1.31^{*} X_{20} - 7.64^{*} X_{12} - .23 X_{17} + 20.86 X_{19}$	6.39	6.43	.74	.04

^{1/} F ratio due to regression: total df = 16

^{2/} SE = Standard error of the estimate

* sign. p = 0.05

** sign. p = 0.01

variable, spring $\text{NO}_3\text{-N}$ in 30 cm (X_{20}) was included in step 2, available water in 120 cm of soil at planting at step 3 (non significant). Soil $\text{NO}_3\text{-N}$ utilized by crop (X_{17}) and spring O.M. in 30 cm of soil (X_{19}) at steps 4 and 5. In equation 5, 74 percent of the variations was explained with a low SE of 6.43 Kg/cm of water. Again, when dealing with an N deficient soil water use efficiency would be expected to be related to soil N and water parameters. Models for wheat tillers per plant, density, and plant height are also reported in Tables 30, 31, and 32.

In all these models, soil nitrogen parameters and soil water are important variables explaining the variations observed in the field. The results of these analyses support the use of the legume crops for improving soil fertility, particularly available N which mineralizes from the legume residues and soil organic matter. The net results can be increased grain yields and protein contents for the succeeding cereal crop.

Table 30. Multiple linear regression equations relating number of tillers per plant of spring wheat to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 15.67 - .35* X_{24}$	4.46	1.90	.23	.23
2. $Y = 29.74 - .31 X_{24} - .89 X_{13}$	4.00*	1.78	.36	.13
3. $Y = 40.23 - .32* X_{24} - 1.35* X_{13} - .37 X_{23}$	3.93*	1.68	.48	.12
4. $Y = 39.70 - .33* X_{24} - 1.43* X_{13} - .67* X_{23}$ + .88 X_{22}	3.69*	1.62	.55	.07
5. $Y = 40.84 - .34* X_{24} - 1.44* X_{13} - .70* X_{23}$ + .88 $X_{22} - .36 X_{26}$	3.35*	1.59	.60	.05

^{1/} F ratio due to regression: total df = 16

^{2/} SE = Standard error of the estimate

* sign. p = 0.05

** sign. p = 0.01

Table 31. Multiple linear regression equations relating wheat plant density to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 238.17 + 10.61 X_{21}$	4.25	25.32	.22	.22
2. $Y = 263.93 + 11.41* X_{21} - 3.69* X_{27}$	5.44*	22.28	.44	.22
3. $Y = 214.34 + 11.42* X_{21} - 4.14** X_{27} + 11.90* X_{22}$	6.53**	19.46	.60	.16
4. $Y = 189.89 + 13.23** X_{21} - 4.99** X_{27} + 23.05* X_{22} - .61 X_{17}$	6.20**	18.32	.67	.07
5. $Y = 116.20 + 12.79 X_{21} - 4.56 X_{27} + 21.28 X_{22} - .51 X_{17} + 2.16 X_{24}$	5.61**	17.78	.72	.05

^{1/}F ratio due to regression: total df = 16

^{2/}SE = Standard error of the estimate

* sign. p = 0.05

** sign. p = 0.01

Table 32. Multiple linear regression equations relating wheat plant height to soil parameters

Equations	F ^{1/}	SE ^{2/}	R ²	R ² Change
1. $Y = 111.40 - 2.53^{**} X_{13}$	11.76**	2.58	.44	.44
2. $Y = 110.99 - 2.61^{**} X_{13} + .83 X_{26}$	8.68**	2.38	.55	.11
3. $Y = 100.18 - 2.69^{**} X_{13} + .94^{*} X_{26} + 8.63 X_{19}$	8.34**	2.16	.66	.11
4. $Y = 129.65 - 3.75^{**} X_{13} + .78 X_{26} + 11.22^{*} X_{19}$ $- 1.84 X_{14}$	8.38**	1.98	.74	.08
5. $Y = 124.58 - 6.43^{**} X_{13} + .68 X_{26} + 9.86^{*} X_{19}$ $- 4.20^{*} X_{14} + 2.88 X_{12}$	8.70**	1.87	.80	.06

^{1/}F ratio due to regression: total df = 16

^{2/}SE = Standard error of the estimate

* sign. p = 0.05

** sign. p = 0.01

Chapter 5

SUMMARY

Seed of sixteen annual legumes were acquired, fourteen from the South Australia Department of Agriculture, including:

Five *Medicago* sp; annual medics, seven *Trifolium* sp; and two *Lupinus* sp; one faba bean cultivar (*Vicia faba* L.) from the Egyptian Ministry of Agriculture, one from Montana, *Medicago lupulina* L., black medic. These annual legumes were grown in rotation with spring wheat (*Triticum aestivum* L.). Conventional alternate crop-fallow (summer-fallow) plots were included as the control.

Results obtained during the legume phase (1979-1980) of the rotation showed that the yield levels of both dry matter and seed for the forage legumes are, in general, encouraging in terms of adapting the Australian Ley system of farming to Montana. High dry matter yielding varieties were Nungarin 5268 Kg/ha, Geraldton 4960 Kg/ha, Northam 4641 Kg/ha, Maral Schaftal 4406 Kg/ha, Clare 4353 Kg/ha and Jemalong 4208 Kg/ha. High seed yielding varieties during the first season included: Jemalong 1964 Kg/ha, Robinson, 1934 Kg/ha, Harbinger, 1846 Kg/ha, and Cyprus, 1171 Kg/ha. Nangeela subclover did not produce any seed due to late flowering. The lupines failed to produce any significant dry matter and seed yields of the faba bean have been found to be encouraging. During the second season,

black medic established a very good stand and seed set.

Wheat grain yield differences obtained during the cereal phase (1981) were statistically significant ($p = .0.05$) among the treatments. All legume treatments yielded more than the cereal-fallow control plots and those which produced significantly higher yields ($p = 0.05$) compared to the control and their percent yield increases are as follows:

Black medic	91.0 percent
Maral Schaftal	56.9 percent
Faba bean	50.5 percent
Daliak subclover	48.2 percent
Unicrop lupine	45.0 percent
Nangeela subclover	44.0 percent
Harbinger medic	41.5 percent
Ultra lupine	37.8 percent

The lupines which failed to produce in 1979 and 1980 seasons had acted like double summer fallow and resulted in high wheat grain yields, protein concentrations and protein yields.

Compared to the summer-fallow control treatment, grain protein concentrations were higher in all legume treatments except for a few treatments which showed a dilution effect due to their high wheat grain yields. Protein yields and N uptake were higher in all legume

treatments. The high dry matter yields, grain yields, protein concentrations, protein yields and N uptake of the legume treatments compared to the control are attributed to the residual effect of the legumes.

Available soil water was uniform over all plots at the beginning of the cereal phase. At the end of the cereal phase it was higher in the cereal-fallow plots compared to the legume treatments. This suggests that improved soil fertility in the legume treated plots increased water use, whereas, soil fertility remained a limiting factor in the control plots. Calculated water use efficiency was also higher for the legume treatments. The water use data and the water use efficiency data all support the hypothesis of superiority in terms of increased soil fertility and productivity of the legume-cereal rotations over the alternate crop-fallow rotations. The cereal-fallow plots had more stored water at harvest in the lower soil depth, 60 - 120 cm, thus increasing the saline-seep hazard.

Soil samples taken after the legume phase and just before planting the spring wheat showed the cereal-fallow control treatment had significantly lower $\text{NO}_3\text{-N}$ in its profile to 120 cm compared to the legume treatments. At harvest time of the spring wheat, $\text{NO}_3\text{-N}$ data were not significantly different but the total $\text{NO}_3\text{-N}$ used during the growing season was much higher in the legume treatments.

The legume treatments also resulted in a slight O.M. and percent N increases over the two year period but were not statistically different from the control.

Stepwise forward procedure was used to develop multiple regression equations relating wheat grain yields, protein content and other yield variables to soil fertility factors. Soil nitrogen in the forms of organic matter and $\text{NO}_3\text{-N}$ were the most important variables explaining the variations obtained in each model. Plant counts made in the summer of 1982 indicated that the varieties black medic, cyprus, Jemalong and Northam were successful in re-establishing themselves after the cereal phase of the rotation.

Chapter 6

CONCLUSIONS

The most important finding of this thesis has been the clear demonstration that the Australian Ley system of farming is adaptable to Montana. The complete rotation cycle including a legume phase, 1979-1980, a cereal phase, 1981, and back to the legume phase, 1982, has been successfully completed with the following legume species:

Medicago Lupulina L., black medic

M. truncatula Gaertn., Jemalong (barrel medic)

M. truncatula Gaertn., Cyprus

Trifolium subterraneum L., Northam

The following cultivars: Nungarin, GERALTON and CLARE which did not complete successfully the entire cycle still show great potential as annual legumes. Faba bean and Maral Schafal clover were not expected to regenerate, but were successful in annual legume/cereal rotation.

The data have shown beyond any doubt that there was an increased soil fertility in the annual legume plots as expressed by increased grain yields, protein content, protein yields, N uptake, etc. The data also showed that the annual legume/cereal rotation has some potential use for saline-seep control. However, the system needs to

be carried on for one or more additional seasons and at other locations before definite recommendations can be formulated.

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APPENDIX

APPENDIX A

Table 1. Profile description of Amsterdam var. silt loam (fine-silty, mixed family of Typic Haploborolls)

Slope 2 percent	Elevation: 1463 meters
Water table: None	Aspect: North
Permeability: Moderate	Air Temperature: 42.6° F
Physiography: Alluvial or colluvial fans	Drainage Class: Well drained
Vegetation: Crops-dryland	Stoniness: Class 0
Parent Material: Eolian, Loess mixed lithology	

Profile DescriptionHorizon

A _{11p}	0 - 16 cm; dark grayish brown (10 YR 4/2) heavy silt loam; very dark brown (10 YR 1/2) moist; strong fine granular structure; friable, sticky, plastic; many fine roots; noncalcareous; diffuse wavy boundary.
A _{12p}	16 - 27 cm. Dark grayish brown (10 YR 4/2) heavy silt loam; brown (10 YR 4/3); very dark brown (10 YR 2/2) moist; moderate fine granular structure; very hard, friable, sticky, plastic; many fine roots; noncalcareous; clear wavy boundary.
B ₂₁	27 - 41 cm. Dark grayish brown (10 YR 4/2) heavy silt loam; brown (10 YR 4/3) crushed; very dark grayish brown (10 YR 3/2) moist; dark brown (10 YR 3/3) crushed moist; strong fine and medium subangular blocky; very hard, friable, sticky, plastic; many fine roots, many fine pores; few medium pores; noncalcareous; diffuse wavy boundary.
B ₂₂	41 - 53 cm. Dark grayish brown (10 YR 4/2) heavy silt loam; brown (10 YR 5/3) crushed; very dark grayish brown (10 YR 3/2); brown (10 YR 4/3) crushed moist; strong medium prismatic structure parting to moderate fine and

Table 1, Continued.

	medium; subangular blocky; very hard, very friable, sticky, plastic; many fine roots, many fine pores, few medium pores; noncalcareous; diffuse wavy boundary.
B ₂₃	53 - 62 cm. Grayish brown (10 YR 5/2) silt loam; light olive brown (2.5 Y 5/3) crushed; dark grayish brown (10 YR 4/2) moist; reddish brown (2.5 YR 4/3) crushed moist; strong medium prismatic structure parting to moderate fine and medium subangular blocky; very hard, very friable, sticky, plastic; many fine roots; many fine pores, few medium pores, few masses of lime; moderately effervescent (Hcl); clear wavy boundary.
C _{1ca}	62 - 80 cm. Light gray (2.5 Y 7/2) silt loam; dark grayish brown (2.5 Y 4/2) moist; weak coarse prismatic structure; slightly hard, very friable, sticky, slightly plastic, common fine roots, many fine pores, few medium pores; calcium carbonate cutans on ped faces; many masses of lime, many thread-like masses of lime; violently effervescent (Hcl); diffuse wavy boundary.
C _{2ca}	80 - 98 cm. Light gray (2.5 Y 7/2) light silt loam; dark grayish brown (2.5 Y 4/2) moist; massive; slightly hard, very friable, slightly sticky, slightly plastic; common fine roots; many fine pores, few medium pores, common masses of lime, common thread-like masses of lime; violently effervescent (Hcl); diffuse wavy boundary.
C _{3ca}	98 - 135 cm. Light gray (2.5 Y 7/5) very fine sandy loam, dark grayish brown (2.5 Y 4/2) moist; weak medium and coarse platy structure; slightly hard; very friable, slightly sticky, slightly plastic, few fine roots; many fine pores, few medium pores, common thread-like masses of lime, few masses of lime, moderately effervescent (Hcl); diffuse wavy boundary.
C ₄	135 - 180 cm. Very fine silt loam.

Table 2. Total rainfall evaporation and number of days with precipitation at experimental site.

Month	Total Rainfall			Total Evaporation			No. of day rainfall		
	1979	1980	1981	1979	1980	1981	1979	1980	1981
	- inches -			- inches -			- days > .10 inch -		
April	1.42	.40	1.65	—*	—	—	6	1	8
May	1.78	5.24	6.15	—	6.27	4.44	6	14	17
June	2.99	2.87	3.26	8.008	6.52	5.90	9	9	10
July	.70	.54	1.07	8.798	8.59	9.54	4	2	3
August	1.27	1.25	.28	7.208	7.23	9.00	4	3	1
Sept.	0.05	2.77	1.40	6.58	4.28	6.30	0	9	5
Oct.	1.65	.56	1.82	3.23	2.26	—	6	2	2
TOTALS	9.86	12.38	15.63	33.82	35.15	35.18	35	40	51

*Data not available.

Table 3. Average monthly temperatures recorded at experimental site.

Month	Average maximum			Average minimum			Average		
	1979	1980	1981	1979	1980	1981	1979	1980	1981
	-----°F-----								
April	53.3	59.3	56.9	30.1	32.2	31.4	41.7	45.8	44.2
May	65.4	65.8	61.4	37.4	38.8	39.4	51.4	52.3	50.4
June	74.8	73.1	69.7	45.2	43.4	43.5	60.0	58.3	56.6
July	82.1	81.4	81.9	49.0	48.9	48.0	65.6	65.2	65.0
August	80.3	76.4	84.9	48.4	45.8	48.2	64.4	61.0	66.6
Sept.	79.3	70.2	74.5	41.7	42.1	40.0	60.5	56.2	57.3
Oct.	62.0	59.7	55.3	33.2	31.5	30.3	47.6	45.6	42.8
AVERAGE	71.0	69.4	69.2	40.7	40.4	40.1	55.9	54.9	54.7

Table 4 . Legume dry matter yields for 1979 season and analysis of variance.

Crop (cultivar)	Yield, Kg/ha			
	Rep. I	Rep. II	Rep. III	Means
<i>T. subterraneum</i> (Nangeela)	3175.9	3858.3	2952.8	3329.00
<i>Medicago truncatula</i> (Jemalong)	3948.0	2788.7	5888.0	4208.24
<i>T. subterraneum</i> (Northam)	5641.8	4709.1	3560.8	4640.57
<i>Medicago truncatula</i> (Cyprus)	3346.5	2465.0	2563.4	2791.63
<i>T. subterraneum</i> (Clare)	2981.2	3878.0	6200.8	4353.32
<i>Medicago littoralis</i> (Harbinger)	2073.2	5135.6	3156.2	3455.09
<i>Triticum aestivum</i> (Newana)	2060.4	1870.1	2832.5	2254.3
<i>T. subterraneum</i> (Daliak)	4265.1	3727.0	3407.7	3799.3
<i>Medicago lupulina</i> (Black medic)	1520.1	509.6	404.6	811.46
<i>T. subterraneum</i> (Geraldton)	5105.0	5070.1	4704.7	4959.9
<i>Medicago truncatula</i> (Ghor)	824.6	1642.6	732.7	1066.64
<i>T. subterraneum</i> (Nungarin)	4293.5	5452.8	6058.6	5268.3
<i>Lupinus angustifolius</i> (Unicrop)	1303.6	15.3	35.0	451.3
<i>Medicago scutellata</i> (Robinson)	4217.0	2626.9	3497.4	3447.07
<i>Vicia faba</i> (Giza III)	2583.1	1703.9	2106.3	2131.1
<i>T. resupinatum</i> (Maral Schaftal)	5369.6	4615.0	3234.9	4406.5
<i>Lupinus albus</i> (Ultra)	1924.8	966.8	1769.5	1553.7

Analysis of Variance

Source	D.f.	S.S.	M.S.	F value	Level of Significance
Blocks	2	.3859E + 06	.1929E + .06		
Treatments	16	.1091E + 09	.6816E + .07	7.947	0.01
Error	32	.2745E + 08	.8578E + 06		

Table 5 . Legume seed or seed pod yields for 1979 season¹ and analysis of variance

Crop (cultivar)	Yield, Kg/ha			
	Rep. I	Rep. II	Rep. III	Means
<i>T. subterraneum</i> (Nangeela)	48.1	0.0	0.0	16.03
<i>Medicago truncatula</i> (Jemalong) ¹	2016.6	1224.8	2560.9	1964.13
<i>T. subterraneum</i> (Northam)	150.9	170.6	142.2	154.6
<i>Medicago truncatula</i> (Cyprus) ¹	1712.6	737.1	1063.0	1170.9
<i>T. subterraneum</i> (Clare)	98.4	113.7	120.3	110.8
<i>Medicago littoralis</i> (Harbinger) ¹	1159.2	2421.3	1957.6	1846.0
<i>Triticum aestivum</i> (Newana)	1896.3	1655.7	2570.0	2040.5
<i>T. subterraneum</i> (Daliak)	41.6	37.2	52.5	43.7
<i>Medicago lupulina</i> (Black medic)	389.3	146.5	140.0	225.3
<i>T. subterraneum</i> (Geraldton)	334.6	389.3	304.0	342.7
<i>Medicago truncatula</i> (Ghor) ¹	623.4	1100.2	511.8	745.1
<i>T. subterraneum</i> (Nungarin)	286.5	374.0	253.7	304.8
<i>Lupinus angustifolius</i> (Unicrop)	0.0	0.0	0.0	0.0
<i>Medicago scutellata</i> (Robinson) ¹	2471.6	1686.4	1644.8	1934.2
<i>Vicia faba</i> (Giza III)	338.2	210.0	302.4	283.5
<i>T. resupinatum</i> (Maral Schaftal)	242.8	0.0	100.6	114.5
<i>Lupinus albus</i> (Ultra)	1117.7	557.7	1084.9	920.1

¹Yields for these crops are for intact seed pods.

Analysis of Variance

Source	D.f.	S.S.	M.S.	F value	Level of Significance
Blocks	2	.171E + 06	.8556E + 05		
Treatments	16	.2867E + 08	.1792E + 07	16.26	0.01
Error	32	.3527E + 07	.1102E + 06		

Table 6. Grain yields of spring wheat and analysis of variance.

1980 Crop	Yield, Kg/ha				Means
	Rep. I	Rep. II	Rep. III		
<i>T. subterraneum</i> (Nangeela)	2853.2	2801.1	2222.9		2625.7
<i>Medicago truncatula</i> (Jemalong)	1991.9	2721.7	2400.3		2371.3
<i>T. subterraneum</i> (Northam)	2536.8	1841.6	1931.9		2103.4
<i>Medicago truncatula</i> (Cyprus)	2507.5	2375.5	1943.8		2275.6
<i>T. subterraneum</i> (Clare)	2330.0	2477.0	1927.7		2244.9
<i>Medicago littoralis</i> (Harbinger)	3004.6	2290.8	2446.7		2580.7
Grain-fallow	2405.0	1714.3	1352.5		1823.9
<i>T. subterraneum</i> (Daliak)	3305.1	2414.3	2388.6		2702.7
<i>Medicago lupulina</i> (Black medic)	4907.8	2765.3	2829.6		3500.9
<i>T. subterraneum</i> (Geraldton)	2701.2	2030.7	2189.1		2307.0
<i>Medicago truncatula</i> (Ghor)	2530.5	2534.2	2115.8		2393.5
<i>T. subterraneum</i> (Nungarin)	2308.3	2481.3	2550.3		2446.6
<i>Lupinus angustifolius</i> (Unicrop)	2814.7	2435.6	2682.7		2644.3
<i>Medicago scutellato</i> (Robinson)	2287.7	1883.9	2201.9		2124.5
<i>Vicia faba</i> (Giza III)	2399.2	3086.5	2753.1		2746.3
<i>T. resupinatum</i> (Maral schaftal)	2737.3	2972.7	2877.3		2862.4
<i>Lupinus albus</i> (Ultra)	2272.4	2366.6	2900.4		2513.1
<u>Analysis of Variance</u>					
Source	D.f.	S.S.	M.S.	F value	Level of Significance
Blocks	2	.1225E + 07	.6123E + 06		
Treatments	16	.6641E + 07	.4151E + 06	2.492	0.05
Error	32	.5329E + 07	.1665E + 06		

Table 7. Protein concentrations of spring wheat grain and analysis of variance.

1980 Crop	% Protein				Means
	Rep. I	Rep. II.	Rep. III		
<i>T. subterraneum</i> (Nangeela)	13.1	13.1	14.0		13.4
<i>Medicago Truncatula</i> (Jemalong)	13.6	13.8	13.9		13.8
<i>T. subterraneum</i> (Northam)	15.7	13.4	14.7		14.6
<i>Medicago Truncatula</i> (Cyprus)	14.1	14.6	15.9		14.9
<i>T. subterraneum</i> (Clare)	14.4	13.3	13.4		13.7
<i>Medicago Littoralis</i> (Harbinger)	16.0	14.6	14.8		15.1
Grain-fallow	15.2	14.8	14.5		14.8
<i>T. subterraneum</i> (Daliak)	13.9	13.9	14.2		14.0
<i>Medicago Lupulina</i> (Black medic)	14.9	15.2	15.4		15.2
<i>T. subterraneum</i> (Geraldton)	14.1	13.7	14.0		13.9
<i>Medicago truncatula</i> (Ghor)	15.4	15.3	15.4		15.4
<i>T. subterraneum</i> (Nungarin)	13.3	13.7	13.8		13.6
<i>Lupinus angustifolius</i> (Unicrop)	15.5	15.8	16.2		15.8
<i>Medicago Scutellafa</i> (Robinson)	15.7	16.0	14.7		15.5
<i>Vicia faba</i> (Giza III)	15.2	15.1	15.4		15.2
<i>T. resupinatum</i> (Maral schaftal)	14.4	14.2	14.6		14.4
<i>Lupinus albus</i> (Ultra)	15.8	15.6	16.5		16.0
<u>Analysis of Variance</u>					
Source	D.f.	S.S.	M.S.	F value	Level of Significance
Blocks	2	.9204	.4602		
Treatments	16	31.75	1.984	7.601	0.01
Error	32	8.353	.2610		

Table 8. Total N content of spring wheat grain and analysis of variance.

1980 Crop	Total N (%)			Means
	Rep. I	Rep. II	Rep. III	
<i>T. Subterraneum</i> (Nangeela)	3.03	2.66	2.83	2.84
<i>Medicago truncatula</i> (Jemalong)	3.12	3.17	2.66	2.98
<i>T. subterraneum</i> (Northam)	3.42	3.03	3.95	3.47
<i>Medicago truncatula</i> (Cyprus)	2.89	2.95	3.61	3.15
<i>T. subterraneum</i> (Clare)	2.77	2.60	2.96	2.78
<i>Medicago Littoralis</i> (Harbinger)	2.95	2.60	2.55	2.70
Grain-fallow	3.42	3.06	3.01	3.16
<i>T. subterraneum</i> (Daliak)	2.89	2.77	2.83	2.83
<i>Medicago Lupulino</i> (Black Medic)	3.42	3.49	3.06	3.32
<i>T. subterraneum</i> (Geraldton)	3.22	2.95	2.66	2.94
<i>Medicago truncatula</i> (Ghor)	3.06	3.36	2.83	3.08
<i>T. subterraneum</i> (Nungarin)	2.90	2.96	3.22	3.03
<i>Lupinus angustifolius</i> (Unicrop)	3.01	3.42	3.36	3.26
<i>Medicago scutellata</i> (Robinson)	3.17	3.06	3.30	3.18
<i>Vicia faba</i> (Giza III)	3.06	3.36	3.01	3.14
<i>T. resupinatum</i> (Maral Schaftal)	3.22	2.89	3.22	3.11
<i>Lupinus albus</i> (Ultra)	3.01	3.17	3.81	3.33
TOTAL	52.56	51.5	52.87	3.08
<u>Analysis of Variance</u>				
Source	D.f.	S.S.	M.S.	f Value
Blocks	2	0.0608		
Treatments	16	2.1546	0.1347	1.30
Error	32	2.2707	0.0710	
Total	50	4.4861		

Level of
Significance

*N.S.

*Not significantly different at the 5% level.

Table 9. Soil organic matter levels, spring and fall, 1981.

1980 Crop	Sample Depth	% O.M. spring, 1981				Sample Depth	% O.M. fall, 1981			
		Rep. I	Rep. II	Rep. III	Means		Rep. I	Rep. II	Rep. III	Means
<i>T. subterraneum</i> (Nangeela)	0-6"	1.71	1.37	1.82	1.63	0-6"	1.63	1.30	1.37	1.43
	0-1'	1.41	1.59	1.75	1.58	0-1'	1.03	0.67	0.93	0.88
<i>Medicago truncatula</i> (Jemalong)	0-6"	1.59	1.52	1.45	1.52	0-6"	1.45	1.13	1.63	1.40
	0-1'	1.41	1.37	1.45	1.41	6-12"	0.96	0.74	0.70	0.80
<i>T. subterraneum</i> (Northam)	0-6"	1.59	1.45	1.45	1.50	0-6"	1.06	1.37	1.13	1.19
	0-1'	1.59	1.09	1.30	1.33	6-12"	1.23	1.20	0.67	1.03
<i>Medicago truncatula</i> (Cyprus)	0-6"	1.59	1.45	1.52	1.52	0-6"	1.48	1.48	1.03	1.33
	0-1'	1.16	1.27	1.13	1.19	6-12"	1.13	1.26	0.90	1.10
<i>T. subterraneum</i> (Clare)	0-6"	1.59	1.52	1.75	1.62	0-6"	1.45	1.23	1.90	1.53
	0-1'	1.34	1.45	1.52	1.44	6-12"	1.06	0.93	1.67	1.22
<i>Medicago littoralis</i> (Harbinger)	0-6"	1.52	1.59	1.75	1.62	0-6"	1.52	1.20	1.71	1.48
	0-1'	1.52	1.49	1.67	1.56	6-12"	1.27	0.80	1.41	1.16
Grain fallow	0-6"	1.52	1.67	1.45	1.55	0-6"	1.52	1.71	1.23	1.49
	0-1'	1.45	1.59	1.06	1.37	6-12"	1.03	0.70	0.83	0.85
<i>T. subterraneum</i> (Daliak)	0-6"	1.52	1.45	1.45	1.47	0-6"	1.45	1.37	1.09	1.30
	0-1'	1.75	1.59	1.37	1.57	6-12"	1.23	1.09	1.09	1.14
<i>Medicago lupulina</i> (Black medic)	0-6"	1.67	1.75	1.52	1.65	0-6"	1.45	1.79	1.49	1.58
	0-1'	1.49	1.16	1.20	1.28	6-12"	0.34	1.16	1.06	0.85
<i>T. subterraneum</i> (Geraldton)	0-6"	1.67	1.59	1.59	1.62	0-6"	1.37	1.56	1.23	1.39
	0-1'	1.20	1.37	1.27	1.28	6-12"	1.37	0.83	0.74	0.98
<i>Medicago truncatula</i> (Ghor)	0-6"	1.41	1.63	1.67	1.57	0-6"	1.13	1.59	1.41	1.38
	0-1'	1.30	1.23	1.67	1.40	6-12"	1.16	0.52	0.80	0.83
<i>T. subterraneum</i> (Nungarin)	0-6"	1.67	1.52	1.75	1.65	0-6"	1.52	1.37	1.52	1.47
	0-1'	1.27	1.45	1.52	1.41	6-12"	1.00	0.55	0.52	0.69
<i>Lupinus angustifolius</i> (Unicrop)	0-6"	1.59	1.52	1.45	1.52	0-6"	0.96	1.86	1.59	1.47
	0-1'	1.52	1.45	1.30	1.42	6-12"	1.09	1.03	0.74	0.95
<i>Medicago scutellata</i> (Robinson)	0-6"	1.75	1.67	1.37	1.60	0-6"	1.71	1.06	1.56	1.44
	0-1'	1.67	1.63	1.34	1.55	6-12"	1.20	1.06	0.80	1.02
<i>Vicia faba</i> (Giza III)	0-6"	1.63	1.37	1.52	1.51	0-6"	1.49	1.30	1.34	1.38
	0-1'	1.16	1.07	1.56	1.27	6-12"	1.37	0.64	0.74	0.92
<i>T. resupinatum</i> (Maral schaftal)	0-6"	1.63	1.67	1.52	1.61	0-6"	1.30	1.82	1.48	1.53
	0-1'	1.23	1.49	1.30	1.34	6-12"	0.90	0.96	0.58	0.81
<i>Lupinus albus</i> (Ultra)	0-6"	1.59	1.52	1.59	1.57	0-6"	1.30	1.52	0.99	1.27
	0-1'	1.13	1.20	1.23	1.19	6-12"	1.03	1.30	0.67	1.00

Table 10. Initial soil chemical analyses, spring 1979.

1980 Crop	Rep. No.	Sample Depth	Nitrate N	Total N	O.M.	pH	EC	Zn	Fe	Cu	Mn
<i>T. subterraneum</i> (Nangeela)	1	0-6"	11.8	.085	1.3	8.4	0.8	.35	9.9	3.1	16.9
		6-12"	11.8		1.0	8.5	0.8	.24	9.6	3.0	13.7
	2	0-6"	6.0	.075	1.3	8.1	0.8	.53	9.3	3.0	19.1
		6-12"	6.8		0.9	8.2	0.8	.68	8.7	2.7	14.7
	3	0-6"	7.8	.085	1.5	8.5	0.7	.46	9.9	2.9	19.1
		6-12"	7.6		1.1	8.5	0.7	.31	9.3	2.9	12.7
<i>Medicago truncatula</i> (Jamelong)	1	0-6"	9.6	.091	1.3	8.5	0.8	.31	9.6	3.1	17.7
		6-12"	10.5		1.0	8.5	0.8	.24	9.0	3.0	13.7
	2	0-6"	8.3	.080	1.2	8.3	0.8	.42	9.0	3.0	19.5
		6-12"	9.1		0.9	8.0	0.8	.27	8.7	2.6	15.1
	3	0-6"	9.2	.085	1.4	8.4	0.7	.38	8.2	2.6	24.6
		6-12"	7.6		1.1	8.4	0.7	.38	7.9	2.5	12.9
<i>T. subterraneum</i> (Northam)	1	0-6"	11.8	.092	1.2	8.6	0.8	.31	8.2	3.2	16.3
		6-12"	13.7		1.1	8.5	0.8	.20	7.9	3.1	13.3
	2	0-6"	13.2	.073	1.6	8.6	0.8	.38	7.6	3.2	15.7
		6-12"	13.2		1.3	8.6	0.8	.35	6.8	3.0	12.7
	3	0-6"	7.6	.076	1.4	8.3	0.7	.42	8.5	2.4	15.7
		6-12"	7.6		1.3	8.3	0.7	.42	8.2	2.4	12.1
<i>Medicago truncatula</i> (Cyprus)	1	0-6"	11.5	.065	1.2	8.6	0.8	.31	8.5	3.1	16.1
		6-12"	8.6		1.1	8.5	0.8	.27	8.2	2.9	14.3
	2	0-6"	6.0	.066	1.1	8.2	0.8	.53	7.6	2.4	14.3
		6-12"	6.5		0.8	8.2	0.8	.38	7.6	2.1	10.9
	3	0-6"	7.3	.066	1.3	8.4	0.6	.42	7.1	2.6	15.7
		6-12"	6.5		1.0	8.4	0.7	.27	7.1	2.4	22.2
<i>T. subterraneum</i> (Clare)	1	0-6"	10.5	.101	1.3	8.5	0.8	.35	8.2	3.1	16.1
		6-12"	8.6		0.9	8.6	0.8	.24	7.1	2.8	11.9
	2	0-6"	10.6	.068	1.7	8.3	0.8	.42	6.8	3.2	16.7
		6-12"	10.6		1.4	8.4	0.8	.27	6.5	2.9	11.9
	3	0-6"	7.3	.085	1.1	8.4	0.7	.38	8.5	2.9	13.9
		6-12"	10.2		1.1	8.4	0.7	.31	8.2	2.4	13.3
<i>Medicago littoralis</i> (Harringer)	1	0-6"	6.7	.073	1.2	8.5	0.8	.38	7.4	3.1	16.5
		6-12"	7.7		1.1	8.5	0.7	.20	7.4	2.9	13.9
	2	0-6"	8.3	.070	1.5	8.2	0.8	.38	9.3	3.0	17.1
		6-12"	9.1		1.2	8.4	0.8	.31	8.7	2.8	12.3
	3	0-6"	8.9	.082	1.3	8.4	0.7	.35	9.0	2.5	14.7
		6-12"	9.7		1.1	8.4	0.7	.27	9.0	2.4	10.9
Grain Fallow	1	0-6"	9.6	.079	1.3	8.3	0.8	.38	7.6	3.0	15.9
		6-12"	11.1		1.1	8.5	0.8	.31	7.1	2.8	14.3
	2	0-6"	7.5	.085	1.5	8.2	0.8	.57	9.6	3.0	17.3
		6-12"	7.5		1.1	8.0	0.8	.46	8.7	2.7	12.3
	3	0-6"	7.5	.081	1.7	8.1	0.8	.49	7.1	2.6	15.1
		6-12"	9.7		1.3	8.0	0.8	.35	6.8	2.2	10.9
<i>T. subterraneum</i> (Delish)	1	0-6"	9.9	.085	1.3	8.5	0.8	.31	7.9	3.1	18.9
		6-12"	10.5		1.1	8.5	0.8	.27	7.6	2.8	14.5
	2	0-6"	6.0	.079	1.3	8.2	0.8	.46	8.5	2.3	14.7
		6-12"	5.0		0.9	8.2	0.8	.31	7.9	2.2	12.5
	3	0-6"	7.0	.089	1.5	8.4	0.7	.35	6.8	2.4	18.3
		6-12"	6.5		1.2	8.3	0.7	.31	8.5	2.2	11.7
<i>Medicago lupulina</i> (Black mecie)	1	0-6"	10.5	.072	1.2	8.5	0.8	.31	8.2	3.1	30.6
		6-12"	10.5		1.1	8.4	0.9	.27	8.5	2.9	13.9
	2	0-6"	6.8	.090	1.5	8.2	0.8	.45	8.2	2.4	13.5
		6-12"	6.0		1.2	8.1	0.8	.24	8.2	2.3	10.1
	3	0-6"	8.9	.073	1.5	8.3	0.6	.42	6.8	2.2	15.9
		6-12"	8.1		1.3	8.4	0.6	.38	6.8	2.7	15.9
<i>T. subterraneum</i> (Geraldton)	1	0-6"	10.5	.087	1.3	8.6	0.8	.27	8.7	3.1	16.7
		6-12"	9.2		1.2	8.5	0.8	.24	8.2	3.1	14.7
	2	0-6"	8.6	.068	1.2	8.1	0.8	.38	8.7	2.4	14.7
		6-12"	8.3		1.5	8.2	0.8	.35	10.4	2.2	10.5
	3	0-6"	6.0	.078	1.5	8.4	0.6	.38	8.2	2.5	15.7
		6-12"	7.3		1.2	8.4	0.7	.31	8.5	2.3	12.5
<i>Medicago truncatula</i> (Dhor)	1	0-6"	7.8	.073	1.3	8.5	0.8	.31	8.5	3.2	15.9
		6-12"	9.2		1.1	8.5	0.8	.20	7.6	2.8	12.9
	2	0-6"	5.6	.092	1.4	8.2	0.8	.46	9.6	3.1	18.1
		6-12"	6.5		1.1	8.2	0.8	.35	8.7	2.8	11.5
	3	0-6"	7.3	.089	1.3	8.5	0.7	.42	9.3	2.7	14.3
		6-12"	7.6		1.0	8.5	0.7	.35	9.0	2.6	17.1
<i>T. subterraneum</i> (Mungarin)	1	0-6"	11.6	.076	1.3	8.5	0.8	.35	8.5	3.1	15.9
		6-12"	10.5		1.1	8.7	0.8	.24	8.2	3.0	12.3
	2	0-6"	9.1	.075	1.2	8.3	0.8	.31	8.5	3.0	19.7
		6-12"	9.8		0.9	8.4	0.8	.27	8.7	2.7	16.5
	3	0-6"	9.2	.095	1.3	8.5	0.7	.49	9.0	2.2	15.5
		6-12"	10.2		1.1	8.5	0.7	.83	9.0	2.5	10.9
<i>Lupinus angustifolius</i> (Unicrop)	1	0-6"	11.1	.087	1.3	8.6	0.8	.38	8.7	3.3	17.3
		6-12"	11.6		1.1	8.6	0.8	.24	8.5	2.9	12.7
	2	0-6"	12.1	.078	1.3	8.1	0.8	.38	9.0	2.9	18.9
		6-12"	11.4		1.1	8.1	0.8	.57	8.7	2.7	14.3
	3	0-6"	7.3	.067	1.5	8.4	0.6	.35	8.7	2.5	14.1
		6-12"	7.3		1.0	8.5	0.7	.31	8.5	2.3	8.1
<i>Medicago scutellata</i> (Robinson)	1	0-6"	11.1	.096	1.4	8.5	0.8	.38	9.0	3.0	16.9
		6-12"	9.1		1.2	8.6	0.8	.27	7.4	2.8	12.9
	2	0-6"	5.6	.073	1.7	8.2	0.8	.38	9.0	3.1	17.9
		6-12"	5.6		1.1	8.1	0.8	.27	7.4	2.3	9.1
	3	0-6"	8.3	.076	1.6	8.1	0.8	.46	7.6	2.6	27.8
		6-12"	7.5		1.1	8.2	0.8	.27	7.1	2.3	10.9
<i>Vicia faba</i> (Giza III)	1	0-6"	8.3	.089	1.4	8.6	0.8	.35	9.0	3.2	22.6
		6-12"	9.5		0.9	8.6	0.8	.24	7.9	2.8	11.3
	2	0-6"	9.8	.047	1.3	8.3	0.8	.42	7.1	3.0	15.7
		6-12"	8.3		1.0	8.3	0.8	.42	8.5	2.9	14.7
	3	0-6"	6.0	.082	1.3	8.4	0.7	.42	8.5	2.6	18.7
		6-12"	6.0		1.1	8.4	0.7	.27	8.5	2.4	11.7
<i>T. nesipinatum</i> (Maral schafel)	1	0-6"	10.6	.074	1.5	8.6	0.8	.35	8.5	3.1	10.9
		6-12"	9.8		0.8	8.6	0.8	.27	6.8	2.8	11.1
	2	0-6"	8.3	.090	1.8	8.1	0.8	.57	8.7	2.4	15.5
		6-12"	7.5		1.3	8.2	0.8	.46	8.7	2.8	12.3
	3	0-6"	8.0	.082	1.5	8.2	0.8	.38	7.4	2.4	13.5
		6-12"	8.3		1.2	8.1	0.8	.31	7.1	2.4	11.3
<i>Lupinus albus</i> (Ultra)	1	0-6"	8.0	.065	1.4	8.6	0.8	.46	7.1	3.2	17.1
		6-12"	8.0		1.3	8.6	0.8	.27	6.8	2.9	12.1
	2	0-6"	8.3	.062	1.3	8.1	0.8	.61	9.6	2.0	18.5
		6-12"	7.5		0.9	8.1	0.8	.49	7.1	2.1	11.5
	3	0-6"	9.2	.086	1.5	8.0	0.8	.38	6.8	2.3	14.3
		6-12"	12.0		1.0	8.1	0.8	.35	6.5	2.1	11.5

Table 10, continued.

1980 Crop	Rep. No.	Sample Depth	Bray P	Olsen P	K	Na	Mg	Ca	Boron	Sulfur
<i>T. subterraneum</i> (Mangoola)	1	0-6"	52	12	294	0.0	3.3	37	0.4	2.2
		6-12"	30	8	240	0.0	3.3	38	0.4	2.9
	2	0-6"	28	11	263	0.0	3.0	39	0.6	2.1
		6-12"	12	6	240	0.1	3.2	40	0.4	0.3
	3	0-6"	30	9	286	0.0	2.6	37	1.0	0.3
		6-12"	22	6	216	0.0	2.6	38	0.4	0.1
<i>Medicago truncatula</i> (Jemalong)	1	0-6"	78	22	286	0.0	3.3	36	0.4	2.9
		6-12"	24	9	232	0.0	2.9	36	0.2	0.4
	2	0-6"	20	12	263	0.1	3.1	39	0.6	0.7
		6-12"	8	8	224	0.1	3.2	41	0.4	0.7
	3	0-6"	29	7	247	0.0	2.0	36	1.0	0.3
		6-12"	21	6	216	0.0	2.6	36	1.0	0.3
<i>T. subterraneum</i> (Northam)	1	0-6"	59	22	302	0.0	3.3	39	0.4	3.7
		6-12"	33	9	263	0.0	3.6	42	0.4	4.1
	2	0-6"	50	12	255	0.1	3.0	39	0.6	0.3
		6-12"	2	9	209	0.0	2.0	40	0.4	0.7
	3	0-6"	46	8	263	0.0	2.3	35	0.6	0.3
		6-12"	24	6	216	0.0	3.0	34	0.4	0.3
<i>Medicago truncatula</i> (Cyprus)	1	0-6"	50	16	278	0.0	3.3	39	0.4	4.9
		6-12"	23	9	263	0.0	3.3	41	0.3	0.7
	2	0-6"	47	11	294	0.0	3.2	41	0.6	0.3
		6-12"	7	8	224	0.1	3.2	39	0.4	0.3
	3	0-6"	50	12	255	0.0	2.3	36	0.6	0.3
		6-12"	31	8	209	0.0	2.6	36	0.4	0.3
<i>T. subterraneum</i> (Clare)	1	0-6"	47	14	286	0.0	2.9	35	0.3	3.7
		6-12"	4	8	224	0.0	2.6	33	0.2	3.7
	2	0-6"	56	15	278	0.0	3.0	36	0.6	0.7
		6-12"	2	8	224	0.1	3.0	41	0.4	0.3
	3	0-6"	33	8	302	0.0	2.8	37	1.0	0.3
		6-12"	20	6	232	0.0	3.0	36	1.0	0.3
<i>Medicago littoralis</i> (Marbinger)	1	0-6"	59	24	201	0.0	2.6	36	0.2	4.1
		6-12"	3	10	232	0.0	2.3	36	0.6	1.8
	2	0-6"	49	12	278	0.1	3.2	41	0.8	0.3
		6-12"	35	6	209	0.1	2.3	30	0.6	0.3
	3	0-6"	36	9	271	0.0	3.0	29	1.0	0.3
		6-12"	15	6	209	0.0	3.0	40	0.6	0.3
Grain Fallow	1	0-6"	42	14	286	0.0	2.3	35	0.6	5.1
		6-12"	4	9	240	0.0	2.9	40	0.4	7.2
	2	0-6"	46	11	271	0.1	3.3	37	0.4	0.3
		6-12"	30	7	193	0.1	3.0	33	0.6	0.3
	3	0-6"	63	13	240	0.0	2.3	33	0.8	0.3
		6-12"	28	9	201	0.0	2.6	34	0.8	0.3
<i>T. subterraneum</i> (Daliek)	1	0-6"	41	11	286	0.0	2.3	35	0.6	0.3
		6-12"	9	8	255	0.0	3.3	39	0.4	1.8
	2	0-6"	59	14	294	0.1	3.2	39	0.6	0.3
		6-12"	11	6	232	0.1	3.1	41	0.4	0.3
	3	0-6"	42	9	224	0.0	2.0	36	0.6	0.3
		6-12"	37	6	224	0.0	2.6	36	0.4	0.3
<i>Medicago lupulina</i> (Black medic)	1	0-6"	47	14	271	0.0	2.0	38	0.4	4.5
		6-12"	14	9	247	0.0	3.3	41	0.4	0.3
	2	0-6"	52	17	263	0.0	2.3	35	0.8	0.3
		6-12"	5	7	278	0.0	2.0	32	0.8	0.3
	3	0-6"	50	14	232	0.0	2.0	34	0.8	0.3
		6-12"	27	8	209	0.1	2.3	35	0.6	0.3
<i>T. subterraneum</i> (Geraldton)	1	0-6"	41	10	278	0.0	3.3	39	0.6	1.1
		6-12"	15	7	232	0.0	3.3	37	0.4	0.7
	2	0-6"	46	12	310	0.0	3.3	38	0.8	0.3
		6-12"	37	8	224	0.1	3.2	41	0.4	0.3
	3	0-6"	41	13	263	0.0	2.3	34	0.6	0.3
		6-12"	22	5	201	0.0	2.6	32	1.0	0.3
<i>Medicago truncatula</i> (Ghor)	1	0-6"	43	14	271	0.0	2.6	35	0.6	0.3
		6-12"	6	8	224	0.0	2.9	31	0.4	0.3
	2	0-6"	47	8	278	0.1	3.2	39	0.8	0.3
		6-12"	29	6	216	0.1	3.2	42	0.4	0.3
	3	0-6"	29	8	271	0.0	3.1	28	1.0	0.3
		6-12"	16	5	193	0.0	2.6	42	1.0	0.3
<i>T. subterraneum</i> (Mungerin)	1	0-6"	56	22	271	0.0	3.3	29	0.6	3.2
		6-12"	14	9	232	0.0	2.9	31	0.4	0.7
	2	0-6"	18	12	263	0.0	3.1	41	0.6	0.3
		6-12"	6	8	232	0.1	3.1	44	0.4	0.7
	3	0-6"	33	8	294	0.0	2.6	35	1.0	0.3
		6-12"	19	6	232	0.0	2.6	33	1.0	0.3
<i>Lupinus angustifolius</i> (Unicrop)	1	0-6"	43	17	271	0.0	2.9	35	0.6	3.6
		6-12"	8	9	224	0.0	3.3	42	0.4	0.3
	2	0-6"	27	13	278	0.0	3.2	42	0.6	1.6
		6-12"	7	8	240	0.1	3.3	41	0.6	0.3
	3	0-6"	29	8	271	0.0	2.8	33	0.6	0.3
		6-12"	15	5	209	0.1	3.0	33	0.6	0.3
<i>Medicago scutellata</i> (Robinson)	1	0-6"	49	15	286	0.0	3.3	40	0.3	3.2
		6-12"	2	8	216	0.1	3.9	39	0.6	2.8
	2	0-6"	41	9	263	0.1	2.6	33	0.6	0.3
		6-12"	24	6	193	0.1	2.6	33	0.4	0.3
	3	0-6"	46	12	255	0.0	2.3	37	0.8	0.3
		6-12"	36	6	209	0.0	2.3	36	0.4	0.3
<i>Vicia faba</i> (Giza III)	1	0-6"	43	12	263	0.0	3.0	38	0.6	4.7
		6-12"	2	7	224	0.0	3.2	41	0.6	1.4
	2	0-6"	39	14	278	0.1	3.1	41	0.8	1.7
		6-12"	7	9	224	0.0	3.3	37	0.6	1.4
	3	0-6"	29	7	247	0.0	2.0	36	0.6	0.3
		6-12"	17	5	193	0.0	2.3	33	0.2	0.3
<i>T. acutipinnatum</i> (Meral schafal)	1	0-6"	52	14	278	0.0	3.1	40	0.6	3.6
		6-12"	8	7	216	0.1	3.2	41	0.6	4.0
	2	0-6"	46	11	278	0.1	3.1	40	0.4	0.3
		6-12"	39	8	240	0.1	3.6	41	0.4	0.3
	3	0-6"	55	9	255	0.0	2.0	34	0.8	0.8
		6-12"	25	7	216	0.0	2.3	34	0.6	0.3
<i>Lupinus albus</i> (Ultra)	1	0-6"	56	21	247	0.0	3.0	38	0.6	2.1
		6-12"	7	8	224	0.1	3.2	40	0.4	2.1
	2	0-6"	37	14	294	0.0	3.2	39	0.6	0.3
		6-12"	8	6	278	0.0	3.3	42	0.6	0.3
	3	0-6"	47	13	224	0.0	2.3	32	0.8	0.3
		6-12"	21	8	193	0.0	2.6	35	0.6	0.3

Table 11. Soil chemical analysis, spring 1981.

1980 Crop	Sample Depth	Nitrate-N			Bray P		
		Rep. I	Rep. II	Rep. III	Rep. I	Rep. II	Rep. III
<i>T. subterraneum</i> (Nangeela)	0-6"	30.9	13.4	12.9	44	40	30
	0-1'	12.7	6.6	4.8	32	21	28
	1-2'	4.2	3.2	3.5	<1	<1	5
	2-4'	2.8	2.3	2.2	4	8	12
<i>Medicago truncatula</i> (Jemalong)	0-6"	18.4	16.9	16.3	39	39	32
	0-1'	7.1	6.5	4.0	37	49	8
	1-2'	3.2	5.6	3.2	<1	<1	16
	2-4'	2.3	3.5	1.8	<1	11	32
<i>T. subterraneum</i> (Northam)	0-6"	14.2	18.1	20.0	43	37	32
	0-1'	7.6	5.8	5.0	37	36	25
	1-2'	5.4	3.3	3.6	<1	<1	1
	2-4'	7.9	3.7	5.6	<1	4	12
<i>Medicago truncatula</i> (Cyprus)	0-6"	16.0	17.3	16.2	40	35	25
	0-1'	7.1	5.2	5.8	22	36	20
	1-2'	3.2	3.0	4.2	<1	6	5
	2-4'	7.1	5.1	3.7	<1	8	9
<i>T. subterraneum</i> (Clare)	0-6"	22.6	21.5	22.7	36	49	31
	0-1'	9.5	8.5	5.1	31	37	23
	1-2'	5.4	3.7	2.7	<1	<1	<1
	2-4'	7.3	3.7	2.4	<1	10	11
<i>Medicago littoralis</i> (Harbinger)	0-6"	16.2	13.4	22.3	35	33	33
	0-1'	8.4	5.5	4.9	8	31	36
	1-2'	1.8	3.5	7.1	<1	<1	<1
	2-4'	6.1	3.7	9.4	15	8	11
Grain-fallow	0-6"	10.9	14.8	12.8	31	32	37
	0-1'	4.4	2.6	2.9	5	32	<1
	1-2'	4.1	4.2	3.7	<1	<1	<1
	2-4'	1.9	2.3	2.0	16	4	5
<i>T. subterraneum</i> (Iwalia)	0-6"	19.3	17.3	11.8	37	36	30
	0-1'	11.7	5.1	4.4	19	49	25
	1-2'	5.2	3.4	4.4	<1	<1	3
	2-4'	3.1	3.8	3.2	<1	<1	9
<i>Medicago lupulina</i> (Black medic)	0-6"	20.3	20.9	24.8	37	27	37
	0-1'	7.4	4.2	4.7	26	33	9
	1-2'	4.7	7.2	7.2	2	<1	7
	2-4'	6.6	7.6	12.2	1	14	9
<i>T. subterraneum</i> (Geraldton)	0-6"	13.1	17.7	23.4	37	35	26
	0-1'	7.2	8.4	5.8	21	41	25
	1-2'	5.6	3.4	2.9	2	<1	5
	2-4'	6.3	4.4	4.8	5	8	13
<i>Medicago truncatula</i> (Ghor)	0-6"	11.7	16.0	9.5	39	32	36
	0-1'	6.1	5.5	4.6	5	32	31
	1-2'	4.6	5.1	4.7	2	<1	<1
	2-4'	7.9	6.6	7.0	1	4	18
<i>T. subterraneum</i> (Nungarin)	0-6"	16.5	12.6	14.8	40	36	31
	0-1'	9.0	5.3	3.5	39	26	23
	1-2'	4.2	2.5	3.7	<1	<1	6
	2-4'	3.6	1.6	3.1	4	25	12
<i>Lupinus angustifolius</i> (Unicrop)	0-6"	12.5	17.4	11.2	40	29	31
	0-1'	7.6	7.1	5.5	25	36	28
	1-2'	9.0	4.5	6.2	<1	<1	5
	2-4'	10.4	8.6	8.2	3	21	19
<i>Medicago scutellata</i> (Robinson)	0-6"	15.0	11.5	18.0	33	28	41
	0-1'	5.6	3.1	6.5	31	25	<1
	1-2'	5.0	3.4	3.0	4	<1	<1
	2-4'	6.1	8.4	7.5	3	3	<1
<i>Vicia faba</i> (Giza III)	0-6"	11.6	16.7	13.9	33	50	43
	0-1'	6.1	4.8	4.0	26	<1	31
	1-2'	6.1	4.2	5.8	<1	<1	3
	2-4'	7.4	2.7	8.9	3	<1	12
<i>T. resupinatum</i> (Meral shaftal)	0-6"	21.0	22.6	16.1	31	35	23
	0-1'	7.1	6.6	7.7	21	35	32
	1-2'	6.3	3.4	4.2	<1	<1	<1
	2-4'	5.3	4.4	4.1	8	12	9
<i>Lupinus albus</i> (Ultra lupines)	0-6"	12.5	12.2	16.1	31	36	40
	0-1'	9.6	5.9	8.5	22	36	26
	1-2'	8.5	3.8	4.4	<1	<1	<1
	2-4'	10.2	5.1	3.7	9	5	8

Table 12. Soil chemical analysis, fall, 1981.

1980 Crop	Sample Depth	Nitrate - N			Bray P		
		Rep. I	Rep. II	Rep. III	Rep. I	Rep. II	Rep. III
<i>T. subterraneum</i> (Nangeela)	0-6"	4.9	2.4	4.4	57	40	32
	6-12"	3.6	2.3	2.9	29	23	2
	1-2'	2.9	1.9	2.7	12	14	1
	2-3'	3.1	1.5	2.3	12	16	8
	3-4'	2.6	1.5	2.1	21	31	18
<i>Medicago truncatula</i> (Jemalong)	0-6"	4.0	3.2	3.0	45	44	26
	6-12"	3.8	3.0	2.8	31	20	<1
	1-2'	2.6	1.7	1.9	5	11	<1
	2-3'	2.4	1.5	1.9	8	18	9
	3-4'	2.4	1.5	1.8	12	32	30
<i>T. subterraneum</i> (Northam)	0-6"	3.2	3.8	2.1	31	66	32
	6-12"	3.4	2.6	2.1	29	23	<1
	1-2'	3.2	1.8	2.1	9	4	<1
	2-3'	2.6	1.5	1.5	10	5	<1
	3-4'	3.1	1.6	1.6	14	16	13
<i>Medicago truncatula</i> (Cyprus)	0-6"	4.9	3.1	4.0	70	39	37
	6-12"	4.4	2.8	2.7	26	32	<1
	1-2'	2.7	1.9	1.8	9	13	<1
	2-3'	3.1	1.6	1.4	8	9	<1
	3-4'	3.4	1.8	1.8	10	17	44
<i>T. subterraneum</i> (Clare)	0-6"	4.7	3.5	3.8	37	82	32
	6-12"	4.0	2.6	2.9	20	9	26
	1-2'	3.4	1.8	2.3	9	1	2
	2-3'	3.0	1.5	1.9	9	8	15
	3-4'	2.4	1.9	1.8	11	13	16
<i>Medicago littoralis</i> (Harbinger)	0-6"	3.9	2.9	3.6	49	21	52
	6-12"	4.1	2.0	2.9	25	4	1
	1-2'	2.7	2.3	2.5	1	<1	1
	2-3'	2.4	1.9	2.0	8	<1	15
	3-4'	2.9	3.0	2.3	16	8	37
Grain-fallow	0-6"	4.5	3.3	3.0	40	20	33
	6-12"	3.9	2.6	2.4	23	<1	<1
	1-2'	3.1	2.0	2.2	6	<1	<1
	2-3'	2.4	1.8	1.5	14	2	5
	3-4'	2.6	1.6	2.0	20	8	26
<i>T. subterraneum</i> (Dallak)	0-6"	4.3	2.7	3.7	45	33	32
	6-12"	3.9	2.4	3.0	23	26	<1
	1-2'	1.4	1.8	2.0	12	<1	<1
	2-3'	2.7	1.4	1.8	14	<1	3
	3-4'	2.6	1.4	2.4	25	10	20
<i>Medicago lupulina</i> (Black medic)	0-6"	4.2	2.8	3.8	45	39	50
	6-12"	2.6	2.4	2.6	4	<1	<1
	1-2'	3.0	1.6	2.0	26	<1	4
	2-3'	1.8	1.2	1.5	14	<1	8
	3-4'	1.9	2.1	5.3	17	16	52
<i>T. subterraneum</i> (Geraldton)	0-6"	3.4	3.4	3.6	64	40	40
	6-12"	2.9	2.2	2.9	25	<1	<1
	1-2'	2.2	1.7	1.9	12	<1	<1
	2-3'	1.9	1.4	2.1	9	<1	<1
	3-4'	2.0	2.3	2.3	16	7	23
<i>Medicago truncatula</i> (Ghor)	0-6"	2.6	2.5	3.6	45	33	30
	6-12"	2.7	2.0	3.5	19	<1	2
	1-2'	2.3	1.4	2.5	4	<1	2
	2-3'	2.0	1.8	2.0	8	<1	2
	3-4'	2.1	2.2	2.7	15	6	18
<i>T. subterraneum</i> (Nungarin)	0-6"	3.0	3.6	3.4	96	49	117
	6-12"	2.6	2.7	3.0	20	14	3
	1-2'	1.9	2.0	2.6	3	12	2
	2-3'	2.0	1.5	1.9	3	12	11
	3-4'	2.5	1.9	1.8	11	19	26
<i>Lupinus angustifolius</i> (Unicrop)	0-6"	2.9	3.4	3.4	75	55	43
	6-12"	2.6	2.5	3.0	25	19	2
	1-2'	1.4	1.4	2.1	<1	9	2
	2-3'	1.5	1.5	1.8	3	16	9
	3-4'	6.0	1.5	1.8	5	35	21
<i>Medicago scutellata</i> (Robinson)	0-6"	3.3	2.5	3.3	45	25	35
	6-12"	2.6	1.6	1.8	32	<1	<1
	1-2'	1.5	1.4	2.1	11	<1	<1
	2-3'	1.2	1.4	1.7	8	8	<1
	3-4'	1.4	1.8	1.8	17	10	12
<i>Vicia faba</i> (Giza III)	0-6"	3.3	3.5	3.6	39	60	36
	6-12"	2.4	2.2	2.9	33	11	1
	1-2'	1.3	1.6	2.1	5	1	2
	2-3'	1.5	1.6	1.6	5	10	31
	3-4'	3.8	1.4	1.8	9	15	36
<i>T. resupinatum</i> (Maral shaftal)	0-6"	3.0	3.1	6.4	44	37	31
	6-12"	2.3	2.5	2.7	1	21	<1
	1-2'	1.6	2.0	2.7	8	<1	<1
	2-3'	1.5	1.4	1.8	8	<1	<1
	3-4'	2.5	1.7	1.5	23	6	26
<i>Lupinus albus</i> (Ultra)	0-6"	3.3	2.5	4.5	32	64	35
	6-12"	2.2	2.8	4.5	20	20	<1
	1-2'	1.6	1.7	2.7	6	8	<1
	2-3'	1.8	1.3	1.6	11	8	<1
	3-4'	2.0	2.8	2.2	22	20	12

Table 13. Cm of water of soil samples taken in spring, April 16-17, 1981.

1980 Crop	Sample Depth	Rep. I	Rep. II	Rep. III	Means
<i>T. subterraneum</i> (Nangeela)	0-1'	7.10	7.35	7.54	7.33
	1-2'	6.09	6.63	7.21	6.64
	2-4'	11.06	10.51	10.85	10.81
<i>Medicago truncatula</i> (Tremalons)	0-1'	7.07	7.45	6.98	7.17
	1-2'	6.50	6.90	6.58	6.66
	2-4'	11.81	11.45	11.67	11.64
<i>T. subterraneum</i> (Northam)	0-1'	7.26	7.49	6.70	7.15
	1-2'	6.40	6.72	6.71	6.61
	2-4'	11.29	12.42	11.34	11.69
<i>Medicago truncatula</i> (Cyrpus)	0-1'	7.41	7.26	6.67	7.11
	1-2'	6.37	6.23	6.78	6.46
	2-4'	9.05	11.95	11.58	10.86
<i>T. subterraneum</i> (Clare)	0-1'	6.85	7.25	7.21	7.10
	1-2'	6.46	7.87	6.83	6.72
	2-4'	11.70	12.73	12.73	12.39
<i>Medicago Littoralis</i> (Harbinger)	0-1'	6.61	6.89	6.88	6.79
	1-2'	6.29	6.65	6.56	6.50
	2-4'	11.73	11.35	11.91	11.67
Grain-fallow	0-1'	6.85	6.80	7.20	6.95
	1-2'	7.01	7.25	6.85	7.03
	2-4'	11.84	12.50	12.56	12.30
<i>T. subterraneum</i> (Daliak)	0-1'	7.97	6.98	7.00	7.32
	1-2'	6.41	6.32	6.96	6.57
	2-4'	10.58	13.26	10.56	11.47
<i>Medicago Lupulina</i> (Black medic)	0-1'	6.68	7.09	7.10	6.96
	1-2'	6.11	6.34	6.39	6.28
	2-4'	11.05	12.28	11.59	11.64
<i>T. subterraneum</i> (Geraldton)	0-1'	7.02	7.42	7.06	7.17
	1-2'	6.25	6.07	6.66	6.33
	2-4'	12.00	9.04	11.73	10.92
<i>Medicago truncatula</i> (Ghor)	0-1'	6.98	7.20	7.08	7.08
	1-2'	6.63	6.54	7.10	6.76
	2-4'	10.90	11.73	12.66	11.76
<i>T. subterraneum</i> (Nungarin)	0-1'	5.53	7.58	7.39	6.83
	1-2'	6.45	6.69	7.11	6.75
	2-4'	12.13	12.62	12.31	12.36
<i>Lupinus angustifolius</i> (Unicrop)	0-1'	6.88	6.63	7.29	6.93
	1-2'	6.40	6.85	6.58	6.61
	2-4'	12.58	11.32	12.24	12.05
<i>Medicago scutellata</i> (Robinson)	0-1'	6.61	6.99	6.98	6.86
	1-2'	6.06	6.89	6.24	6.39
	2-4'	10.88	11.66	11.64	11.39
<i>Vicia faba</i> (Giza III)	0-1'	6.79	6.36	6.90	6.68
	1-2'	6.43	6.06	7.24	6.57
	2-4'	10.51	10.07	11.94	10.84
<i>T. resupinatum</i> (Maral shaftal)	0-1'	6.82	7.21	7.37	7.14
	1-2'	6.27	6.17	6.77	6.40
	2-4'	9.61	12.03	10.61	10.75
<i>Lupinus albus</i> (Ultra)	0-1'	6.63	6.79	6.95	6.79
	1-2'	6.51	6.35	6.90	6.59
	2-4'	12.20	11.58	12.49	12.09

Table 14. Cm of water of soil samples taken at harvest, September 24, 1981.

1980 Crop	Sample Depth	Rep. I	Rep. II	Rep. III	Means
<i>T. subterraneum</i> (Nangeela)	0-6"	1.45	1.51	1.68	1.55
	6-12"	1.92	2.00	1.90	1.94
	1-2'	4.01	4.01	4.33	4.11
	2-3'	5.15	4.68	5.15	4.99
	3-4'	5.65	5.23	6.08	5.65
<i>Medicago truncatula</i> (Jemalong)	0-6"	1.57	1.62	1.67	1.62
	6-12"	2.25	2.10	1.90	2.08
	1-2'	4.41	4.44	4.00	4.29
	2-3'	5.11	4.85	4.19	4.72
	3-4'	5.77	5.51	4.66	5.31
<i>T. subterraneum</i> (Northam)	0-6"	1.51	1.60	1.61	1.58
	6-12"	2.12	2.01	2.05	2.06
	1-2'	3.98	3.95	3.82	3.92
	2-3'	4.61	4.51	4.37	4.50
	3-4'	5.28	4.96	5.25	5.16
<i>Medicago truncatula</i> (Cyprus)	0-6"	1.54	1.54	1.73	1.61
	6-12"	2.20	2.03	1.87	2.10
	1-2'	4.09	4.20	4.44	4.24
	2-3'	4.57	4.88	4.81	4.75
	3-4'	5.36	4.79	5.22	5.12
<i>T. subterraneum</i> (Clare)	0-6"	1.58	1.64	1.74	1.65
	6-12"	2.10	1.97	2.02	2.03
	1-2'	4.36	4.20	4.06	4.21
	2-3'	4.90	4.55	4.75	4.73
	3-4'	5.49	4.79	4.87	5.05
<i>Medicago littoralis</i> (Harbinger)	0-6"	1.54	1.68	1.69	1.64
	6-12"	2.22	1.95	2.11	2.09
	1-2'	4.16	4.14	3.79	4.03
	2-3'	4.21	4.61	4.05	4.29
	3-4'	4.69	5.07	4.53	4.76
Grain-fallow	0-6"	1.58	1.67	1.49	1.58
	6-12"	2.15	2.30	2.06	2.17
	1-2'	4.68	5.40	5.02	5.04
	2-3'	5.36	5.22	5.15	5.25
	3-4'	5.54	5.93	5.36	5.61
<i>T. subterraneum</i> (Dallak)	0-6"	1.32	1.48	1.66	1.49
	6-12"	1.98	1.98	2.13	2.03
	1-2'	4.13	3.92	4.28	4.11
	2-3'	4.49	4.75	4.84	4.69
	3-4'	5.00	5.10	5.28	5.13
<i>Medicago lupulina</i> (Black medic)	0-6"	1.56	1.46	1.55	1.52
	6-12"	2.07	1.67	2.01	1.92
	1-2'	4.25	3.47	3.72	3.81
	2-3'	4.27	3.95	3.84	4.02
	3-4'	4.59	4.51	4.99	4.70
<i>T. subterraneum</i> (Geraldton)	0-6"	1.71	1.61	1.82	1.71
	6-12"	2.23	2.15	2.06	2.15
	1-2'	4.33	4.02	4.09	4.15
	2-3'	4.36	4.93	4.60	4.63
	3-4'	4.80	5.02	5.09	4.97
<i>Medicago truncatula</i> (Ghor)	0-6"	1.57	1.64	1.71	1.64
	6-12"	2.22	2.05	2.05	2.11
	1-2'	4.06	4.73	4.23	4.34
	2-3'	4.80	5.07	4.72	4.86
	3-4'	5.12	5.82	5.01	5.32
<i>T. subterraneum</i> (Nungarin)	0-6"	1.56	1.89	1.83	1.76
	6-12"	2.20	2.23	2.08	2.17
	1-2'	4.40	4.45	4.08	4.31
	2-3'	5.10	4.89	4.06	4.68
	3-4'	5.81	5.39	5.10	5.43
<i>Lupinus angustifolius</i> (Unicrop)	0-6"	1.50	1.54	1.62	1.55
	6-12"	1.95	2.09	2.26	2.10
	1-2'	3.64	4.40	4.50	4.18
	2-3'	4.52	5.05	4.58	4.72
	3-4'	6.03	5.15	4.77	5.32
<i>Medicago scutellata</i> (Robinson)	0-6"	1.67	1.39	1.55	1.54
	6-12"	1.81	1.91	1.74	1.82
	1-2'	4.07	3.76	3.40	3.75
	2-3'	4.86	4.49	4.23	4.53
	3-4'	5.36	4.99	4.96	5.11
<i>Vicia faba</i> (Giza III)	0-6"	1.51	1.66	1.59	1.59
	6-12"	2.02	2.12	2.05	2.06
	1-2'	4.15	4.29	3.67	4.04
	2-3'	5.02	4.25	4.39	4.55
	3-4'	5.30	5.12	4.82	5.08
<i>T. aestivatum</i> (Maralschaftal)	0-6"	1.57	1.57	1.62	1.59
	6-12"	1.96	1.70	1.78	1.81
	1-2'	3.97	4.02	3.51	3.83
	2-3'	4.43	3.89	4.18	4.16
	3-4'	5.19	4.87	4.38	4.82
<i>Lupinus albus</i> (Ultra)	0-6"	1.49	1.33	1.65	1.49
	6-12"	1.98	2.06	2.00	2.01
	1-2'	4.04	4.57	3.74	4.11
	2-3'	4.71	5.15	4.09	4.65
	3-4'	5.34	5.10	4.86	5.10

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