THE UNIVERSITY OF ALBERTA

EVALUATION OF FABA BEAN (*Vicia faba* L.) YIELD AND NITROGEN PRODUCTION IN CENTRAL ALBERTA.

BY

CORNEL LAWRENCE RWEYEMAMU

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Evaluation Of Faba Bean (*Vicia faba* L.) Yield And Nitrogen Production In Central Alberta submitted by Cornel Lawrence Rweyemamu in partial fulfilment of the requirements for the degree of Master of Science in Agronomy.

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ABSTRACT

The effect of seeding rate on yield, yield components and nitrogen yield of *Vicia faba* L. was evaluated in 1984 and 1985 at one site in Central Alberta, Canada. A completely randomized block design experiment with four replications, containing three faba bean cultivars (Ackerperle, Aladin and Outlook) and one experimental line from the University of Alberta breeding program (80F-21) were used. One barley (*Hordeum vulgare* L.) cultivar (Conquest) was used in the study. Two seeding rates of 33 and 50 seeds/m^2 were used for the faba bean treatments and 50 kg/ha seeding rate was used for barley treatment. Individual plots consisted of 8 rows, 6 metres long, spaced 23 centimetres between rows and between plots. No fertilizer was applied. Faba bean seeds were inoculated with Nitragin Company Q culture rhizobia at the rate of 610 grams per hectare.

Data was collected for days to flowering, maturity, and for plant height. TDM yield, seed yield, vegetative yield, HI, seed yield per plant, pods per plant, seeds per pod, one thousand seed weight, percent germination, production score and percent nitrogen were determined. Total nitrogen yield, net symbiotic nitrogen fixation and economic value were computed.

The seeding rates had a significant effect only on

plant density; pods per plant in 1984 and 1985; TDM yield at flowering in 1984; plant height; HI; percent nitrogen at 29 Days After Flowering; nitrogen production at flowering and 29 Days After Flowering in 1985. Significant cultivar effect was quite common for most of the variables tested while the significant interactions between the seeding rates and the cultivars were very rare in this study.

The seed yield was correlated with number of seeds per plant, pods per plant and also by number of seeds per pod and 1000 seed weight. TDM yield was correlated with plant height, seed yield, vegetative yield, seed yield per plant, 1000 seed weight, production score, nitrogen production and net symbiotic nitrogen fixation. Nitrogen production was correlated to plant height, pods per plant, 1000 seed weight in 1985, and to TDM, seed yield, vegetative yield, HI, seed yield per plant and percent nitrogen in 1984 and 1985. Net symbiotic nitrogen fixation was correlated to seed yield per plant, plant height, HI in 1985; and to TDM, seed yield, production score and nitrogen production in 1984 and 1985. Barley was better adapted to dry conditions than faba bean which did well in a moister environment. The net symbiotic nitrogen was very variable ranging from 23 to 185 kg/ha at maturity. The nitrogen yield was 180 to 325 kg/ha for faba bean and 138 to 195 kg/ha for barley, with the value of \$77.40 to \$139[illegible]59.34 to \$83.85, respectively. Due to the incons[illegible] cultivar [illegible] seed, TDM and nitrogen production, it was not [illegible] to recommend the best cultivar suitable for Central Alberta from the three licensed faba bean cultivars used in this study. However, the 33 and 50 seeds/m^2 seeding rates showed that depending on seed size, they can result in plant density of 400 to 500 thousand per hectare which is recommended for growers in Central Alberta.

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1. INTRODUCTION

Faba bean, *Vicia faba* L. was introduced into agriculture in the late neolithic period based on the available archeological evidence. The first findings of the crop date from the early bronze age (ca.3000 B.C.) and were made in Eastern Mediterranean region (Zohary, 1977). From the centre of diversity in Near East, faba bean radiated out in four directions: to Europe, along the North African coast to Spain, along the Nile to Ethiopia and from Mesopotamia to India (Cubero, 1974).

Small faba bean, *Vicia faba equina* and *minor*, recently attracted some interest in Western Canada due to their agronomic performance and high protein content (Evans et al., 1972). Faba bean cultivars from Western Europe were first introduced to Western Canada in the early 1970s. Production began on about 800 hectares in Manitoba in 1972 and rose to 5600 hectares in Manitoba and Saskatchewan the following year. In Alberta about 5000 hectares (of which 1500 hectares were irrigated) were grown in 1978 (Krogman et al., 1979). Faba bean is now an established grain legume in Western Canada. During 1973 - 1975, approximately 80% of the crop was grown for silage, but in recent years 75-80% of the faba bean was grown for grain for human consumption. In 1981, the hectares declined to 1600. The decline was primarily due to the slow movement and low price of the grain. Most of the faba bean for grain is produced in the irrigated areas of Southern Alberta. The crop for silage is grown in both Central and Northern areas of Alberta.

Faba bean is the fourth most important pulse crop in the world after drybeans (*Phaseolus vulgaris* L.), dry peas (*Pisum sativum* L.) and chickpeas (*Cicer arientinum* L.). Faba bean is an important source of dietary protein especially in the rural communities in the less developed countries where the crop is mainly used for human consumption (Saxena and Stewart, 1983). In Europe, the large seeded types have been used for human consumption for a long time and small seeded types for animal feed (Thompson and Taylor, 1982). The crop was introduced to Canada to be used as a protein feed for livestock due to high cost of alternative protein supplements in recent years. Research on the feeding characteristics of faba bean at the University of Alberta and Manitoba indicates that the crop can be used by all classes of livestock and poultry (Agriculture Canada, 1975; Manitoba Agriculture, 1981).

Seed yields of 2200 to 6329 kg/ha have been obtained by both farmers and researchers in the western provinces (Kondra, 1975; Alberta Agriculture, 1982). The yields have been found to be related to cultivar, agronomic practices and environmental conditions. From research results it has been concluded that faba bean yield in Canada is unreliable and yield fluctuates widely from season to season as well as from location to location.

It has been found that faba bean is a good nitrogen fixer in Western Canada. The amount of nitrogen fixed by faba bean in Western Canada ranges from 54 to 146 kg/ha have been reported (Rice, 1976; Dean and Clark, 1977; Richards and Soper, 1982).

Faba bean is well adapted to fit into cropping rotation and can be grown on either summerfallow or, when moisture is adequate, on well prepared cereal stubble in Western Canada. Faba bean can be used as a "break crop" when soil has become depleted through continuous cereal cultivation. Faba bean is particulary appropriate following corn in a rotation, since faba bean is tolerant to atrazine residues in the soil. Since faba bean is a good nitrogen fixer it may increase residual soil nitrogen for use by subsequent crops. To obtain maximum yields, seeds should be inoculated with *Rhizobium leguminosarum* strain. Nitrogen application is not usually required.

There is limited information on the amount of nitrogen fixed by faba bean and TDM production in Central Alberta. The objectives of this study were to evaluate the relative seed and TDM production and estimate nitrogen fixation of four faba bean cultivars. Since faba bean is regarded as "break crop" the nitrogen balance, after grain harvest was calculated. Conclusions should help both the crop growers and animal producers in Central Alberta in formulating rotation programs and understanding the adaptation of the crop.

2 LITERATURE REVIEW

2.1 Nomenclature and Distribution of *Vicia faba* L.

The genus *Vicia* is of the family Leguminosae (Fabaceae). It is clear what is meant by *Vicia faba* L. and its botanical varieties, *major*, *equina*, *minor*, and *paucijuga*, but commonly used English names can be confusing (Bond, 1979). The specific classification of Muratova (1937) involves the species being divided into two subspecies, *paucijuga*, and *eu-faba*. The *eu-faba* has three varieties, large-seeded var *major*, intermediate var *equina*, and small seeded var *minor* (Hawtin and Hebblethwaite, 1983). In Europe and U.K., *V.faba equina* and *minor* are usually referred to as field beans, and *major* as broad beans. The field beans are further subdivided into horse beans (*equina*), which may either be winter or spring sown types, and tick beans (*minor*). Broad beans are often classified as either longpod or Windsor beans. In the U.S.A. and in some international literature eg. that of THE INTERNATIONAL CENTER FOR AGRICULTURAL RESEARCH IN DRY AREAS (ICARDA), the whole species is known as field beans (Bond, 1979; Hawtin and Hebblethwaite, 1983). The term faba bean originated from Canada and has been adopted to denote the entire species. In Canada however, the term faba bean usually refers to *V. faba equina* or *minor* (Bond, 1979). Other names for the crop include "Egyptian", "fava", "garden", "pigeon", "spring", "spanish", "winter". (Hawtin and Hebblethwaite, 1983) and "vicia" beans which is another term occasionally used, but can include *narbonensis* beans (Bond, 1979). In this thesis the name "faba bean" will be used to denote *V. faba equina* and *minor*.

From the centre of origin, faba bean production spread to other parts of Africa, America and Europe. The production of faba bean throughout the world can be divided into a number of major geographical regions:

(i) America

According to Muratova (1937), faba bean made its way to North America first in 1602, when Captain Hosnold succesfully planted the crop on Elizabeth Island, off the coast of Massachusetts. Ackerperle, Diana and Erfordia were imported to Canada from Europe (Evans and Slinkard, 1975). Aladin is the first Canadian-bred cultivar of faba bean (McVetty et al., 1981). Outlook is the second cultivar (Rowland et al., 1982), Pegasus is the third cultivar (McVetty et al., 1985) and the fourth cultivar bred in Canada is Encore, released in 1985, adapted to irrigated areas of Western Canada where it is the highest yielding cultivar (Rowland et al., 1986). Production in Canada is mainly in Manitoba, Saskatchewan and Alberta. Faba bean, *V. faba minor* and *V. faba equina* seed is exported for human food and used for animal feed as whole plant silage.

With exception of certain regions of California, and more recently in northern states such as Montana, faba bean is rarely grown in the U.S.A.. In Central and Southern America, the crop is grown in Brazil, Mexico, Guatemala, Ecuador, Paraguay and Peru (Hawtin and Hebblethwaite, 1983).

(ii) Asia

In Central Asia faba bean production can be divided into three main subzones: (a) Irrigated production in Central and Southern Iraq and Southern Iran. (b) Rainfed production in higher elevated areas around the Caspian Sea in Afghanistan. (c) The post monsoon period crop in Northern India and Nepal (Hawtin and Hebblethwaite, 1983). In Eastern Asia, China is the largest producer of faba bean. However, recently the production has declined (Tao, 1981). Japan has also experienced substantial decline in production (Kogure, 1979; 1980).

(iii) Europe

The faba bean production areas in Europe include Northern Europe i.e. Northern Spain, Northern Italy, Southwest France, Greece, Yugoslavia, Sweden, Denmark and

Finland. The largest producers are Czechoslovakia, United Kingdom and France (Moreno and Martinez, 1980).

(iv) Africa and Mediterranean Region

Faba bean is among the most important pulse crop in Ethiopia. Ethiopia is a net exporter (Hawtin and Hebblethwaite, 1983) producing about 7% of the world production (Della, 1985; Telaye, 1985). The crop is important in Egypt and in northern provinces of Sudan (Saxena and Stewart, 1983).

The crop is important in the Mediterranean region, which comprises the countries of North Africa, i.e. Morocco, Algeria, Tunisia, and Libya; West Asia, i.e. Jordan, Lebanon, Syria, Turkey, Cyprus, and Southern Europe i.e. Italy, Spain, Portugal, and South-West France (Hawtin and Chancellor, 1979; Hawtin and Hebblethwaite, 1983).

(v) Oceania

To diversify agricultural production, alternate crops including faba bean is grown in South Australia. The highest yields are obtained from cultivars of Mediterranean origin (Baldwin, 1980). The crop is also grown on Canterbury plains in New Zealand (Hawtin and Hebblethwaite, 1983).

Faba bean production is widespread in temperate and subtropical regions of the world. A wide diversity of types is grown, with small-seeded *minor* and *equina* cultivars being prominent in Northern Europe, the Nile Valley, Ethiopia, Afghanistan, the Indian subcontinent, and North America. In most other regions, such as in the Mediterranean Basin, Western Asia, China, Latin America, *major* types are more important. Faba bean has played an important part in the agriculture of many regions in the past. Decline of production has mainly been due to competition with more profitable and reliable crops, such as wheat, barley, and rapeseed.

2.2 Growth and Development

Faba bean is an erect growing annual legume with hypogeal type of germination. The plant height ranges from 1.0 - 1.5 metres and most of the commercial cultivars possess excellent stem strength. The plants have an indeterminate flowering habit with clusters of four to eight flowers at each node of the stem, but few flowers normally produce pods. The pods are borne along the length of the stem, ranging from 1 to 8 pods at each node. Each pod contains three to four seeds. The seeds contain 25 to 30 % protein and are relatively high in energy and contain very little oil (Rowland, 1955; Evans, 1975; Manitoba Agriculture, 1981).

Faba bean has shown a typical C_3 plant biochemical process (Outlook and Fisher, 1975). On translocation, it has been found, that the bulk of assimilates out of any leaf move to the nearest sink (Fritz, 1973). Thus, in the vegetative plant the youngest exporting leaves feed the stem apex and new unfolding leaves; basal leaves export mostly downwards to the stem and root system, and the leaves in the middle of the plant can transport to the upper and lower sinks (Fritz, 1973; Pearson, 1974). The pattern of distribution however, varies to some extent throughout the day (Pearson, 1974).

Kipps and Boulter (1973) and Peat (1983) observed that an accumulation of assimilates during vegetative growth, particulary in stems and roots disappeared during fruit development. These assimilates were used mostly for continued vegetative growth and accompanying flowering and were not translocated to the developing fruits and seeds. Seed growth occurred predominantly as a result of current photosynthesis, but became major sink for assimilates only late in the cycle. However, short term storage of assimilates during pod growth is important for future seed production.

There is no absolute requirement for environmental conditions in order to initiate flowering in faba bean but the timing of flowering and the position of flowers on the plant is markedly influenced by both photoperiod and by growing temperature (Evans, 1959). Low-temperature vernalization or cool growing conditions accelerate flower initiation (Chakravarty et al., 1956; Evans, 1959; Saxena and Wassimi, 1979).

An important feature of the faba bean physiology has been the demonstration that nitrogen fixation and nitrate uptake by the root system can continue throughout the period of fruit development (Cooper et al., 1979).

2.3 Yield

2.3.1 Components of Seed Yield

Yield component studies in faba bean are much more recent than studies of yield and yield components in small grain cereals (Neal and McVetty, 1984). In faba bean seed yield is a product of a number of plants per unit area and four plant components: number of pod bearing nodes per plant, number of pods per pod-bearing node, number of seeds per pod and average seed size (Rowland, 1955; Kambal, 1969 b; Ishag, 1973 ; Thompson and Taylor, 1977). The most stable of these plant components in relation to environment is the number of seeds per pod and average seed size.

Plant density is determined by various considerations, but is largely under grower(s) control. The environment generally plays little part in the actual number of plants obtained, within reasonable limits.

Usually the larger the seed the lower the plant density at which the yield plateau is reached (Thompson and Taylor, 1977). Changing the plant density results in variation in the other components of yield. The number of pod bearing nodes per plant is the least stable of the components of seed yield (Ishag, 1973; Thompson and Taylor, 1977). The number of pods per plant is generally significantly reduced at higher plant densities due to light competition at different times during development of the plant (Thompson and Taylor, 1977; Pandey, 1981; Thompson and Taylor, 1982), and is slightly positively correlated to seed yield (Kambal, 1969 b; Foti, 1979; Omar and Howtin, 1980; Pandey, 1981; and Neal and McVetty, 1984).

The average number of seeds per pod is a relatively stable character. The cultivars available have up to nine seeds per pod. Most of the cultivars used in Canada have 2 to 3 seeds per pod (McVetty et al., 1986). Some researchers have observed the positive correlation between the number of seeds per pod and seed weight (Poulsen and Knudsen, 1980). Seeds per pod are unaffected by time of seeding, irrigation regimes and seeding rates (Thompson and Taylor, 1977; Farah, 1981; McVetty et al. (1986), also by light competition (Thompson and Taylor, 1981). Usually fewer seeds per pod are produced at the upper nodes where shrivelled ovules are very common (Ishag, 1973; Adock and Lawes, 1976).

Seed weight varies considerably among cultivars. In addition, considerable variation within cultivar when grown in different environments has been reported (Picard and Berthelem, 1980; McVetty *et al*. (1981); McVetty *et al*. (1985); Rowland *et al*. (1986)). Some results have shown that early leaf senescence was linked with lower seed yield (Dantuma and Thompson, 1983). Light competition towards the end of the growing season can result in a decrease in seed size (Thompson and Taylor, 1981).

Flower abortion in faba bean is the single most important factor preventing the realization of yield potential (Kambal, 1969 a; Free and Williams, 1976; Peat, 1982). Flower abortion is due to the limited availability of sink capacity and competition between sinks (Chapman and Peat, 1978). Competition between the vegetative and reproductive parts is the other main reason for low and unstable yield of faba bean. Pods which set first compete for assimilates with the growing root and stem apex and with the developing pods. Young pods and vegetative sinks compete for stored assimilates in the stem; the young pods do not receive more than 10% of the fixed carbon until flowering has ended (Gehringer and Keller, 1980; Gates *et al*., 1983).

Yield is a complex character determined by agronomic, genetic and climatic factors. In a three year study, Canadian bred cultivars in dry land testing, performed better in Eastern Canada, than they did in Western Canada in the same testing seasons. Cultivars Encore, Aladin and

Outlook grown in Eastern Canada had their greatest yield advantage of about 30, 44 and 39% respectively over those grown in Western Canada. Yield in Eastern Canada was still higher than under irrigation in Western Canada by 12, 21 and 16% for the three cultivars. Yields of Encore in Eastern Canada were only 95% of those of Aladin, but slightly greater than Outlook (Rowland <u>et al</u>., 1986). In an experiment to compare faba bean yield and cereal crop yield (wheat), in Eastern and Western provinces of Canada, faba bean seed yields were highest in Manitoba (4,388 kg/ha) and slightly (338 kg/ha) above the wheat; in Saskatchewan, faba bean yields (2,836 kg/ha) were 618 kg/ha below wheat. In the Eastern provinces, faba bean yields (3,263 kg/ha) were considerably higher (by 1088 kg/ha) than those of wheat, but so were their environmental variances. From these results it was concluded that the cereal crop was better adapted to dry conditions, while faba bean responded more favorably to a moister environment (Seitzer and Evans, 1976).

2.3.2 Total Dry Matter (TDM) Yield

The maximum values of faba bean TDM are attained sometime before complete senescence of plant tissues, the decline in values during the later period of growth being attributed mainly to losses of senescent leaves (Danatuma and Taylor, 1983). TDM yields of 14.5 to 22.0 t/ha have been recorded in the Netherlands (Dantuma and Thompson, 1983). In Manitoba 4.5 to 6.2 t/ha has been reported by McVetty et al. (1986). A study to determine the value of faba bean as forage crop in Central Alberta and compare the relative productivity of cultivars of faba bean on two different soil types was conducted by Berkenkamp and Meeres (1986) at Lacombe and Bluffton Research stations. In their study, cultivar Aladin produced 0.9 to 12.2 t/ha while Outlook produced 11.4 to 13.1 t/ha on the black chernozemic soil of Lacombe. At Bluffton on grey luvisolic soil, Aladin produced 2.9 to 7.9 t/ha and Outlook produced 3.4 to 7.1 t/ha. Cultivar Herz Freya had a highest TDM production of 10.7 to 14.3 t/ha at Lacombe while Outlook had the highest TDM production of 2.9 to 7.6 t/ha at Bluffton. The mean TDM yields at Bluffton were less than half those at Lacombe.

The TDM production has been found to increase approximately linearly with plant density up to a point where competition between individuals for light and other resources start. This results in the decline of relative growth rate (RGR) of individual plants which causes the total yield to depart from its linear relationship with density, becoming asymptotic (Pandey, 1981). Research results have shown that the density required for maximum seed yield is the minimum plant density to produce maximum yield of dry matter during the period of pod production (Abo El-Zatab et al., 1981).

2.3.3 Nitrogen Yield

Faba bean produces large quantities of dry matter and seeds of very high protein levels, and thus has a very high demand for nitrogen. Faba bean grown in Scotland may accumulate up to 19.8 t. dry matter per hectare containing 3.2% N and yield up to 9 t/ha of dry seed (Sprent and Bradford, 1977). The protein content varies considerably within varieties (Cubero, 1984). The protein content of faba bean seed has been reported to range between 23 - 35% (Evans <u>et al</u>, 1972; Bhatty, 1974) and of vegetative dry matter to range between 2.3 to 3.2% (Sprent and Bradford, 1977; Day <u>et al</u>., 1979). The average percent protein in the forage of the licensed cultivars in Western Canada has been reported to be 17.8 to 18.6% in Central Alberta. Crude protein production ranging from 1114 to 2520 kg/ha has been reported in Central Alberta by Berkenkamp and Meeres (1986).

2.4 Effect of Population Density and Seeding Date

2.4.1 Seeding Rate

Field surveys have shown that many faba bean producers have been planting at less than recommended seeding rates with apparent success in Western Canada.

European research results have shown that faba bean can be grown successfully over a wide range of seeding rates or plant densities (Hodgson and Blackman 1956; Sprent *et al*. 1977; Day *et al*. 1979; Kellar and Burkhard, 1981). In Manitoba, at 60 - 260 kg/ha seeding rates, Seitzer and Evans (1973) concluded that seeding rates of 140 kg/ha or more gave comparable yields for the tall, late, nonbranching cultivar, Ackerperle. In another study using the cultivars, Aladin, Herz-Freya and Outlook, McVetty *et al* (1986) concluded that seeding rate of 80 kg/ha resulted in significantly lower seed yield and TDM production, but resulted in the highest seed weight and greatest number of pods per plant. Seeding rates of 120, 160 and 200 kg/ha resulted in equivalent yield and TDM, but significantly fewer pods per plant and reduced seed weight was noted as the seeding rate increased. In Central Alberta seeding rates of 150 and 200 kg/ha gave equivalent seed yield and were significantly higher than the 100 kg/ha rate for Erfordia and Kleinkornige cultivars. A seeding rate of 200 kg/ha was found to be an optimum for faba bean as forage in Central Alberta (Berkenkamp and Meeres, 1986).

From the research results in western provinces of Canada, a seeding rate of 135 to 180 kg/ha is recommended, with the higher rates being used for the larger-seeded cultivars (Agriculture Canada, 1975). Studies in Central Alberta have shown that higher seeding rates at closer spacing give higher seed yields. In Southern Alberta the seeding rate recommended for the small seeded cultivars is 160 to 180 kg/ha while for large seeded cultivars seeding rate of 180 to 210 kg/ha is recommended (Alberta Agriculture, 1982).

A number of researchers have reported that as plant density increases, branching and number of pods reaching maturity decreases, but seed yield increases in a range of 11 to 133 plants per $2m^2$ but the seed size remains almost unaffected (Soper, 1952; Hodgson and Blackman, 1956; Sprent et al., 1977; Barry and Storey, 1979; Pandey, 1981). It has also been reported that high plant density results in increased mutual shading of leaves. This contributes to limitation of carbon assimilates and hence abscission. However, it has also been shown that shading of basal nodes can lead to more pod production at the top of the stem whereas defoliation of lower half of the plant depresses pod development in the upper part. This could be due to the alteration of the hormone balance within plants rather than to mutual shading (Hodgson and Blackman, 1956; Sprent et al, 1977; Smith, 1982). High plant density seems to favor early canopy development and increase light interception, but this advantage may be outweighed by a reduced harvest index. As observed by Abo El-Zahab et al. (1981), the density to produce maximum seed yield was the minimum plant density to produce maximum TDM during the period of production.

2.4.2 Row Spacing

Experiments in the United Kingdom (McEwen, 1972; Ingram and Hebblethwaite, 1976), Sweden (Sjodin, 1978), Canada (Seitzer and Evans, 1973; Kondra, 1975) have shown that narrow rows (12 to 18 cm) particularly at higher seeding rates give the highest seed yields. Seed size and protein are usually not affected. Results in Central Alberta, showed that row spacing did not effect seed protein, but affected the percent germination of the harvested seed in cultivar Wiseburger Kleinkornige, an indication that maturity was also affected in this cultivar. The narrowest row spacing in this study (15 cm) produced the highest percent germination (Kondra, 1975).

The faba bean growers in Alberta are advised to aim for about 400,000 to 450,000 plants per hectare in rows spaced at 18 cm to maximize seed yield. This means that there will be 7 to 8 plants per meter row (Alberta Agriculture, 1982). In Manitoba a seeding rate of 46 plants/m^2 is recommended (McVetty et al., 1986).

2.4.3 Seeding Date

Optimum seeding date depend on weather conditions in spring and summer in a particular country. However, in countries where hot or dry conditions start in early summer, spring seedings are not normally recommended

(Ziliotto and Toniolos, 1979) as yields are likely to be very low. In regions where winters are very severe, faba bean is seeded in spring. In Western Canada, faba bean should be planted early to obtain high yields. Seeding by the first week of May or even as early as the last week of April is recommended. Studies in Central Alberta indicate that yield can be reduced by 9 to 12% for every week that seeding is delayed after the first week of May (Alberta Agriculture, 1982). If delayed seeding is inevitable, early maturing varieties such as Outlook and Aladin are recommended (Alberta Agriculture, 1982).

Date of seeding has shown significant effect on both seed yield and seed quality in Central Alberta due to early fall frosts damage to the crop (Kondra, 1975). In Central Saskatchewan, the first three weeks of May is the optimum time for seeding faba bean. After this time, yield decrease partially due to a lower number of pods per plant (Rowland, 1978). The same was reported by McVetty et al. (1986) in experiments conducted in Winnipeg, Manitoba. Literature indicates that seeding date is an important parameter to consider when attempting to maximize yields.

2.5 Nitrogen Yield Determination

2.5.1 Nitrogen Accumulation

This method involves measuring the total nitrogen accumulated in the crop. It is based on the assumption that the crop derived all its nitrogen via symbiotic fixation under field conditions. Growth on low-fertility soils or on soils artificially impoverished in available nitrogen is no guarantee that all nitrogen is obtained by fixation (LaRue and Patterson, 1981).

2.5.2 Difference Methods

These methods refer to the measure of fixation by the nitrogen accumulation technique when the contribution of soil N to the total N of legumes is estimated. Such methods are also referred to as the "N balance" methods. The "N balance" methods are based on the "N balance" between an N_2-fixing (fs) and non-fixing (nfs) system (Rennie, 1984 a). Thus N_2 fixed = N yield (fs) - N yield (nfs) and

$$\% \text{ N dfa} = \left[\frac{\text{N yield (fs)} - \text{N yield (nfs)}}{\text{N yield (fs)}}\right] \times 100$$

where %N dfa is the percent plant N derived from the atmosphere.

The "difference methods" have been used extensively to estimate N_2 fixation (LaRue and Patterson, 1981). When these methods are used, the two assumptions made are: (1) The N-fixing plant (fs) and non-fixing plant [i.e. reference plant (nfs)], absorb the same proportion of soil N and applied N during the growing season. (2) Both plants will take up soil N in proportion to the amount available, and the difference due to growth patterns and root morphology will not be significant (McAuliffe et al., 1958). However, an increase in total plant N due to rhizobial inoculation may be the result of N_2 fixation or increased efficiency of fertilizer or soil N use due to the alteration of rooting habits (Rennie, 1984 a). There are three versions of the "difference methods", commonly used.

2.5.2.1 Legume versus Non-legume

Soil N contribution to a fixing legume is estimated by growing a non-legume concurrently with the legume. Annual small grains, such as wheat, barley, oats, and sorghum have been used (Rizk, 1966; Fried and Broeshart, 1981; Richards and Soper, 1979; Fried et al., 1983).

Using this method, faba bean has been reported to fix N at a rate of 54 to 111 kg/ha (Richards and Soper, 1982); 10 to 60 kg/ha (Fried et al., 1983).

2.5.2.2 Nodulating versus Non-nodulating Legume

The advantage of using non-nodulating genotypes as a control is that the growth pattern, root morphology, and N uptake pattern are assumed to be nearly identical (LaRue and Patterson, 1981). Using this version, soybean (*Glycine max* L.) was estimated to fix 14 to 84 kgN/ha (Weber, 1966). In soybeans, non-nodulating iso-lines are available for only a few cultivars. Unfortunately, near isogenic, non-nodulating, and nodulating cultivars are not yet available for faba bean (LaRue and Patterson, 1981).

2.5.2.3 Inoculated versus Non-inoculated Legume

This method requires a soil free of native *Rhizobium* species, capable of establishing an effective symbiosis with the legume being studied. It sometimes becomes impossible to have a soil, free of native *Rhizobium* species for control treatments (Chowdhury, 1975; Kang et al., 1975), and in the areas where legumes are routinely grown, soils may not have appropriate *Rhizobium* species (Semu et al., 1979). When using this technique, considerable care is required to prevent contamination of uninoculated soil with *Rhizobium* species. Due to these reasons, this procedure has limited application in routine evaluation of nitrogen fixation. With this version it is assumed that root structure and function are not altered by presence of nodules, although this assumption has to be proven experimentally (LaRue and Patterson, 1981). Using this version, Bezdicek _et al_. (1978) in their two year study at Prosser, Washington, working with soybean, the crop was found to fix 263 and 311 kgN/ha in the two years.

2.5.3 ^{15}N Isotope Dilution

^{15}N isotope dilution (ID) has been used to determine the percent plant N derived from the fertilizer (%N dff), soil (%N dfs), and atmosphere (%N dfa) in several annual grain legumes (Rennie, 1984 a). In this method, the fixing crop and non-fixing control are grown in soil to which ^{15}N has been added as a small amount of labelled nitrate or ammonium (McAuliffe _et al_., 1958). The plant obtaining part of its N from the atmosphere will have less of the isotope.

Thus, N_2 fixed =

$$\left[1 - \frac{\text{atm. \% } ^{15}\text{N excess (fs)}}{\text{atm. \% } ^{15}\text{N excess (nfs)}}\right] \times \text{N yield (fs)}$$

where: atm % ^{15}N excess = atom % ^{15}N excess and, % ^{15}N excess is calculated with reference to the natural ^{15}N abundance of the atmosphere (e.g. 0.3663 atom % ^{15}N (Rennie, 1984a).

$$\%\text{N dfa} = \left[1 - \frac{\text{atm. \% } ^{15}\text{N excess (fs)}}{\text{atm. \% } ^{15}\text{N excess (nfs)}}\right] \times 100$$

After harvest, total N is determined. Analysis of

^{15}N: ^{14}N ratio is then performed on a "VG Micromass 602 D isotope ratio mass spectrometer" (Rennie et al., 1978). Atom % ^{15}N excess is calculated with reference to the natural abundance of the atmosphere (0.3663 atom % ^{14}N) (Mariotti, 1983). The calculation of %N dfa (% nitrogen derived from the atmosphere) is yield-dependent, requiring only that the fs (N_2-fixing) and nfs (non-fixing system) assimilate identical proportions (but not necessarily identical quantities) of N from the soil and/or fertilizer (Rennie and Rennie, 1983). The calculation of N_2 fixed is yield-dependent, because an estimate of N yield of fixing system is required, as shown in the equation above. The isotope dilution technique has been shown to have an inherently higher precision than yield-dependent ^{15}N techniques such as the "A"-value or yield-dependent "difference methods" for calculating %N dfa (Rennie, 1979). Talbott et al. (1982) working with six cultivars of soybeans concluded that spatial variability in N-Uptake in the non-fixing system was the main error source when calculating %N dfa.

Rennie (1984 a) working with soybeans and fieldbeans (*Phaseolus vulgaris* L.) in Southern Alberta, concluded that the "difference method" was more reliable when soil N was low, so that non-fixing plants showed signs of N deficiency by anthesis. The "difference method" is less accurate than the ^{15}N technique to estimate N_2 fixation in field grown legumes.

A number of workers have used the isotope dilution method both in field and greenhouse experiments to estimate nitrogen fixation in legumes. These include Broadbent et al. (1982) in California who estimated 61 kg N/ha fixed by Ladino clover (*Trifolium repens* L.) and Rennie (1984 a) in Alberta who estimated 64 to 118 kg N/ha in soybean (*Glycine max* L.). and 30 to 121 kg N/ha in field beans (*Phasedus vulgaris* L.) There is no information on this method used to estimate nitrogen fixation in faba bean (*Vicia faba* L.).

2.5.4 Acetylene Reduction

The ^{15}N dilution is an expensive method to determine fixed N, and is insensitive when compared with acetylene reduction which measures nitrogenase activity (Roughley et al., 1983). Nitrogenase reduces acetylene to ethylene. Thus we have, $C_2H_2+2e^-+2H \rightarrow C_2H_4$ instead of: $N_2+6e^-+6H^+ \rightarrow 2NH_3$ giving, in theory, an acetylene:nitrogen ratio of 3:1. Typically, freshly excised roots are incubated in a chamber, with 1 - 20% C_2H_2 for 1/2 to 2 hr. A sample of the gas phase is then removed, and the ethylene produced is measured by gas chromatography. In practice, the ratio 3:1 is not usually obtained and it is essential to cross-check the assay with ^{15}N or total N methods (LaRue and Patterson, 1981; Roughley et al., 1983).

The reliability of the acetylene reduction, to assess nitrogenase activity of the field grown plants, requires that all nodules be recovered. This is extremely difficult to ensure with faba bean grown in heavy soils. A number of variations of the method have been described (Hardy et al., 1973), and it has been found that hydrogen evolution by faba bean varies widely with plant age, temperature, and environmental factors (Roughley et al., 1983). Using this method in Western Canada, the values of N fixed by faba bean are reported to be 88 to 132 kgN/ha, in Central Alberta (Rice, 1976), 67.5 to 146 kgN/ha (Dean and Clark, 1977), and 145 kgN/ha (Dean et al., 1980) in Manitoba.

2.6 Factors Affecting Nitrogen Fixation

2.6.1 *Rhizobium* Ecology

There are many factors which can interfere with the nitrogen fixation process. The amount of nitrogen fixed by the legume rhizobia symbiotic system, is influenced by many chemical and physical factors of the environment, which may affect the host plant, the *Rhizobium*, and the development and effective functioning of nodules. *Rhizobium* is the generic name for the bacteria forming nitrogen fixing nodules on Leguminosae. Rhizobia, which nodulate the faba bean, belong to *Rhizobium leguminosarum*, but form nodules also on the genus *Pisum*, *Lathyrus*, and *Lens*. In a survey of farmers' fields in Manitoba, it was found that to obtain good yields and residual soil nitrogen, seeds of faba bean have to be inoculated (Candlish and Clark, 1975). Studies have also shown that nitrogen fixation depends on precise associations of plant genotype and *Rhizobium* genotype. The associations are so specific, that it would not be possible to predict the general symbiotic performances of any strain, except in association with particular plant genotypes (Mytton et al., 1977; El-Sherbeeny et al., 1977 a,b). Similar interactions have been discussed by Hobbs and Mahon (1982), in relation to peas (*Pisum sativum* L.) and by Pinchbeck et al. (1980) in relation to spanish clover (*Desmodium sandwicense* E. Mey).

Ineffective *R. leguminosarum* in the soil can be highly competitive against an applied inoculum of strain effective on faba bean (Button, 1975). Experiments in Manitoba however, showed that acetylene reduction and yield of faba bean, inoculated with pea inoculum or uninoculated (indigenous soil inoculum), were significantly inferior to faba bean inoculated with rhizobia specific for faba bean (Dean and Clark 1977).

The growth of most strains of *R. leguminosarum* is reduced below pH 5.0, while the optimum range is a pH of 5.5 to 7.5 (Norris, 1965). The effect of soil temperature depends on the soil type the optimum range is from 10° to 18°C. High temperature has a more negative effect on *Rhizobium* in coarse textured soil than in fine textured or organic soils, and in moist, than dry soils (Marshall, 1964). Nodule activity stops in faba bean, when soil temperature below 5° to 6°C at 10cm depth, and nodule development is very slow at 10°C (Fyson and Sprent, 1982). For the formation and functioning of nodules, a liberal supply of oxygen is necessary. Soil oxygen levels are usually well below 20 % and at this level, both nodule formation and functioning will be suboptimal. Iron is essential for rhizobia, and low concentrations of salts are beneficial.

There is a high degree of correlation between soil-water and nitrogen fixing activity during the vegetative period (Sprent, 1972). Hence, fixation of nitrogen is maximum at soil moisture around field capacity (Sprent, 1972; Sprent and Bradford, 1977; Foulds, 1978; Gallancher and Sprent, 1978). High levels of salts in the soil also reduce N_2-fixation (Pilai and Sei, 1966; Islam and Ghoulam, 1981; El-Shakweel et al., 1982; and Yousef and Sprent, 1983).

2.6.2 Methods of Inoculum Application

If the soils in the area contain no indigenous *Rhizobium* spp, inoculation results in significant yield increases in legumes grown in the area. A survey of 72 inoculated fields of field beans (*P. vulgaris*) in Southern Alberta showed, that only 7% had sufficient nodules (<50 per plant) to support adequate growth, without the addition of fertilizer (Rennie and Kemp, 1983). Inoculant can be applied directly to seed or indirectly through soil application.

Using the direct inoculation method, powdered inoculant may be applied as a dry powder, without the use of an adhesive agent. This method results in poor nodulation (Roughley et al., 1983; Elegba and Rennie, 1984). Due to such results, the manufacturers have voluntarily removed this method from their list of recommended application methods (Elegba and Rennie, 1984). Alternatively, the powdered inoculant may be prepared as a suspension in water, applied to the seed, and then allowed to dry before sowing (Roughley et al. 1983). Adhesive agents (stickers of the inoculant to the seedcoat), which maintain the required effective contact between the rhizobia and the newly emerged roots have proven to be very effective (Elegba and Rennie, 1984).

In Western Canada, Elegba and Rennie (1984) are the only workers who have reported on the effect of different inoculant adhesive agents. From their findings, the use of water as an adhesive agent did not prove to be suitable, as the water did not nourish the bacteria, or protect them from desiccation. It was found that the best adhesive agents to be used by the farmers in Alberta, were gum arabic (40%, wt/vol), carboxymethyl cellulose (4%, wt/vol), and wallpaper glue (10%, wt/vol). Also Nitrigum and Nitracoat, which are already in use in Alberta, were satisfactory.

Indirect inoculation refers to the method by which the rhizobia are introduced into the soil, separately from the seed. With this method, two techniques are used: (1) Spraying liquid inocula directly into the soil, and (2) applying solid inocula in one of several forms (Roughley et al., 1983). Schiffman and Alper (1968) reported the application of liquid inocula successfully in Israel, for inoculating groundnuts (*Arachis hypogea* L.). Solid inocula consists of coarse particles of peat impregnated with rhizobia. This method is now common in the U.S.A. (Burton, 1975).

Indirect application is essential when the seed itself has been treated with a pesticide harmful to rhizobia, when sowing seed with a very toxic seed-coat factor, or for sowing large areas of grain legumes where, because of seed size, the large volume of seed makes other methods of inoculation impractical (Roughley et al., 1983). As conflicting recommendations exist on the effect of seed-applied pesticides, e.g. Captan on N_2 fixation by *R. leguminosarum*, it is necessary to select superior N_2 fixing strains of *R. leguminosarum* that are tolerant of, or resistant to, recommended rates of pesticides (Rennie et al., 1985). Recommendation for seed-applied pesticide, Captan, has been achieved in the *Rhizobium phaseoli* - *Phaseolus vulgaris* L. N_2 fixing symbiosis (Rennie, 1986).

2.6.3 Effect of Soil Nitrogen

In faba bean production, fertilizer nitrogen is rarely applied, as there has been a general assumption that nitrate uptake by legumes results in a corresponding reduction in nitrogen fixation. Studies have shown that the maximum demand of N in faba bean, is associated with seed and pod development (Cooper et al., 1976). However, some studies have shown that applied N does not affect the nitrogen content of seed, compared to seed from plants which received their nitrogen supply exclusively from *Rhizobium* bacteria (Schroeder, 1983).

In the U.S.A., it has been shown that faba bean plants provide all the required plant nitrogen when properly inoculated in low soil nitrogen (Lockerman et al., 1983), and in Manitoba, it was reported that a small amount of soil nitrogen is beneficial to help the crop growth (Dean and Clark, 1977). In Central Alberta, Berkenkamp and Meeres (1986), reported that high fertility soil produced high forage TDM, with higher percent protein than the faba bean grown in the sites with lower fertility. Under controlled environmental conditions, plants which received no fertilizer, fixed 87% of their requirements (Richards and Soper, 1979).

Literature shows that yield, protein content, and symbiotic nitrogen fixation, are infrequently and unpredictably affected by rate, type, and time of nitrogen application (Richards and Soper, 1979; 1982; Schroeder, 1983).

2.7 Utilization

2.7.1 Seed For Human Consumption

The export market has been the major outlet for faba bean in Western Canada. The export market has not been constant. Egypt is the largest buyer of Canadian faba bean. Egyptians prefer larger seed beans which are consumed whole, while smaller beans are ground into paste. Egypt is not a consistent buyer of Canadian faba bean, for Canada's main competitors in export market have also increased. The United Kingdom supplies faba bean to Egypt and produces both large and small seeded crop (Canadian Grain Council, 1984). The main domestic use of faba bean in Canada is livestock feed. The market is dominated by canola and cereals. The domestic market for human consumption is very small and largely confined to ethnic population (Rowland and Drew, 1982).

2.7.2 Seed For Animal Feed

According to Canada Grain Council (1984), faba bean provides an excellent on-farm protein supplement. Whole faba bean contain about 28 to 30% protein and is high in lysine. They contain about 1% oil, and do not require processing. Therefore raw-beans are crushed or ground, and added to most rations as replacement of soybean meal, rapeseed, or other vegetable meals. Extensive research on feeding characteristics of faba bean has shown that the crop can be used on all classes of livestock and poultry. A ration containing 20% faba bean by weight, produces highly satisfactory results on young pigs weighing in the 5 to 14 kg and 12 to 35 kg range.

Faba bean is also utilized as a protein supplement in commercially prepared rations by feed mills in Western Canada. Although there have been no problems associated with faba bean, feed mills only utilize it on a small scale. Their use is dependent on their price and availability in relation to the price of other protein supplements such as soybean meal and canola meal (Craddock, 1974; Canadian Grain Council, 1984). Faba bean meal is worth about $0.17 per kilogram (Aherne, 1974).

2.7.3. Forage

The quality of faba bean seed as food and feed has been extensively examined, but the whole plant as fodder has received litte attention. The whole plant produces a good quality silage. Dry matter intake and body weight gain were greater with faba bean than grass-legume silage, but milk yield and feed quality were similar for both sources (McKnight and McLeod, 1977). Faba bean and grass-legume silages, with and without grain, were equally consumed and utilized by dairy heifers and lactating cows (Ingalls et al., 1979). Thoralacius et al. (1979) have shown that faba bean (CV Diana) crop residue, after threshing for seed, was superior to wheat straw, and similar to alfalfa-brome hay in feed value when fed to sheep. In Central Alberta, Aladin, Herz Freya and Outlook produced good yields of very high protein forage. The results showed that faba bean is valuable in supplementing low protein fodder in intensive feeding operations (Berkenkamp and Meeres, 1986).

2.7.4 Green Manure

The energy shortage of the 1970s and knowledge that nitrogen prices may continue to escalate renewed interest in growing legume as green manure crops to furnish nitrogen (Reddy et al., 1986). Faba bean, like most other legumes is known to increase soil nitrogen levels and consequently, the productivity of succeeding cereal crop in Western Canada (Canadian Grain Council, 1984). The cost of inoculum used is usually very low, costing approximately $2.00 per hectare (Rennie, 1984b). Rennie (1984b) reported the value of nitrogen to be $70/ha when the crop fixed 100 kg N/ha in Western Canada. Using the current values of nitrogen fixed in Central Alberta and the amount of protein produced in Central Alberta as shown by Berkenkamp and Meeres (1986) the value of nitrogen produced is about $170/ha depending on the growing conditions and the cultivar used.

There is no published work on the value of faba bean used as a green manure crop in Western Canada. However, Townley-Smith and Slinkard (Personal Communication, 1984) are evaluating the effect of faba bean as green manure crops on subsequent yields of wheat in Western Canada. Research in other countries show that green manure does increase soil organic matter and soil nitrogen as well as other nutrients. The beneficial effects of green manure on soil physical properties are widely known as evidenced by increased water infiltration, water holding capacity, water content, aeration, permeability, root depth and by decreased soil crusting, bulk density, runoff and erosion (ASA, 1984).

If faba bean is grown for green manure, the seed-cost in this case becomes an important factor since the seed-cost is high and the recommended seeding rates per hectare are also high.

3. MATERIALS AND METHODS

3.1 Location

The experiments were carried out in 1984 and 1985 at Edmonton Research Station, University of Alberta, on clay loam soil 53° 30'N. Latitude, 113° 31'W. Longitude. Precipitation over the growing season in 1984 was 249.4 mm, and 336.6 mm in 1985. The sites used for the experiment in both years, had been under fallow for three years, and no fertilizer had been applied in the area for the previous six years.

3.2 Plant Material

Three cultivars of *Vicia faba* L. ("Ackerperle", "Aladin", and "Outlook") and one experimental line from the University of Alberta breeding program ("80F-21") were used. Line 80F-21 was the earliest to mature, 93 Days After Seeding (DAS), in 1984 and 100 DAS in 1985. Cultivars: Outlook, Aladin, and Ackerperle matured in 99, 101, and 103 DAS in 1984 and in 110, 113, and 118 DAS in 1985 respectively.

One barley (*Hordeum vulgare* L.) cultivar "Conquest" was used in the study. Barley matured in 93 DAS in 1984, and in 100 DAS in 1985 growing seasons.

3.3 Experimental Design

A completely randomized block design experiment with four replications, containing four faba bean cultivars, and one barley cultivar were used. Two seeding rates of 33 and 50 seeds/m^2 were used for the four faba bean cultivars. Faba bean seeding rates were adjusted, based on cultivar "80P-21", for percent germination. The corresponding kg/ha rates of viable seed are given in Appendix I. Seeding rate for barley was 50 kg/ha. Individual plots consisted of 8 rows; 6 metres long, spaced 23 centimetres between rows and between plots. No fertilizer was applied. Plots were seeded with a "Swift Current Power Seeder", four row cone type press drill, with double disc openers, which has packing wheels before and after the seed is placed in the soil. The seeding dates were May 7 and May 3 for 1984 and 1985 respectively. Depth of seeding was 7.0 cm and the seeds were inoculated with Nitragin Company Q Culture (THE NITRAGIN COMPANY. CLEARWATER, FLORIDA. 33516 U.S.A.) rhizobia using a direct method. In this method, the powdered inoculant was applied as a dry dust to the seed at seeding. The rate of inoculum applied was 610 grams per hectare.

Weeds were controlled by hand at 14, 30 and 50 days after emergence.

3.4 Data Collection

3.4.1 Growth Stages

Daily observations were made, to obtain the number of days from seeding, to the major different growth stages. The days from seeding to flowering, and to maturity were recorded. The days from seeding to flowering were taken when 75% of the plants in each plot had at least three open flowers on the main raceme. Days to maturity were taken when 80% of the plants had more than 25% black pods on the main raceme, in each plot. The days to growth stages were not statistically analyzed, because no variability among the replicates was observed.

3.4.2 Plant Height

The plant height in centimetres was calculated as the average of four measurements within each plot, when the plants were at maturity.

3.4.3 Plant Density

Plant density was determined by counting the number of plants in two square metres of each plot. The counts were done one day prior to each harvesting date.

3.4.4 Total Dry Matter (TDM) Yield

Total dry matter yield per two square metres was defined as the vegetative yield plus the seed yield. An area of two square metres was cut at the ground level from the centre three rows by 2.9 metres of each plot with a sickle. Whole plant samples were also harvested at flowering and 29 days after flowering (DAF) for TDM analysis. The samples were air dried in cotton bags after cutting, until three days prior to the threshing, at which time they were put in forced air driers at 40°C for four days.

3.4.5 Seed Yield

The seed yield per two square metres from each plot was determined from the TDM samples harvested at maturity. Threshing was done by using an "Almaco Plot Threshing" rub-bar type. The same values from two square metres were used to calculate seed yield in kg/ha.

3.4.6 Vegetative Yield

The vegetative yield was calculated by taking the difference between TDM and seed yield values.

3.4.7 Harvest Index (HI)

The harvest index was obtained by dividing the seed yield value by TDM value.

3.4.8 Seed Yield per Plant

The seed yield per plot was divided by the plant density at maturity of the corresponding plot.

3.4.9 Number of Pods per Plant

At maturity, the average number of pods was calculated from twenty plants, chosen at random from each plot.

3.4.10 Number of Seeds per Pod

From each plant selected for pod number, 5 pods were taken at random, and the average number of seeds per pod was calculated for each plot.

3.4.11 One Thousand Seed Weight

After threshing, a thousand seeds from each seed yield sample were weighed.

3.4.12 Percent Germination

One hundred seeds from each plot were replicated four times. Seeds were placed in damp paper towels in cold chambers, at 5°C for five days. The seeds were then assessed for embryo growth (germination), and percent of germinated seeds calculated.

3.4.13 Production Score

The production score was obtained by adding the seed yield (t/ha), biological yield (TDM) (t/ha), and harvest index (HI) for each sample (Stoskopf, 1981).

3.4.14 Percent Nitrogen

Nitrogen analyses were made on samples harvested at 75% flowering and 29 Days After Flowering (DAF). At these stages, vegetative and reproductive parts were not separated. At maturity, vegetative and reproductive parts were separated for nitrogen analysis. Barley was harvested at the time, when the earliest faba bean cultivar was ready for harvest, at flowering and at 29 DAF. At maturity barley was harvested when a thumb-nail dent in the kernel remained visible for some time.

The N content was determined by analysing duplicate 0.5 grams of ground samples for each plot. The grinding was initially done, by using "Thomas-Wiley Laboratory Mill Model 4". The samples were reground in a coffee grinder, "Type KSM2". A micro-Kjeldahl analysis using 40-tube block digester and steam distillation, was used to determine the percent nitrogen.

3.4.15 Nitrogen Yield

The nitrogen yield was calculated from the appropriate plot yield values.

3.4.16 Net N_2 Derived From Symbiotic Fixation

Net symbiotic nitrogen fixation of faba bean was determined by subtracting total N yield in the barley TDM, from total N yield in the faba bean TDM.

In using this method, there were two major assumptions. First, the nitrogen contained in the non-legume (barley), was assumed to arise totally from the soil nitrogen pool. Secondly, the legume (faba bean) and non-legume took up soil nitrogen in proportion to the amount available, and differences due to growth patterns and root morphology were not significant, (although no evidence shows that exploitation of soil nitrogen is equal between a legume and non-legume control).

This "difference method" was chosen among the number of methods available for estimating nitrogen fixed by crops, because it is the most simple method that could be used in this experiment. Also, as pointed out by Henzell and Norries (1962), there is no method available, which can determine the absolute amount of atmospheric N, fixed by legumes under field conditions.

The net quantity of N in faba bean derived from symbiotic fixation, was calculated by the following method: S=P-B

Where S= Quantity of N derived from symbiotic N fixation in faba bean (whole-crop) in kg/ha.

P= Total faba bean N (whole-crop) in kg/ha.

B= Total N contributed by the soil measured as total N in barley (whole crop) in kg/ha.

The percent of fixed nitrogen was calculated as follows:

$$\%N \text{ fixed} = \left[\frac{\text{Net N derived from symbiosis (S)}}{\text{Total N (P)}}\right] \times 100$$

3.4.17 Economic Benefit of N Fixation

This was calculated by using the current faba bean seed cost ($/ha), and current price for nitrogenus fertilizer (urea). The benefit cost ratio was calculated by dividing the value of N fixed ($ of N fixed per hectare), by seed cost ($/ha).

3.4.18 Nitrogen Balance

Nitrogen balance was calculated as follows:
Total nitrogen fixed (kg/ha), minus total nitrogen taken off with harvested grain (kg/ha), as outlined by Herridge (1982).

3.4.19 Soil Sampling

Soil samples for chemical analysis were taken from each corner of the trial site and between the replications at seeding time. Samples were taken to 0-6 and 6-12 cm soil depths.

Soil samples were air dried in the laboratory at 25°C for four days, ground to pass through a 2 mm sieve. The soil samples were then sent to an Agricultural Soil and Feed Testing Laboratory (ASFTL), Alberta Agriculture in Edmonton, for analysis for NO_3^-N; $NaHCO_3$-extractable P; NH_4OAC-exchangeable K; pH and organic matter. (Carson, personal communication 1984).

3.4.20 Analysis of Data

The experiments were subjected to Factorial Analysis of Variance for faba bean data, and as RCBD for comparisons with barley. Each year was treated as a separate experiment.

Days of different growth stages and growth periods were not analysed on treatment combination basis by analysis of variance, since no differences between replications were observed.

(i) Anova for factorial analysis

Model: $Y_{ijk} = U+B_i+C_j+R_k+CR_{jk}+E_{ijk}$

Source of Variation	Degrees of Freedom	F value [Tabulated] 0.05	0.01
Blocks (B)	3		
Rates (R)	1	4.32	8.02
Cultivar (C)	3	3.07	4.87
Rates x Cultivar (RxC)	3	3.07	4.87
Error	21		
Total	31		

(ii) Anova for RCBD

Model: $Y_{ij} = U+B_i+T_j+E_{ij}$

Source of Variation	Degrees of freedom	F-value [Tabulated] 0.05	0.01
Blocks (B)	3		
Treatments (T)	8	2.36	3.36
Error	24		
Total	35		

The cultivar means in all treatments were compared using the Duncan's Multiple Range Test at P=0.05.

The simple correlations among yield related characters and those related to nitrogen fixed were calculated for both years.

4. RESULTS AND DISCUSSION

4.1 General Observations

The environmental data emphasize the contrasting conditions in 1984 and 1985 especially for rainfall and soil moisture (Appendix II). In 1984, less than 250 mm precipitation fell during the growing season. In 1985, over 336 mm of precipitation fell during the growing season. In the 1984 growing season, the soil moisture content below 15 cm (soil depth) went as low as -15 bars (which is the permanent wilting point), but in the 1985 growing season the soil moisture content never went as low.

The soil NO_3 - N was 48 and 30 ppm at 0-6 and 6-12 cm soil depth in 1984, respectively, and 14 and 11 ppm in 1985. The soil pH was 5.9 and 6.2 for both soil sampling depths in both years (Appendix III).

The prominent weed species in both experiments were: redroot pigweed (*Amaranthus retrofluxus* L.), lambs quarters (*Chenopodium album* L.), chickweed (*Stellaria media* L.), common groundsel (*Senecia vulgaris* L.), pineapple weed (*Matricaria matricarioides* L.), barnyard grass (*Echinochloa crusgalii* L.), Canada thistle (*Cirsium arvense* L.) and volunteer rapeseed. Hand hoeing controlled effectively most of the weeds.

Diseases and pests of faba bean that have been prevalent in Europe and other parts of Western Canada were not present in either year of this study.

4.2 Growth Stages

The number of days after seeding (DAS) to first flower were 53, 56, 56, 58 in 1984 and 58, 64, 64 and 67 in 1985 for 80F-21, Outlook, Aladin and Ackerperle, respectively (Table I). DAS to maturity were 93, 99, 101 and 103 in 1984; 100, 110, 113 and 118 in 1985 for 80F-21, Outlook, Aladin and Ackerperle, respectively. Barley matured in 93 and 100 DAS in 1984 and 1985 respectively. Maturity in 1985 was delayed in all cultivars as compared to 1984 probably because of the cooler damp weather which occured during the maturation period.

4.3 Plant Density

The seeding rates had a significant effect on plant density at flowering and maturity in both years (Table 2). The cultivar effect was significant only at flowering in 1985. There was no significant interaction effect. Within the cultivars, the high seeding rate resulted in significantly higher plant densities in most cases. This is more evident in the 1985 results than in the 1984 results (Table 3). Within seeding rates there were very few significant differences among cultivars.

Both seeding rates in 1984 resulted in plant densities lower than those recommended in Alberta, but in the 1985 growing season, the 50 seeds/m^2 resulted in the recommended range of a plant density of 400 to 500 thousand plants per hectare of cultivars like Ackerperle (Alberta Agriculture, 1982). The results in this study, show that depending on the seed size, the 33 to 50 seeds/m^2 should give an adequate plant density for the faba bean growers in Central Alberta.

4.4 Plant Height

The seeding rates had a significant effect in 1985 (Table 2). The cultivar effect was significant in both years. There was no significant interaction effect in either years. Comparison of low and high seeding rate within cultivars indicated no significant differences. The earliest maturing line (80F-21), had significantly lower plant height in 1984 at both seeding rates (Table 4). Plants in 1985 were generally shorter than those in the 1984 experiment.

Faba bean literature does not indicate the effect of seeding rates on plant height in Western Canada. Sjodin (1978) in Sweden concluded, in contrast to Hodgson and Blackman (1956) that plant height decreased with increasing seeding rate.

The results in the present study show that plant height was higher than that reported by researchers who have tested some of the cultivars used in this study in different Research Stations in Western Canada. Average plant height in this study was 107, 116 and 106 cm for cultivars Outlook, Aladin and Ackerperle in 1984, respectively and 93, 101 and 97 cm in 1985. McVetty et al. (1981) reported 100 and 95 cm for cultivars Aladin and Ackerperle, respectively, while Rowland et al. (1986) reported plant height of 89, 102 and 108 cm for cultivars Outlook, Aladin and Ackerperle, respectively. The temperature, rainfall, light and edaphic factors may be the key factors affecting plant height.

4.5 Total Dry Matter (TDM)

At maturity the faba bean crop contained 30 to 40% dry matter on a fresh weight basis. This is in agreement with the value given by Alberta Agriculture (1982). Seeding rates had no significant effect on TDM yield in both years at all harvest times except at flowering in 1984 (Table 2). Cultivar effect was significant at flowering and maturity in 1984 and 1985. The interaction effect was not significant in both years. The seeding rates effect reported in this study on TDM yield in both years is in agreement with that reported by McVetty et al. (1986).

TDM production increased with time and the maximum values were attained at maturity (Table 5). In 1984 and 1985, the TDM yields at flowering were low ranging from 0.76 to 2.08 t/ha. This stage would be too early for a silage harvest. At 29 DAF, in 1984 there were no significant differences between treatment means. However, in 1985 at 29 DAF, Outlook (50 seeds/m^2) and Ackerperle (33 seeds/m^2) had TDM yields significantly higher than all other treatment means. At maturity, there were few significant differences between treatment means. The results in this study show that harvesting for silage could be done using any of the currently licensed cultivars at 33 and 50 seeds/m^2 seeding rates.

The high values of TDM production such as these reported in this study are similar to those reported in high yielding environments ("maximum yield" plots) in Scotland (Thompson and Taylor, 1982) and in North East Polder in the Netherlands (Dantuma and Grashoff, 1984). The TDM values in this study are higher than those reported by McVetty et al. (1986) in their two year study in Manitoba, where the highest TDM production reported was 6.02 t/ha. However, TDM values in this study are similar to those reported by Berkenkamp and Meeres (1986) in Central Alberta who worked with a number of cultivars in their study including Aladin and Outlook in black chernozemic soils. In their study, the TDM production values ranged from 8.58 t/ha to 14.31 t/ha. In this study TDM production at maturity ranged from 6.74 to 9.03 t/ha in 1984 and from 8.69 to 13.64 in 1985.

A barley treatment was included in a Randomized Complete Block Analysis to make a comparison among faba bean treatments and barley which is commonly grown for silage (Appendix IV). Barley had a significantly higher TDM production than faba bean treatments at flowering, 29 DAF and maturity in 1984 and at flowering in 1985 (Table 6). Barley was not significantly different from faba bean treatments at 29 DAF and maturity in 1985. Comparison of faba bean and barley TDM production, showed that faba bean averaged 66% of barley in 1984 and 106% in 1985. TDM production of oats (*Avena sativa* L.) was reported to be higher than faba bean by Berkenkamp (1984) in Central Alberta.

The higher TDM production of barley in the dry year of 1984 could have been due to the higher root density, duration and rate of extension since faba bean is inherently shallow rooting (80 to 90 cm) compared to cereals (120 to 200 cm) as reported by Hebbthwaite (1984). The root density and penetration have been found to be important in exploitation of soil moisture reserves (particulary if water becomes limited in a period of drought). This could have resulted in faba bean having less water available to it as compared to the barley crop, especially in 1984 which was a dry year.

4.6 Seed Yield (kg/ha)

The seeding rates had no significant effect in 1984 and 1985 on seed yield (Table 2). However, cultivar effect was significant in both years. There was no significant interaction between the seeding rates and cultivars in 1984, but it was significant in 1985. There were few significant differences between treatments. The results in this study are in contrast to those reported by Kondra (1975) who observed that seeding rates significantly affected seed yield using two small faba bean cultivars, Erfodia and Wiseburger Kleinkornige in Central Alberta. In his study it was observed that the low seeding rate (33 seeds/m^2) produced the lowest yield while 33 and 50 seeds/m^2 seeding rates did not differ significantly in yield. The results in this study are in agreement with those reported by McVetty et al. (1986) who worked with the cultivars Aladin, Herz Freya and Outlook and observed that seed yield was unaffected at seeding rates 33 and 50 seeds/m^2 in Manitoba.

Seed yield in 1984 ranged from 2741 to 4001 kg/ha (Table 7) and in 1985 ranged from 3853 to 6009 kg/ha. Seed yields reported in this study are similar to those reported by Kondra (1975); Alberta Agriculture (1982); Rowland et al. (1982). Faba bean literature indicates that in Southern Alberta, where it is drier, yield is usually lower than that reported in the present results, unless the crop is irrigated (Krogman *et al*. (1980); Rowland *et al*. (1982); Rowland *et al*. (1986)).

Comparing the results in this study and the faba bean literature, if the crop is seeded in the first week of May, the farmers can use any of the current licensed cultivars at 33 seeds/m^2 seeding rate for seed production. Such a low seeding rate can result in maximum profit due to the reduction of the high seed costs resulting from high seeding rates per hectare currently recommended in Western Canada.

Seed yield of barley was not significantly different from faba bean treatments in 1984 which was relatively a dry year (Table 8). In 1985 barley yield was significantly lower than Aladin (50 seeds/m^2). This is similar to the results of Seitzer and Evans (1976) who concluded from their study that wheat was better adapted to dry conditions, while faba bean responded more favourably to a moister environment.

4.7 Vegetative Yield

The seeding rates had no significant effect on vegetative yield (Table 2). The cultivar effect on vegetative yield was significant in both years. There was no significant interaction between the seeding rates and cultivars in both years. The significant differences between treatments were few (Table 9). Barley vegetative yield was significantly higher than any faba bean-rate treatments in 1984 but not in 1985 (Table 10). This is similar to TDM results at maturity.

4.8 Harvest Index (HI)

The seeding rates had no significant effect on the HI in 1984, but had a significant effect on HI in 1985 (Table 2). The cultivar and the interaction effect were not significant in 1984 and 1985. The seeding rate effect on HI in 1984 in this study is in agreement with the results reported by Kellar and Burkhard (1981) for cultivar Maris Bead and the results by McVetty et al. (1986) who reported on cultivars Outlook, Aladin and Herz Freya.

In 1985, Aladin (33 seeds/m^2) had a significantly lower HI than all other treatments (Table 11). The HI values ranged from 0.40 to 0.47 in 1984 and 0.35 to 0.50 in 1985. The HI value is of less importance to the farmers, but it is character used in many studies to provide some measure of the partition of assimilate between the seed product and the rest of the plant.

In 1984 barley HI was significantly lower than all faba bean treatments (Table 12). In 1985, barley HI was significantly lower than all faba bean treatments except 80F-21 (33 seeds/m^2) and Aladin (33 seeds/m^2). The low HI values in barley show that the crop has lower partition of assimilate between seed and the rest of the plant than faba bean crop.

4.9 Seed Yield Per Plant

The seeding rates had no significant effect on yield per plant in both years (Table 2). The cultivar effect was significant in both years. The interaction of seeding rate and cultivars was not significant in 1984, but was significant in 1985.

The seeding rate effect on yield per plant reported in this study is in contrast to those reported by other researchers including El-Saeed (1968), Kambal (1968) who reported that as seeding rate increased, yield per plant decreased, but yield per unit area of land increased. The non-significant interaction effect on yield per plant reported in this study is in agreement with the results reported by Salih (1981) in Sudan.

In 1984, there were few significant differences between treatments (Table 13). In 1985, Ackerperle (50 seeds/m^2) had a significantly higher yield per plant than all other treatments.

The seed yield per plant is very important trait to the faba bean breeder, however, it is of less importance to the farmer who is usually interested in the crop yield per unit area.

4.10 Number of Pods per Plant

The seeding rates and cultivars had a significant effect on the number of pods per plant in 1984 and 1985 (Table 2). The interaction of seeding rates and cultivars was not significant in both years.

The seeding rate effect on pods per plant in this study is in agreement with results by El-Saeed (1968), Salih (1981) and McVetty _et al_. (1986) in Sudan and Manitoba, Canada, respectively, who reported that the number of pods per plant dropped as the seeding rate increased. The cultivar differences reported in this study has also been reported by a number of researchers including Sjodin (1978) in Sweden who worked on three cultivars: Primus, Sving and SV0560, and El-Hosary _et al_. (1983) who worked with a set of sixteen cultivars in Egypt.

In 1984 and 1985, there were few significantly different treatment means on pod production (Table 13). The values of pods per plant reported in this study are higher than those reported by McVetty _et al_. (1986) who used cultivars Aladin, Outlook and Herz Freya and reported values of 15.4 and 12.8 pods per plant at the 100 and 150 kg/ha seeding rates.

4.11 Number of Seeds per Pod

The seeding rates, cultivars and interaction between seeding rates and cultivars had no significant effect on the number of seeds per pod in 1984 and 1985 (Table 2). Such results have also been reported by Thompson and Taylor (1981) in Scotland and McVetty et al. (1986) in Manitoba. Even under irrigation (Farah, 1981), or where competition for light has been imposed (Thompson and Taylor, 1981) the number of seeds per pod has proven to be the most consistent component of yield.

The results in the present study indicate that the average number of seeds per pod is a stable character.

4.12 One Thousand Seed Weight

The seeding rates had no significant effect on one thousand seed weight in 1984 and 1985 (Table 2). The cultivar effect was significant in both years. The interaction of seeding rates and cultivars was significant in 1984 but not in 1985.

The resu[illegible] this study are in agreement with the findings of H[illegible]n and Blackman (1956) who reported that the seed weight remained constant over a wide range of seeding rates. The findings in this study are in contrast to the results reported by Ishag (1973a), Seitzer and Evans (1973), Keller and Burkhard (1981) who reported that seed size increased with seeding rate or McVetty et al. (1986) who reported that seed weight declined significantly from a maximum seed weight at 100 kg/ha seed rate to minimum seed weight at 250 kg/ha. The cultivar effect on seed weight has been reported by a number of workers including Bianco et al. (1979), Picard and Berthelem (1981), McVetty et al. (1981), Rowland et al. (1982), Rowland et al. (1986) who reported that seed weight varies considerably between cultivars and sometimes within cultivars. Picard and Berthelem (1981) reported that there was a considerable variation within a cultivar when grown in different environments. In the present results there were few significant differences between treatments.

Seed weight is the component of yield in which compensation of earlier losses of pods may occur thus in certain environmental conditions enhancing final yield.

4.13 Percent Germination

The seeding rates did not [illegible] significant effect on percent germination in 198[illegible] (Table 2). The cultivar effect was significant in both years. However, there was no significant interaction effect between the seeding rate and the cultivars in 1984 and 1985.

The results on seeding rate effect are in agreement with the results by Kondra (1975) who reported that seeding rate did not affect percent germination significantly in an experiment carried out in Central Alberta using cultivars Erfordia and Kleinkornige. The cultivar effect on percent germination could be through the difference in seed size or maturity. In 1984, the earliest maturing treatment (80F-21 at 33 and 50 seeds/m^2) had the significantly higher percent germination than the other faba bean treatments (Table 14). In 1985, Aladin (33 and 50) had the lowest percent germination. The results in this study show that line 80F-21 which had the smallest seed size and earliest maturity, had the highest percent germination in both years.

The high percent germination in the present study shows that the seeds had completed the normal development at harvest as reported by El-Bagoury (1975). From the percent germination data in this study, it can be concluded in contrast to Kondra (1975) that seeds harvested in the Edmonton area from the crop sown in the first week of May, can be used as a seed source for planting subsequent crops.

4.14 Production Score

The seeding rates had no significant effect on the production score in 1984 and 1985 (Table 2). There were significant cultivar and interaction effects on the production score in both years. Literature on faba bean does not show any production scores. Such values have been reported on barley, corn and wheat (Stoskopf, 1981).

There were few significant differences between treatments in both years (Table 15). Although the general literature on barley, corn and wheat shows that production scores are especially useful to show the most responsive cultivars (DeLoughery and Crookston 1979), production scores were not effective in making a differentiation between treatments in the present study.

4.15 Percent Nitrogen (%N)

The seeding rates had no significant effect on percent nitrogen in 1984 and 1985 except at 29 DAF in 1985 (Table 2). The cultivars had a significant effect at flowering, 29 DAF in the whole-crop and in vegetative parts at maturity in 1984. The cultivar effect was also significant on seed nitrogen at maturity in 1985. There was no significant interaction effect between seeding rates and cultivars in both years.

Since the protein percent was calculated by using a conversion factor %N x 6.25, the treatment effects on protein followed the same pattern as percent nitrogen (Tables 18 and 19).

The lack of seeding rate effect on percent nitrogen reported in the present study is in agreement with findings reported by Seitzer and Evans (1973); Kondra

(1975), and McVetty et al. (1986).

The lack of cultivar effect on seed percent nitrogen reported in 1984 few differences in 1985 is in contrast to most of the information on faba bean in the literature which shows that there are large intra-varietal variation and intervarietal variations in seed percent nitrogen (Griffiths and Lawes, 1977; Griffiths and Lawes, 1978). The variability for seed percent nitrogen is both by genetic content and environmental components (Bond, 1977) and symbiosis with particular *R. leguminosarum* (Griffiths and Lawes, 1977). Picard (1977) has also suggested that high seed percent nitrogen may be associated with late maturity of seeds.

The results on protein values are in agreement with those reported by Bhatty (1974), Kondra (1975), and Evans et al. (1982) who worked with faba bean in Saskatchewan, Central Alberta and Manitoba, respectively. Black-seeded genotypes have been reported to have higher percent nitrogen values than brown-seeded genotypes (Singh and Singh, 1984). In this study, there were no appreciable differences among the black-seeded line (80F-21) and the other three yellow-seeded cultivars i.e. Outlook, Aladin and Ackerperle used.

The barley percent nitrogen was significantly different from all faba bean treatments in 1984 and 1985 except in vegetative parts in 1985 (Table 17). The seed percent nitrogen reported in this study are similar to that reported by Alberta Agriculture (1984). The values of percent nitrogen reported in this study for vegetative parts are also in agreement with that reported by Alberta Agriculture (1984) for barley straw from "Conquest" cultivar grown in Alberta. The literature shows that nitrogen levels of barley are generally higher in southern crop districts of Alberta than in the North.

The seed protein values reported in this study (Table 18) are below those reported by El-Sayeed _et al_. (1982) at ICARDA where seed protein in world collection faba bean was analyzed and values were up to 37.8% and values of 41% have been reported by Picard (1977) in France. The values in this study and those found in the literature show that it is possible for faba bean breeders in Canada to increase protein values in the existing cultivars for feed purpose if need should arise.

From this study, it is shown that all licensed cultivars can be used to produce high quality forage and seed for use as a protein supplement in feed. The protein values at flowering and 29 DAF show that faba bean crop can be harvested at those growth stages as whole plants for high quality silage and farmers can use any of the currently licensed cultivars at 33 seeds/m^2 seeding rate for seed and vegetative production. The vegetative parts, after threshing for seed, can be used to feed the livestock since the percent nitrogen in vegetative material was superior to barley straw (Table 19) and that of wheat and barley as reported by Thoralacius *at al.* (1979) and Alberta Agriculture (1984).

4.16 Nitrogen Yield

The seeding rates had no significant effect on nitrogen yield in 1984 and 1985 except at flowering and 29 DAF in 1985 (Table 2). The cultivar effect was not significant at 29 DAF in 1984 and in seeds at maturity in 1985. The interaction effect was not significant in both years.

Barley had a significantly higher nitrogen yield than faba bean treatments at flowering in 1984 (Table 21). Seed had a significantly lower nitrogen yield while barley vegetative parts had the significantly higher nitrogen yield at maturity in 1984. Barley had the significantly lower total nitrogen yield at 29 DAF and at maturity in 1985.

The protein yield at 29 DAF (ie. when the pods in the lowest inflorescences are fully developed in size) indicates that the cultivars can be used to produce very high protein forage which is valuable in supplementing low protein fodder in intensive feed operations.

4.17 Net Symbiotic Nitrogen Fixation

The seeding rates had no significant effect on the amount of nitrogen fixed by faba bean in 1984 and 1985 (Table 2). The cultivar effect was significant on net nitrogen fixation in both years while the interaction effect was non-significant.

The results on the effect of seeding rate on nitrogen fixation reported in this study are in agreement with those reported by Sprent and Bradford (1977) in Scotland and Witty et al. (1980) in England who observed that plant density did not have much influence on nitrogen fixation per unit area and within the range of economic seeding rates, fixation per unit area remained remarkably constant. The cultivar effect in this study is in agreement to that reported by El-Sherbeeny et al. (1977b) in Wales, U.K. who reported that in the eight faba bean cultivars examined, large differences in nitrogen fixation were apparent between them. The absence of interaction in this study is however in contrast to that reported by El-Sherbeeny et al. (1977b). In 1984, there was no net nitrogen fixation until maturity (Table 24). At maturity Outlook (50 seeds/m^2) had a significantly higher amount of net nitrogen fixed than line 80F-21 (50 seeds/m^2) treatment which had the lowest amount of net nitrogen fixation. In 1985, net nitrogen fixation was observed at flowering only in Aladin (50 seeds/m^2). At 29 DAF, cultivar Outlook (50 seeds/m^2) had the significantly lower net fixation than all other treatments. At maturity few significant differences were observed.

At maturity in 1984, the maximum net nitrogen fixed was 43 kg/ha by Outlook (50 seeds/m^2). In 1985, the 29 DAP and maturity results show that faba bean fixed relatively a higher amount of nitrogen than in 1984. In 1985, 38 to 58 of the plant percent nitrogen was from fixation. The net amount of nitrogen estimated in 1984 is lower than that reported in the literature, while the 1985 results are in agreement with the literature values for Western Canada as reported by Rice (1976); Dean et al. (1980); Richard and Soper (1982).

The results show that nitrogen requirements were not fully met from symbiotic fixation and a substantial amount of nitrogen came from the soil. The wide range of the amount of nitrogen fixed by faba bean reported in this study is common in field experimental results as observed by Nutman (1976).

The variable amounts of net fixed nitrogen estimated in this study could be due to a number of effects that influence the physical and chemical factors which do affect the host and *Rhizobium* interaction. Since Western Canadian soils do not have indigenous rhizobia for faba bean (Candlish and Clark, 1975; Rennie et al. 1982), therefore competition between indigenous rhizobial strains and those applied did not arise in this study. The independently controlled genetic variations among the cultivars used and the *Rhizobium* used may have influenced the results on nitrogen fixation, as reported by

El-Sherbeeny *et al.* (1977a); El-Sherbeeny *et al.* (1977b); Mytton *et al.* (1977) and Dean and Clark (1979).

The amount of nitrogen fixed in 1984 and 1985 between 29 DAP and maturity suggest that farmers can plough-in the crop after 29 DAP if the crop is to be used as green manure.

4.18 Economic Benefit Of Net Nitrogen Fixation

The economic benefit results show that the value of the nitrogen fixed at maturity, was 0 to 40% of the seed cost in 1984 when the nitrogen value was $0.43 per kilogram (Table 25). In 1985, there was higher economic benefit when 43 to 140% of the seed cost were recovered.

The values of benefit cost ratio of 1984 and 1985 are higher than that reported by Townley-Smith and Slinkard (Unpublished, 1984) for faba bean grown in Western Canada, where the value of 10% was reported. The benefit cost ratios in the present study show that the economic benefit can improve as: the nitrogen-supplying power of the soil declines; the price of nitrogen fertilizer increases and that of the seed decreases.

From the present study, it can be concluded that faba bean can be used to produce a relatively cheap green manure which can be used to maintain the soil fertility. This could make farmers save on expensive artificial N fertilizers and reduce environmental hazards (pollution).

4.19 Economic Value of Nitrogen Yield

At seeding the soil nitrogen values were $20.15 and $8.41 per hectare for 1984 and 1985, respectively (Table 26). At harvest the total nitrogen produced (in TDM) by faba bean crop had a value of $92.07 and $113.04 per hectare for 1984 and 1985, respectively. Of these values, $10.28 and $54.77 were from nitrogen fixation for 1984 and 1985. The grain nitrogen in faba bean was equivalent to $66.54 and $91.79 for 1984 and 1985. The barley crop yielded nitrogen equivalent to $81.79 and $56.58 for 1984 and 1985. The grain contained nitrogen equivalent to $42.53 and $37.52 for 1984 and 1985, respectively. The amount of the net soil nitrogen balance was a loss of 130.83 kg/ha in 1984 and 86.09 kg/ha in 1985. In economic values, the soil nitrogen balance (CAN$) was a loss of $56.26/ha and $37.02/ha for 1984 and 1985, respectively. As expected the TDM harvest at maturity had a value of $92.07 and $113.04/ha in 1984 for faba bean and $81.79 and $56.58/ha in 1985 for barley. The harvest of barley grain resulted into a loss of nitrogen equivalent to $42.53 and $37.52/ha in 1984 and 1985, respectively.

Most of the nitrogen was removed from the area of production at the time of harvest as it was contained in the grains harvested (Table 20). This means if the seed is harvested, as is usually the case, most of the nitrogen is removed with the harvested grain crop. Depending on the environmental conditions and agronomic practices, faba bean crop can reduce the soil nitrogen status.

Although it is usually said that faba bean fit well into a rotational system because the succeeding non-fixing nitrogen crop does benefit from nitrogen fixed by the previous faba bean crop, farmers should be aware that, when the faba bean grain is harvested, the non-fixing crop succeeding the crop may not benefit from a significant increase in nitrogen. The benefit noted during the rotation program(s) could be mainly due to the fact that the legume crop does improve the soil structure and break disease cycles, and not from the enrichment of the soil with nitrogen as suggested by some literature.

4.20 Simple Correlations

In 1984, plant density was significantly correlated with vegetative yield; pods per plant and production score (Table 27). In 1985, plant density was correlated only with seeds per pod.

Plant height was significantly correlated to TDM, seed yield, vegetative yield in 1984 and 1985. This variable had also a highly significant negative correlation with pods per plant and was significantly correlated with seeds per pod, 1000 seed weight, percent germination in 1984 and with seed yield per plant, production score, nitrogen production and net amount of nitrogen fixed in 1985.

TDM was significantly correlated to plant height, seed yield (kg/ha), vegetative yield in 1984 and 1985. TDM was also correlated to 1000 seed weight, production score, nitrogen production and net symbiotic nitrogen in 1984; also to seed yield per plant, production score, nitrogen production and net nitrogen fixation. There was a significant negative correlation between TDM and the seed percent nitrogen in 1985.

Seed yield (kg/ha) was significantly correlated to plant height, TDM, vegetative yield, HI, seed yield per plant, pods per plant in 1984 and 1985; seeds per pod, 1000 seed weight in 1984, production score, nitrogen production and net symbiotic nitrogen fixed in 1984 and 1985. Seed yield was negatively correlated to the seed percent nitrogen.

Vegetative yield was significantly correlated with plant density in 1984; plant height, TDM, seed yield, production score, nitrogen production in 1984 and 1985. There was a significant negative correlation with seed yield per plant in 1984; seed yield per pod in 1984 and 1985; 1000 seed weight and percent germination in 1984.

HI was significantly correlated to plant height in 1985 and to seed yield in 1984 and 1985. It was also significantly correlated to 1000 seed weight in 1984; production score, nitrogen production in 1984 and 1985 and net symbiotic nitrogen in 1985.

Seed yield per plant was significantly correlated to plant height and to TDM in 1985; to seed yield in 1984 and 1985. Seed yield per plant was negatively correlated to vegetative yield in 1984, but was significantly correlated to pods per plant in 1984 and 1985; pods per plant; 1000 seed weight, production score in 1985 and to nitrogen production in 1984 and 1985; also to net symbiotic nitrogen in 1985.

Pods per plant were significantly correlated to seed yield and seed yield per plant in 1984 and 1985. There were significant correlations between pods per plant and 1000 seed weight, production score, net nitrogen fixation in 1985 and nitrogen production in 1984 and 1985. Pods per plant negatively correlated with plant density, plant height and production score in 1984.

Seeds per pod were significantly correlated to plant density, seed yield and percent germination in 1984. There was a significant negative correlation between seed per pod and plant height in 1984 and with vegetative yield in 1984 and 1985.

The 1000 seed weight was significantly correlated to plant height, TDM, HI and percent germination in 1984. There were significant correlations between 1000 seed weight with seed yield, seed yield per plant and nitrogen production in 1985, and significant negative correlations between 1000 seed weight and vegetative yield in 1984 and seed percent nitrogen in 1985.

Percent germination was negatively correlated to plant height a[illegible]tative yield in 1984, but significantly [illegible]d to seeds per pod in 1984. Production sc[illegible]gnificantly correlated to plant [illegible]ty; seed yield in 1984; and to plant height, seed [illegible] per plant and pods per plant in 1985. There were [illegible]gnificant correlations with TDM, vegetative yield and HI in 1984 and 1985. However, the percent germination was negatively correlated to production score in 1984.

Production score was significantly correlated to plant de[illegible]ty and seed yield in 1984 and to plant height and seed yield per plant in 1985. There were significant correlations with TDM, vegetative yield, HI nitrogen production and net nitrogen fixation in 1984 and 1985.

Seed percent nitrogen was negatively correlated to TDM, seed yield (kg/ha) and 1000 seed weight in 1985. There were significant correlations with nitrogen production 1984 and 1985.

Nitrogen production was significantly correlated to plant height in 1985; to TDM, seed yield, vegetative yield, HI, seed yield per plant in 1984 and 1985; pods per plant, 1000 seed weight in 1985; to production score in 1984; to seed percent nitrogen and to nitrogen fixation in 1984 and 1985.

Net nitrogen fixation was significantly correlated to plant height in 1984; TDM; seed yield in 1984 and 1985 and to HI, seed yield per plant in 1985, also to production score and as expected to nitrogen fixation in both years.

The highly significant correlation reported between plant density and seeds per pod in 1985 (Table 27), is in contrast to that reported by Neal and McVetty (1984). The significant correlations reported between plant height and 1000 seed weight in 1984 is in agreement with that reported by El-Hosary et al. (1983) in Egypt; and Neal and McVetty (1984) in Manitoba. The significant correlation of plant height and seed yield per plant was also reported by El-Hosary et al. (1983); and Neal and McVetty (1984).

TDM significant correlations with seed yield per plant in 1985 and with 1000 seed weight in 198[illegible] agreement with Neal and McVetty (1984). The lack of a correlation of TDM with HI is in agreement with Ishag (1973a), but is in contrast to Nagl (1981); and Neal and McVetty (1984) who reported a significant correlation between TDM and HI.

The significant correlations of HI with seed yield and 1000 seed weight is in agreement with that reported by Neal and McVetty (1984). However, the significant correlation with plant height is in contrast to that reported by Neal and McVetty (1984) who reported the significant negative correlation from their experimental results.

The significant correlations between seed yield per plant and height, TDM are in agreement with El-Hosary et al. (1983); and Neal and McVetty (1984) respectively. The significant correlation between seed yield per plant and pods per plant in both years are in agreement with Ishag (1973a); Neal and McVetty (1984), but are in contrast to El-Hosary et al. (1983). The highly significant correlation between seed yield per plant and 1000 seed weight in 1985 is similar to that reported by Ishag (1973a); El-Hosary et al. (1983); and Neal and McVetty (1984).

The absence of correlations between pods per plant and seeds per pod reported in the present study is in contrast to El-Hosary et al. (1983) who reported a highly negative correlation between the two variables, but is similar to that of Neal and McVetty (1984).

The significant correlation of seeds per pod with plant density is in contrast to that reported by Neal and McVetty (1984). The negative correlation with plant height is in agreement with that reported by El-Hosary et al. (1983).

The significant correlation of 1000 seed weight with plant height is similar to that reported by El-Hosary et al. (1983); and Neal and McVetty (1984). The 1000 seed weight with TDM, HI correlations have also been reported by Neal and McVetty (1984).

The lack of a correlation between net symbiotic nitrogen fixation and plant density in 1984 and 1985 is in agreement with the results reported by Sprent and Bradford

(1977) and Witty et al. (1977) who reported that nitrogen fixation remained constant within the range of economic seeding rate per unit area. The significant correlations between the net symbiotic nitrogen and TDM reported in this study show that nitrogen fixation is yield-dependent as reported by Rennie (1984a) in soybeans and those reported between the net symbiotic nitrogen and nitrogen production are in agreement with Graham and Setter (1983) who reported such correlations in cowpeas (*Vigna unguiculata* (L) Walp).

The significant correlations with TDM in this study show that TDM can provide a good estimate of the crop's ability to perform in the given environment in which it is grown. The seed yield per plant, pods per plant and 1000 seed weight can be good estimators of seed yield per unit area within a range of economic seeding rates per unit area.

The negative correlations between the seed nitrogen content and TDM, seed yield, seed weight show that an increase in faba bean seed quality would be difficult, since an increase in seed percent nitrogen (or percent protein) will likely result in a decrease in seed yield.

5. SUMMARY AND CONCLUSIONS

As expected, seeding rate had a significant effect on plant density in both years. Seeding rate also affected plant height (1985), TDM at flowering (1984), HI (1985), pods per plant, percent nitrogen at 29 DAF (1985), nitrogen yield (1985) at flowering and at 29 DAF. However, there was no significant effect on major economic traits such as TDM at 29 DAF and at maturity; seed yield, percent nitrogen and nitrogen yield at maturity. Percent nitrogen and nitrogen yield at 29 DAF were affected in 1985.

The cultivar effect was significant on plant density at flowering (1985), plant height (1984 and 1985), TDM yield at flowering and maturity, seed yield per area and per plant, pods per plant, one thousand seed weight, vegetative yield, percent germination and production score (1984 and 1985). Cultivar effect was also significant on percent nitrogen at flowering and 29 DAF and in vegetative parts (1984). Nitrogen yield was affected by cultivar effect at flowering (1984 and 1985), 29 DAF (1985) in seeds (1984), vegetative parts and TDM (1984 and 1985) at maturity. However, the cultivar effect was inconsistent between years and few significant differences between treatments were found. Therefore all licensed cultivars are equally acceptable for seed or silage production. The interaction effect of seeding rate x cultivar was significant only on seed yield per unit area and per plant

(1985), one thousand seed weight (1984), production score (1984 and 1985).

The seed yield was highly correlated to number of seeds per plant, pods per plant and to the lesser extent to number of seeds per pod and one thousand seed weight. The number of seeds per pod was nearly the same in four cultivars used in this study. The HI's responded in inverse direction to vegetative yield. The barley HI's were significantly lower than those of faba bean. This shows that barley has a lower partition of assimilate between seed and the rest of the plant than faba bean. The significant correlations with TDM in this study show that TDM can provide a good estimate of the crop's ability to perform in the given environment in which it is grown. The seed yield per plant and thousand seed weight can be good estimators of seed yield per unit area within a range of economic seeding rates per unit area. The negative correlations between the seed nitrogen content and TDM, seed yield, seed weight show that an increase in faba bean seed quality would be difficult to obtain, since an increase in seed percent nitrogen (or percent protein) will likely result in a decrease in seed yield.

The maximum TDM values were attained at maturity. The correlations between TDM and, plant height, seed yield, vegetative yield, production score, nitrogen yield were significant and positive. Production scores were not effective in making a differentiation between the cultivar performance. Barley was better adapted to dry environmental conditions than faba bean, while faba bean responded favourably to a moister environment as measured by TDM.

Nitrogen yield was correlated to plant height, pods per plant, 1000 seed weight in 1985, and to TDM, seed yield, vegetative yield, HI, seed yield per plant and percent nitrogen in 1984 and 1985. Net symbiotic nitrogen fixation was correlated to seed yield per plant, plant height, HI in 1985; and to TDM, seed yield, production score and nitrogen production in 1984 and 1985.

The maximum net nitrogen fixed per hectare was 185 kg which accounted 57% of the total seasonal symbiotically fix N. The nitrogen requirements were not fully met from symbiotic fixation and most of it was from the soil. The variable amounts of net symbiotic fixed nitrogen in this study could be due to a number of factors which influence the host and *Rhizobium* interaction, and those which affect plant growth such as soil nitrogen and [illegible]. The value of the net fixed nitrogen in this study averaged $10.28 and $54.77 for 1984 and 1985, respectively. The nitrogen yield averaged 214 and 263 kg/ha in faba bean which valued $92.02 and $113.04 for 1984 and 1985, respectively while barley yielded 190 and 139 kg/ha which had the value of $81.70 and $59.77 for 1984 and 1985, respectively. The nitrogen yield values and the amount of nitrogen fixed between 29 DAP and maturity suggest that farmers can plough-in the crop after 29 DAF if the crop is to be used as green manure.

The results in this study may be helpful to both faba bean researchers and growers in Central Alberta. The licensed cultivars performed well at the lower seeding rate of 33 seeds/m^2 than that currently recommended by Alberta Agriculture for growers. Since yield increase were minimal for increase in seeding rate from 33 to 50 seeds/m^2, it is unlikely that further increases in seeding rate would result in any increase in yield. Before the 33 seeds/m^2 seeding rate is used, however, the grower should ensure that seed and environmental conditions are favourable for high rate of emergence, since density below that recommended for Central Alberta could result into significantly reduced TDM, seed yield and nitrogen production. It was not possible to recommend one best licensed cultivar to be used in Central Alberta. It was also observed that most of the nitrogen was removed from the area of production with grain harvested leading to the conclusion that faba bean crop can reduce the soil nitrogen status.

Table 1. Days to and date of flowering and maturity

Growth Stage	Cultivar	DAS* 1984	DAS* 1985	DATE 1984	DATE 1985
Flowering	80F-21	53	58	June 29	July 1
	Outlook	56	64	July 2	July 6
	Aladin	56	64	July 2	July 6
	Ackerperle	58	67	July 4	July 9
	Conquest[1]	47	53	June 23	June 29
Maturity	80F-21	93	100	Aug. 8	Aug. 11
	Outlook	99	110	Aug. 14	Aug. 21
	Aladin	101	113	Aug. 16	Aug. 21
	Ackerperle	103	118	Aug. 18	Aug. 29
	Conquest	93	100	Aug. 8	Aug. 11

*DAS: Days After Seeding.
1 Conquest: Barley Cultivar.

Table 2. Factorial analysis of variance

Variable Tested	Rate (R) 1984	Rate (R) 1985	Cultivar (C) 1984	Cultivar (C) 1985	Interaction (RxC) 1984	Interaction (RxC) 1985
Plant Density (per m^2)						
at flowering	**	*	NS	*	NS	NS
at maturity	**	*	NS	NS	NS	NS
Plant Height (cm)	NS	**	*	*	NS	NS
Total Dry Matter (tons/ha)						
at flowering	*	NS	*	*	NS	NS
at 29DAF	NS	NS	NS	NS	NS	NS
at maturity	NS	NS	*	*	NS	NS
Seed Yield (kg/ha)	NS	NS	*	*	NS	*
Vegetative Yield (tons/ha)	NS	NS	*	*	NS	NS
Harvest Index	NS	**	NS	NS	NS	NS
Seed yield per plant (grams)	NS	NS	*	**	NS	*
Pods per plant	**	*	*	**	NS	NS
Seeds per pod	NS	NS	NS	NS	NS	NS
Thousand seed weight (grams)	NS	NS	**	*	**	NS
Percent germination	NS	NS	*	**	NS	NS
Production Score	NS	NS	*	*	*	*
Percent nitrogen						
at flowering	NS	NS	*	NS	NS	NS
at 29DAF	NS	*	*	NS	NS	NS
in seeds at maturity	NS	NS	NS	*	NS	NS
in vegetative parts at maturity	NS	NS	*	NS	NS	NS
Total %N at maturity	NS	NS	NS	NS	NS	NS
Nitrogen Yield (kg/ha)						
at flowering	NS	*	*	*	NS	NS
at 29DAF	NS	*	NS	*	NS	NS
in seeds at maturity	NS	NS	*	NS	NS	NS
in vegetative parts at maturity	NS	NS	*	*	NS	NS
Total N at maturity	NS	NS	*	*	NS	NS
Net symbiotic N fixation	NS	NS	*	**	NS	NS

**,* significant at 1% and 5% level respectively.

Table 3. Plant density ($2m^{-2}$) of faba bean

1984

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	AT FLOWERING	AT MATURITY
33	80F-21	27 cd*	27 c
	Outlook	27 cd	25 c
	Aladin	26 d	25 c
	Ackerperle	25 d	25 c
50	80F-21	42 a	33 ab
	Outlook	35 b	34 a
	Aladin	38 ab	28 bc
	Ackerperle	33 bc	31 bc

1985

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	AT FLOWERING	AT MATURITY
33	80F-21	36 b	42 a
	Outlook	36 b	32 b
	Aladin	34 b	31 b
	Ackerperle	35 b	31 b
50	80F-21	47 a	43 a
	Outlook	49 a	39 a
	Aladin	47 a	42 a
	Ackerperle	47 a	40 a

* Means within each column followed by same letter are significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 4. Plant height (cm) of faba bean

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	PLANT HEIGHT (cm) 1984	PLANT HEIGHT (cm) 1985
33	80F-21	95 b*	89 bc
	Outlook	106 a	95 ab
	Aladin	116 a	103 a
	Ackerperle	106 a	95 ab
50	80F-21	96 b	83 c
	Outlook	107 a	91 bc
	Aladin	115 a	103 a
	Ackerperle	112 a	98 ab

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 5. Total dry matter production (tons/hectare) of faba bean

1984

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY
33	80F-21	1.25 c*	6.29 a	6.74 b
	Outlook	1.53 bc	6.46 a	8.62 a
	Aladin	1.81 ab	7.42 a	8.28 ab
	Ackerperle	1.46 bc	6.51 a	9.03 a
50	80F-21	1.52 bc	6.53 a	7.36 ab
	Outlook	2.03 a	6.62 a	8.91 a
	Aladin	2.08 a	6.02 a	8.56 a
	Ackerperle	1.72 abc	6.54 a	7.68 ab

1985

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY
33	80F-21	0.76 c	6.75 b	9.56 bc
	Outlook	1.34 abc	8.89 b	10.50 bc
	Aladin	1.31 abc	8.95 b	12.19 ab
	Ackerperle	1.03 abc	10.76 a	11.50 abc
50	80F-21	0.92 bc	6.21 b	8.69 c
	Outlook	1.13 abc	10.26 a	10.81 abc
	Aladin	1.72 a	8.44 b	13.64 a
	Ackerperle	1.63 ab	7.68 b	11.00 abc

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 6. Total dry matter production (tons/hectare) of faba bean and barley.

1984

FABA BEAN SEEDING RATE(seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29DAP	AT MATURITY	%FABA BEAN COMPARED TO BARLEY TDM
33	80F-21	1.25 c*	6.29 b	6.74 d	55
	Outlook	1.52 b	6.46 b	8.62 bc	70
	Aladin	1.81 b	7.42 b	8.28 bc	68
	Ackerperle	1.46 b	6.51 b	9.03 bc	74
50	80F-21	1.52 b	6.53 b	7.36 cd	60
	Outlook	2.03 b	6.32 b	8.91 bc	73
	Aladin	2.08 b	6.01 b	8.56 bc	70
	Ackerperle	1.72 b	6.54 b	7.67 bcd	63
	Conquest	5.79 a	15.08 a	12.27 a	-

1985

FABA BEAN SEEDING RATE(seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29DAP	AT MATURITY	%FABA BEAN COMPARED TO BARLEY TDM
33	80F-21	0.76 d	6.75 a	9.56 bc	92
	Outlook	1.34 bc	8.89 a	10.50 abc	101
	Aladin	1.31 bc	8.95 a	12.19 ab	117
	Ackerperle	1.03 cd	10.76 a	11.50 ab	111
50	80F-21	0.92 cd	6.21 a	8.69 c	84
	Outlook	1.13 cd	10.26 a	10.81 abc	104
	Aladin	1.72 b	8.45 a	13.64 a	131
	Ackerperle	1.63 b	7.68 a	11.00 abc	106
	Conquest	2.34 a	7.08 a	10.34 abc	-

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 7. Seed yield (kilograms per hectare).

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	SEED YIELD (kg/ha) 1984	1985
33	80F-21	2741 b*	3853 c
	Outlook	4001 a	5281 ab
	Aladin	3390 ab	4272 bc
	Ackerperle	3756 a	5134 abc
50	80F-21	3338 ab	4121 bc
	Outlook	3851 a	4769 abc
	Aladin	3985 a	6009 a
	Ackerperle	3436 ab	4846 abc

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 8. Seed yield of faba bean and barley (kilograms per hectare).

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	SEED YIELD (kg/ha) 1984	1985
33	80F-21	2741 b*	3853 b
	Outlook	4001 a	5281 ab
	Aladin	3390 ab	4272 b
	Ackerperle	3756 a	5134 ab
50	80F-21	3338 ab	4121 b
	Outlook	3851 a	4769 ab
	Aladin	3985 a	6009 a
	Ackerperle	3439 ab	4846 ab
	Conquest	3529 ab	3953 b

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 9. Vegetative yield of faba bean (tons per hectare).

[illegible] SEEDING RATE (seeds/m^2)	CULTIVAR	VEGETATIVE YIELD (tons/ha) 1984	1985
33	80F-21	4.00 c*	5.71 abc
	Outlook	4.62 abc	5.22 bc
	Aladin	4.89 ab	7.92 a
	Ackerperle	5.27 a	6.37 abc
50	80F-21	4.02 c	4.57 c
	Outlook	5.06 a	6.04 abc
	Aladin	4.58 abc	7.63 ab
	Ackerperle	4.24 bc	6.15 abc

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 10. Vegetative yield of faba bean and barley (tons per hectare).

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVARS	VEGETATIVE YIELD (tons/ha) 1984	1985
33	80F-21	4.00 d*	5.71 ab
	Outlook	4.62 bcd	5.22 b
	Aladin	4.89 bc	7.92 a
	Ackerperle	5.27 b	6.40 ab
50	80F-21	4.02 d	4.57 b
	Outlook	5.06 b	6.04 ab
	Aladin	4.58 bcd	7.63 a
	Ackerperle	4.24 cd	6.15 ab
	Conquest	8.74 a	6.42 ab

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 11. Harvest index of faba bean

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	HARVEST INDEX 1984	HARVEST INDEX 1985
33	80F-21	0.41 a*	0.40 a
	Outlook	0.46 a	0.50 a
	Aladin	0.40 a	0.35 b
	Ackerperle	0.42 a	0.45 a
50	80F-21	0.45 a	0.48 a
	Outlook	0.43 a	0.44 a
	Aladin	0.47 a	0.44 a
	Ackerperle	0.44 a	0.44 a

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 12. Harvest index of faba bean and barley.

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	HARVEST INDEX VALUES 1984	1985
33	80F-21	0.41 a*	0.40 cd
	Outlook	0.46 a	0.50 a
	Aladin	0.40 a	0.35 d
	Ackerperle	0.42 a	0.45 abc
50	80F-21	0.45 a	0.48 ab
	Outlook	0.43 a	0.44 bc
	Aladin	0.47 a	0.44 bc
	Ackerperle	0.44 a	0.44 bc
	Conquest	0.29 b	0.38 d

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 13. Seed yield per plant (g), number of pods per plant, number of seeds per pod and 1000 seed weight (g).

1984

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	SEED YIELD PER PLANT (g)	NUMBER OF PODS PER PLANT	NUMBER OF SEEDS PER POD	1000 SEED WEIGHT(g)
33	80F-21	10.3 bc*	22.6 a	3.5 a	271 cd
	Outlook	15.9 a	20.1 ab	3.4 a	329 bc
	Aladin	13.6 abc	18.2 bc	3.2 a	410 a
	Ackerperle	14.9 ab	20.6 ab	3.3 a	438 a
50	80F-21	10.0 c	17.5 bc	3.4 a	215 d
	Outlook	12.0 abc	17.1 bc	3.4 a	335 b
	Aladin	13.8 abc	15.1 c	3.3 a	447 a
	Ackerperle	10.9 bc	18.5 bc	3.3 a	339 b

1985

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	SEED YIELD PER PLANT (g)	NUMBER OF PODS PER PLANT	NUMBER OF SEEDS PER POD	1000 SEED WEIGHT(g)
33	80F-21	9.2 b	20.0 bc	3.8 a	263 bc
	Outlook	13.7 b	25.9 a	3.6 a	353 ab
	Aladin	11.5 b	20.9 bc	3.7 a	435 a
	Ackerperle	21.0 a	17.7 c	3.6 a	384 a
50	80F-21	10.1 b	23.0 ab	3.7 a	265 bc
	Outlook	12.0 b	22.1 abc	3.9 a	255 c
	Aladin	14.6 b	21.0 bc	3.9 a	413 a
	Ackerperle	12.5 b	18.4 bc	3.6 a	386 a

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 14. Percent germination of faba bean.

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	PERCENT GERMINATION 1984	1985
33	80F-21	98 a*	96 a
	Outlook	85 c	90 bc
	Aladin	89 bc	80 e
	Ackerperle	89 bc	93 ab
50	80F-21	99 a	92 ab
	Outlook	87 bc	86 cd
	Aladin	88 bc	84 de
	Ackerperle	92 b	93 ab

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 15. Production score of faba bean.

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	PRODUCTION SCORE 1984	PRODUCTION SCORE 1985
33	80F-21	50.5 c*	53.4 bc
	Outlook	58.62 a	65.8 a
	Aladin	52.7 bc	51.5 c
	Ackerperle	54.8 abc	61.6 ab
50	80F-21	55.7 ab	60.8 ab
	Outlook	55.8 ab	59.6 abc
	Aladin	59.5 a	63.7 a
	Ackerperle	56.2 ab	59.9 abc

* Means within each column followed by same letter are not significantly different at the 0.05 as determined by Duncan's Multiple Range Test.

Table 16. Nitrogen content (%N) of faba bean

1984

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	AT MATURITY VEGETATIVE PARTS	AT MATURITY TOTAL
33	80F-21	4.3 bc*	3.9 c	4.3 a	1.5 ab	2.7 a
	Outlook	4.4 bc	4.2 ab	4.3 a	1.3 ab	2.7 a
	Aladin	5.0 a	4.0 bc	4.4 a	1.4 abc	2.6 a
	Ackerperle	4.8 ab	4.4 a	4.3 a	1.3 abc	2.6 a
50	80F-21	4.4 bc	4.0 bc	4.4 a	1.6 a	2.9 a
	Outlook	4.3 bc	3.9 bc	4.4 a	1.2 abc	2.8 a
	Aladin	4.0 bc	4.0 bc	4.3 a	1.2 abc	2.7 a
	Ackerperle	4.6 abc	4.2 ab	4.3 a	1.1 c	2.5 a

1985

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	AT MATURITY VEGETATIVE PARTS	AT MATURITY TOTAL
33	80F-21	4.4 a	3.7 a	4.7 a	0.8 a	2.4 a
	Outlook	4.5 a	3.9 a	4.5 abc	0.8 a	2.7 a
	Aladin	4.7 a	3.9 a	4.4 abc	0.8 a	2.1 a
	Ackerperle	4.6 a	3.8 a	4.3 c	0.8 a	2.4 a
50	80F-21	4.2 a	3.5 a	4.6 ab	0.8 a	2.6 a
	Outlook	5.0 a	3.7 a	4.5 abc	0.7 a	2.4 a
	Aladin	4.7 a	3.6 a	4.4 bc	0.8 a	2.4 a
	Ackerperle	4.5 a	3.7 a	4.4 abc	0.8 a	2.4 a

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 17. Nitrogen content (%N) of faba bean and barley.

1984

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	AT MATURITY VEGETATIVE PARTS	AT MATURITY TOTAL
33	80F-21	4.3 bc*	3.9 c	4.3 a	1.5 ab	2.7 a
	Outlook	4.4 abc	4.2 abc	4.3 a	1.3 abcd	2.7 a
	Aladin	5.0 a	4.0 abc	4.4 a	1.4 abcd	2.6 a
	Ackerperle	4.8 ab	4.4 a	4.3 a	1.3 abcd	2.6 a
50	80F-21	4.4 abc	4.0 bc	4.4 a	1.6 a	2,9 a
	Outlook	4.3 bc	3.9 bc	4.4 a	1.2 abc	2.8 a
	Aladin	4.0 c	4.0 bc	4.3 a	1.2 abc	2.7 a
	Ackerperle	4.6 abc	4.2 ab	4.3 a	1.1 d	2.5 a
	Conquest	2.9 d	2.0 d	2.8 b	1.1 d	1.6 b

1985

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	AT MATURITY VEGETATIVE PARTS	AT MATURITY TOTAL
33	80F-21	4.4 a	3.7 a	4.7 a	0.8 a	2.4 a
	Outlook	4.5 a	3.9 a	4.5 ab	0.8 a	2.7 a
	Aladin	4.7 a	3.9 a	4.4 ab	0.8 a	2.1 a
	Ackerperle	4.6 a	3.8 a	4.3 b	0.8 a	2.4 a
50	80F-21	4.2 a	3.5 a	4.6 ab	0.8 a	2.6 a
	Outlook	5.0 a	3.7 a	4.5 ab	0.7 a	2.4 a
	Aladin	4.7 a	3.6 a	4.4 ab	0.8 a	2.4 a
	Ackerperle	4.5 a	3.7 a	4.4 ab	0.8 a	2.4 a
	Conquest	3.1 b	1.8 b	2.2 c	0.8 a	1.3 b

* Means within each column followed by same letter are significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 18. Percent protein of faba bean (%N x 6.25)

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	AT MATURITY VEGETATIVE PARTS	AT MATURITY TOTAL
1984						
33	80F-21	26.9 bc*	24.4 c	26.9 a	9.4 ab	16.9 a
	Outlook	27.5 bc	26.3 ab	26.9 a	8.1 ab	16.9 a
	Aladin	31.3 a	25.0 bc	27.5 a	8.8 abc	16.3 a
	Ackerperle	30.0 ab	27.5 a	26.9 a	8.1 abc	16.3 a
50	80F-21	27.5 bc	25.0 bc	27.5 a	10.0 a	18.1 a
	Outlook	26.9 bc	24.4 c	27.5 a	7.5 abc	17.5 a
	Aladin	25.0 c	25.0 bc	26.9 a	7.5 abc	16.9 a
	Ackerperle	28.8 abc	26.3 ab	26.9 a	6.9 c	15.6 a
1985						
33	80F-21	27.5 a	23.1 a	29.4 a	5.0 a	15.0 a
	Outlook	28.1 a	24.4 a	28.1 abc	5.0 a	16.9 a
	Aladin	29.4 a	24.4 a	27.5 abc	5.0 a	13.1 a
	Ackerperle	28.8 a	23.8 a	26.9 c	5.0 a	15.0 a
50	80F-21	26.3 a	21.9 a	28.8 ab	5.0 a	16.3 a
	Outlook	31.3 a	23.1 a	28.1 abc	4.4 a	15.0 a
	Aladin	29.4 a	22.5 a	27.5 bc	5.0 a	15.0 a
	Ackerperle	28.1 a	23.1 a	27.5 abc	5.0 a	15.0 a

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 19. Percent protein of faba bean and barley (%N x 6.25)

1984

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAP	AT MATURITY		
				SEED	VEGETATIVE PARTS	TOTAL
33	80F-21	27.0 bc*	24.1 c	26.7 a	9.7 ab	16.9 a
	Outlook	27.5 abc	26.1 abc	26.8 a	8.1 abcd	16.9 a
	Aladin	31.5 a	25.2 abc	27.7 a	8.7 abcd	16.3 a
	Ackerperle	29.8 ab	27.4 a	26.8 a	8.0 abcd	16.3 a
50	80F-21	27.4 abc	24.7 bc	27.7 a	10.2 a	18.1 a
	Outlook	26.5 bc	24.4 bc	27.8 a	7.6 abc	17.5 a
	Aladin	25.2 c	24.8 bc	27.1 a	7.3 bcd	16.9 a
	Ackerperle	28.8 abc	26.5 ab	26.6 a	5.5 d	15.6 a
	Conquest	17.9 d	12.8 d	17.6 b	6.5 cd	10.0 b

1985

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAP	SEED	VEGETATIVE PARTS	TOTAL
33	80F-21	27.4 a	23.0 a	28.9 a	4.7 a	15.0 a
	Outlook	28.3 a	24.1 a	28.2 ab	5.0 a	16.9 a
	Aladin	29.4 a	24.0 a	27.6 ab	5.2 a	13.1 a
	Ackerperle	28.6 a	23.8 a	26.9 b	5.1 a	15.0 a
50	80F-21	26.4 a	22.1 a	28.7 ab	5.2 a	16.3 a
	Outlook	28.1 a	22.8 a	28.1 ab	4.6 a	15.0 a
	Aladin	29.1 a	22.3 a	27.3 ab	5.0 a	15.0 a
	Ackerperle	27.9 a	23.1 a	27.4 ab	5.2 a	15.0 a
	Conquest	19.6 b	11.1 b	13.9 c	5.0 a	8.1 b

* Means within each column followed by same letter are significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 20. Nitrogen yield of faba bean (kilograms per hectare).

1984

FABA BEAN SEEDING RATE(seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	VEGETATIVE YIELD	TOTAL
33	80F-21	53.8 c*	245.3 a	117.9 b	60.0 a	177.9 d
	Outlook	67.3 bc	271.3 a	172.0 a	60.1 a	232.1 ab
	Aladin	90.5 a	326.5 a	149.2 ab	68.5 a	217.7 cd
	Ackerperle	70.1 bc	280.[illegible] a	165.3 ab	68.5 a	233.8 a
50	80F-21	66.9 bc	287.3 a	146.9 ab	64.3 a	211.2 cd
	Outlook	87.3 a	291.3 a	169.4 a	60.7 a	230.1 bc
	Aladin	83.2 a	258.9 a	171.4 a	54.9 a	226.3 cd
	Ackerperle	79.1 abc	281.1 a	147.7 ab	46.6 b	194.3 cd

1985

FABA BEAN SEEDING RATE(seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAF	AT MATURITY SEED	VEGETATIVE YIELD	TOTAL
33	80F-21	33.4 d	249.8 ab	181.1 a	45.7 bc	226.8 b
	Outlook	60.3 abc	349.7 ab	237.6 a	41.6 bc	279.4 ab
	Aladin	61.6 abc	349.1 ab	187.9 a	63.4 a	251.3 b
	Ackerperle	47.4 cd	408.9 a	220.8 a	50.9 abc	271.7 ab
50	80F-21	38.6 cd	217.4 ab	189.6 a	36.6 c	235.2 b
	Outlook	56.5 bcd	379.6 ab	214.6 a	42.3 bc	256.9 b
	Aladin	80.8 a	304.4 ab	264.4 a	61.0 a	325.4 a
	Ackerperle	73.4 ab	284.2 ab	213.2 a	49.2 abc	262.4 ab

* Means within each column followed by same letter are not significantly different at 0.05 level as determined by Duncan's Multiple Range Test.

Table 21. Nitrogen yield of faba bean and barley (kilogram per hectare).

1984

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAP	AT MATURITY SEED	VEGETATIVE PARTS	TOTAL
33	80F-21	53.8 c*	245.3 a	117.9 bc	60.0 bc	177.9 b
	Outlook	67.3 bc	271.3 a	172.0 a	60.1 bc	232.1 a
	Aladin	90.5 b	326.5 a	149.2 ab	68.5 b	217.7 ab
	Ackerperle	70.1 bc	280.0 a	165.3 a	68.5 b	233.8 ab
50	80F-21	66.9 bc	287.3 a	146.9 ab	64.3 b	211.2 ab
	Outlook	87.3 b	291.3 a	169.4 a	60.7 b	230.1 a
	Aladin	83.2 b	258.9 a	171.4 a	54.9 bc	226.3 ab
	Ackerperle	79.1 bc	281.1 a	147.7 ab	46.6 c	194.3 ab
	Conquest	167.9 a	301.6 a	98.8 c	96.1 a	194.9 ab

1985

FABA BEAN SEEDING RATE (seeds/m^2)	CULTIVAR	AT FLOWERING	AT 29 DAP	AT MATURITY SEED	VEGETATIVE PARTS	TOTAL
33	80F-21	33.4 b	249.8 abc	181.1 b	45.7 b	226.8 b
	Outlook	60.3 ab	349.7 ab	237.6 ab	41.8 b	279.4 ab
	Aladin	61.6 ab	349.1 ab	187.9 b	63.4 a	251.3 ab
	Ackerperle	47.4 ab	408.9 a	220.8 ab	50.9 ab	271.7 ab
50	80F-21	38.6 ab	217.4 bc	189.6 b	36.6 c	235.2 b
	Outlook	56.5 ab	379.6 c	214.6 ab	42.3 b	256.9 ab
	Aladin	80.8 a	304.4 ab	264.4 a	61.0 a	325.4 a
	Ackerperle	73.4 a	284.2 ab	213.2 ab	49.2 ab	262.4 ab
	Conquest	72.5 a	127.4 c	87.0 c	51.4 ab	138.4 c

* Means within each column followed by same letter are not significantly different at the 0.05 level as determined by Duncan's Multiple Range Test.

Table 22. Protein yield (kg/ha x 6.25) of faba bean.

1984

FABA BEAN CULTIVAR SEEDING RATE(seeds/m^2)		AT FLOWERING	AT 29 DAP	AT MATURITY SEED	VEGETATIVE YIELD	TOTAL
33	80F-21	336 c*	1533 a	737 b	376 a	1112 d
	Outlook	421 bc	1696 a	1075 a	376 a	1451 ab
	Aladin	566 a	2041 a	933 ab	428 a	1361 cd
	Ackerperle	438 abc	1750 a	1033 ab	428 a	1461 a
50	80F-21	418 bc	1796 a	918 ab	402 a	1320 cd
	Outlook	546 ab	1821 a	1059 a	379 a	1438 bc
	Aladin	520 ab	1618 a	1071 a	343 a	1414 c
	Ackerperle	494 abc	1757 a	923 ab	291 a	1214 cd

1985

FABA BEAN CULTIVAR SEEDING RATE(seeds/m^2)		AT FLOWERING	AT 29 DAP	AT MATURITY SEED	VEGETATIVE YIELD	TOTAL
33	80F-21	209 d	1561 ab	1132 a	286 bc	1418 b
	Outlook	377 abc	2186 ab	1485 a	261 bc	1746 ab
	Aladin	385 abc	2182 ab	1174 a	396 a	1571 b
	Ackerperle	296 cd	2556 a	1380 a	318 abc	1698 ab
50	80F-21	241 cd	1359 b	1185 a	229 c	1470 b
	Outlook	353 bcd	2373 ab	1341 a	264 bc	1606 b
	Aladin	505 a	1903 ab	1653 a	381 a	2034 a
	Ackerperle	459 ab	1776 ab	1333 a	308 abc	1640 ab

* Means within each column followed by same letter are not significantly different at 0.05 level as determined by Duncan's Multiple Rate Test.

Table 23. Protein yield (kg/ha x 6.25) of faba bean and barley.

FABA BEAN CULTIVAR SEEDING RATE(seeds/m^2)		AT FLOWERING	AT 29 DAF	AT MATURITY SEED	VEGETATIVE YIELD	TOTAL
1984						
33	80F-21	336 c*	1533 a	737 bc	376 bc	1112 b
	Outlook	421 bc	1695 a	1075 a	376 bc	1451 a
	Aladin	566 b	2041 a	933 ab	428 b	1361 ab
	Ackerperle	438 bc	1750 a	1033 a	428 b	1461 ab
50	80F-21	418 bc	1796 a	918 ab	402 b	1320 ab
	Outlook	546 b	1821 a	1059 a	379 b	1438 a
	Aladin	520 b	1618 a	1071 a	343 bc	1414 ab
	Ackerperle	494 bc	1757 a	923 ab	291 c	1214 ab
	Conquest	1049 a	1885 a	618 c	601 a	1218 ab
1985						
33	80F-21	209 b	1561 abc	1132 b	286 b	1418 b
	Outlook	377 ab	2186 ab	1485 ab	261 b	1746 ab
	Aladin	385 ab	2182 ab	1174 b	396 a	1571 ab
	Ackerperle	296 ab	2556 a	1380 ab	318 ab	1698 ab
50	80F-21	241 ab	1359 bc	1185 b	229 c	1470 b
	Outlook	353 ab	2373 c	1341 ab	264 b	1606 ab
	Aladin	505 a	1903 ab	1653 a	381 a	2034 a
	Ackerperle	459 a	1776 ab	1333 ab	308 ab	1640 ab
	Conquest	453 a	769 c	544 c	321 ab	865 c

Table 24. Amount of net nitrogen fixed by faba bean (kilograms per hectare).

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	AT FLOWERING 1984	AT FLOWERING 1985	AT 29 DAF 1984	AT 29 DAF 1985	AT MATURITY 1984	AT MATURITY 1985	%N FIXED 1984	%N FIXED 1985
33	80F-21	-	-	-	127 ab*	-	88 b	-	39
	Outlook	-	-	-	191 a	41 ab	143 ab	18	51
	Aladin	-	-	-	191 a	28 ab	112 ab	13	45
	Ackerperle	-	-	-	253 a	38 ab	134 ab	17	49
50	80F-21	-	-	-	88 b	23 b	84 b	11	38
	Outlook	-	-	-	18 c	43 a	121 ab	18	47
	Aladin	-	7	-	170 ab	36 ab	185 a	16	57
	Ackerperle	-	-	-	124 ab	-	128 ab	-	48

- No net nitrogen fixation

* Means within each column followed by same letter are not significantly different at 0.05 level as determined by Duncan's Multiple Range Test.

Table 25. Ecnonomic benefit of nitrogen fixation in faba bean relative to fertilizer nitrogen

1984

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	SEED COST ($/ha)[1]	Kg N FIXED/ha	VALUE OF FIXED N ($/ha)[2]	BENEFIT COST RATIO
33	80F-21	44	-	-	-
	Outlook	44	41	18	0.40
	Aladin	44	28	12	0.27
	Ackerperle	44	37	16	0.36
50	80F-21	66	24	10	0.15
	Outlook	66	43	18	0.28
	Aladin	66	36	16	0.24
	Ackerperle	66	-	-	-

1985

FABA BEAN SEEDING RATE (seeds/m²)	CULTIVAR	SEED COST ($/ha)[1]	Kg N FIXED/ha	VALUE OF FIXED N ($/ha)[2]	BENEFIT COST RATIO
33	80F-21	44	88	38	0.86
	Outlook	44	143	61	1.40
	Aladin	44	112	48	1.09
	Ackerperle	44	134	57	1.31
50	80F-21	66	84	36	0.55
	Outlook	66	121	58	0.88
	Aladin	66	210	90	0.43
	Ackerperle	66	128	55	0.84

[1] Based on faba bean seed costing $0.44/kg (1985).
[2] Based on urea nitrogen fertilizer costing 0.43/kgN in Alberta and 100% fertilizer use efficiency.

Table 26. Nitrogen balance sheet

VARIABLE	AVERAGE VALUE (kg/ha) 1984	1985
FABA BEAN		
Soil nitrogen at seeding [0-12cm depth]	46.87 ($20.15)	19.56 ($8.41)
Total nitrogen yield [Crop N]	214.11 ($92.07)	262.88 ($113.04)
Symbiotic fixed nitrogen [Average]	23.91 ($10.28)	127.38 ($54.77)
Nitrogen derived from the soil	190.20 ($81.79)	138.56 ($59.58)
Nitrogen taken off with harvested grain	154.74 ($66.54)	213.47 ($91.79)
Nitrogen taken off with harvested TDM	214.11 ($92.07)	262.88 ($113.04)
Nitrogen taken off with vegetative material only	59.38 ($25.53)	49.43 ($21.25)
Soil nitrogen balance *	-130.83	-86.09
Net soil N balance (CAN $/ha)+	($-56.26)	($-37.02)
BARLEY		
Total nitrogen from the soil	190.20 ($81.79)	138.56 ($56.58)
Nitrogen taken off with harvested TDM	190.20 ($81.79)	138.56 ($56.58)
Nitrogen taken off with harvested grain	98.90 ($42.53)	87.26 ($37.52)

* Soil N Balance (kg/ha) = N fixed (kg/ha) - N taken off with faba bean harvested grain (kg/ha)

+ Based on appropriate cost of fertilizer (Urea) i.e. $0.43/kilogram.

Table 27. Correlations among all variables across all faba bean cultivars and replications 1984 above; 1985 below.

	PLANT HEIGHT	TDM	SEED YIELD (kg/ha)	VEGETATIVE YIELD	HI	SEED YIELD PER PLANT	PODS PER PLANT	SEEDS PER POD	1000 SEED WEIGHT	%GERMINATION	PRODUCTION SCORE	SEED % N	N PRODUCTION	NET SYMB N
PLANT DENSITY	-0.19	0.12	-0.19	0.35	-0.19	-0.22	-0.39	0.11	0.19	-0.19	0.34	0.03	0.25	0.20
	0.18	0.17	0.14	0.01	-0.29	-0.28	-0.27	0.59	-0.20	0.02	0.24	0.01	0.11	0.14
PLANT HEIGHT	-	0.42	0.68	0.73	-0.18	0.30	-0.44	-0.39	0.56	-0.45	0.25	0.05	0.23	0.13
	-	0.84	0.60	0.88	0.32	0.46	0.06	0.21	0.05	-0.25	0.63	0.16	0.63	0.87
TDM	-	-	0.48	0.77	0.11	0.03	0.27	0.00	0.47	-0.16	0.44	-0.15	0.57	0.60
	-	-	0.40	0.70	0.17	0.52	0.24	0.03	-0.19	0.01	0.60	-0.46	0.67	0.89
SEED YIELD (kg/ha)	-	-	-	0.54	0.39	0.46	0.49	0.54	0.30	0.14	0.36	-0.33	0.59	0.35
	-	-	-	0.37	0.48	0.70	0.51	0.32	0.37	-0.19	0.27	-0.39	0.65	0.40
VEGETATIVE YIELD	-	-	-	-	-0.10	-0.30	0.07	-0.41	-0.43	-0.52	0.56	0.02	0.56	0.25
	-	-	-	-	-0.07	-0.29	-0.10	-0.34	-0.16	-0.13	0.84	0.10	0.49	0.18
HI	-	-	-	-	-	0.22	-0.23	0.09	0.59	0.09	0.86	-0.05	0.46	0.19
	-	-	-	-	-	0.27	0.21	0.13	0.25	0.06	0.84	0.03	0.45	0.46
SEED YIELD PER PLANT	-	-	-	-	-	-	0.52	0.04	0.24	0.03	0.00	0.07	0.62	0.05
	-	-	-	-	-	-	0.57	0.01	0.35	0.13	0.39	-0.21	0.67	0.69
PODS PER PLANT	-	-	-	-	-	-	-	0.28	-0.28	0.27	0.65	0.08	-0.02	-0.12
	-	-	-	-	-	-	-	0.27	-0.10	0.19	0.33	0.07	0.52	0.13
SEEDS PER POD	-	-	-	-	-	-	-	-	-0.15	0.60	-0.14	-0.23	0.08	0.04
	-	-	-	-	-	-	-	-	0.21	0.22	0.10	-0.11	0.20	0.20
1000 SEED WEIGHT	-	-	-	-	-	-	-	-	-	0.38	0.21	-0.03	0.30	0.23
	-	-	-	-	-	-	-	-	-	-0.19	0.07	-0.58	0.79	0.29
%GERMINATION	-	-	-	-	-	-	-	-	-	-	-0.23	0.14	0.17	0.01
	-	-	-	-	-	-	-	-	-	-	0.29	0.11	0.04	0.09
PRODUCTION SCORE	-	-	-	-	-	-	-	-	-	-	-	0.13	0.53	0.40
	-	-	-	-	-	-	-	-	-	-	-	0.26	0.33	0.83
SEED %NITROGEN	-	-	-	-	-	-	-	-	-	-	-	-	0.54	0.15
	-	-	-	-	-	-	-	-	-	-	-	-	0.37	-0.06
N PRODUCTION	-	-	-	-	-	-	-	-	-	-	-	-	-	0.98
	-	-	-	-	-	-	-	-	-	-	-	-	-	0.99
NET SYMBIOTIC N	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-

n = 32 r = 0.34 at 5%
r = 0.44 at 1%

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Appendix I. Initial percent germination, seed size and seed rate.

CULTIVARS	INITIAL% GERMINATION	SEED SIZE (g/1000 SEEDS)	SEED/m^2 33	50 (kg/ha viable seeds)
80F-21	98	240	80	120
Outlook	95	348	115	175
Aladin	92	409	135	205
Ackerperle	92	366	120	185

Appendix II. Environmental data for 1984 and 1985 growing seasons.

TIME DURING THE GROWING SEASON	TOTAL RAINFALL (mm)	TOTAL IRRADIANCE 400-700nm $E.m^{-2}d^{-1}$	MEAN SOIL MOISTURE† (BELOW 15 cm bars)	MEAN AIR TEMPERATURE MAX. °C	MEAN AIR TEMPERATURE MIN. °C	MEAN RELATIVE HUMIDITY MAX. °C	MEAN RELATIVE HUMIDITY MIN. °C	MEAN SOIL TEMPERATURE BELOW 10cm MAX. °C	MEAN SOIL TEMPERATURE BELOW 10cm MIN. °C
1984									
May 2 to May 13	24.0	427.41	-0.73	13.35	0.58	89.00	45.42	12.70	6.78
May 14 to May 27	59.0	407.73	-0.53	15.57	4.70	93.79	53.00	13.78	9.04
May 28 to June10	62.0	527.03	-0.43	19.03	6.92	90.64	49.64	16.26	10.94
June11 to June24	20.0	629.59	-0.41	23.56	8.34	94.43	43.43	21.40	14.00
June25 to July 8	17.6	639.42	-10.34	23.53	8.00	92.71	47.59	17.19	13.73
July 9 to July29	36.0	980.29	-15.15	26.59	8.65	95.29	43.67	17.22	13.73
July30 to Aug.12	2.6	569.13	-10.27	29.44	12.21	93.64	38.29	19.74	16.44
Aug.13 to Aug.27	20.6	32.31	-10.39	25.39	7.75	94.60	38.71	17.74	14.29
Aug.28 to Sept. 2	7.6	170.34	-10.17	16.10	3.64	86.29	31.14	14.37	11.67
Total rainfall (mm)	249.4								
1985									
May 1 to May 16	5.0	-	-	-	-	-	-	-	-
May 17 to June 2	10.2	475.10	-0.80	20.60	4.60	89.00	31.00	16.84	11.76
June 3 to June 23	69.9	-	-	-	-	-	-	-	-
June24 to July 14	2.5	1120.4	-11.22	26.79	8.90	88.93	34.20	17.74	14.18
July15 to Aug.18	158.4	647.0	-8.51	25.54	7.82	88.57	38.95	17.66	14.77
Aug.19 to Aug.25	74.2	218.9	-0.71	22.18	8.39	87.42	52.50	16.81	13.86
Aug.26 to Sept.2	16.4	-	-	-	-	-	-	-	-
Total rainfall (mm)	336.6								

† Field Capacity is about -0.33 bar; Permanent Wilting Point is about -15 bars.

Appendix III. Some soil characteristics at experimental sites at seeding time for 1984 and 1985 growing seasons (Avarage of Samples).

YEAR	SEEDING DATE	SOIL TYPE	TEXTURE	SOIL REACTION (pH)		SOIL N (ppm)		SOIL P (ppm)		SOIL K (ppm)	
				0-6 cm	6-12 cm	0-6 cm	6-12 cm	0-6 cm	6-12 cm	0-6 cm	6-12 cm
1984	7/5/84	Clay loam	Fine	5.9	5.9	48	30	19	18	299	313
1985	4/5/85	Clay loam	Fine	6.2	6.2	14	18	11	11	327	319

In both years harvesting was done in August of each year.

Appendix IV. Randomized complete block analysis of variance summary.

VARIABLES TESTED	CULTIVAR-RATE TREATMENTS 1984	1985
Total Dry Matter (TDM)		
at flowering	*	**
at 29 DAF	**	NS
at maturity	**	*
Seed Yield	**	*
Vegetative Yield	*	*
Harvest Index	**	**
Nitrogen Production		
at flowering	**	*
at 29 DAF	*	*
in seeds at maturity	**	*
in vegetative parts at maturity	**	*
Total %N at maturity	*	*

**,* Significant at 1% and 5% level respectively.