ESTABLISHMENT AND EVALUATION OF COVER CROPS UNDERSEEDED IN SWEET CORN IN DELTA, BRITISH COLUMBIA

by

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ABSTRACT

A two year field experiment was carried out in Delta Municipality, British Columbia. The study was designed to investigate the effects of dates of underseeding different cover crops such as crimson, red clover and alsike clovers and annual ryegrass and fall rye with sweet corn. The experiment was conducted as a split plot, randomized complete block design with 12 treatment combinations and four replicates. Main plots were the two dates of cover crop planting, one shortly after emergence and the second at sidedressing time (~30 cm). Subplots were comprised of an unseeded control plus five different cover crops seeded under sweet corn.

In the 1992-1993 and 1993-1994 growing seasons, the effects of cover crops on fresh and dry cob yield of sweet corn were not significant. In the 1992-1993 experiment the type of underseeded cover crops had no effect on either fresh or dry stalk yield, while in the 1993-1994 growing season stalk yields were reduced by fall rye and annual ryegrass relative to red clover. Early planting of cover crops significantly reduced the fresh and dry stalk yield of sweet corn.

There were no differences due to cover crops in the corn ear leaf nitrogen concentration in the 1992-1993 growing season. However, in the 1993-1994 growing season, sweet corn/fall rye had significantly lower ear leaf nitrogen concentrations than sweet corn/red clover. In the 1993-1994 growing season the ear leaf nitrogen concentrations of early underseeded sweet corn were significantly lower than ear leaf

nitrogen concentration of late underseeded sweet corn.

In the 1992-1993 growing season, red clover produced the highest cover crop dry matter yield. Nitrogen concentrations in alsike and red clovers were higher than that of annual ryegrass. In 1993-1994 growing season, crimson clover produced the highest dry matter yield. The nitrogen content of crimson clover was higher than that of alsike clover, fall rye and annual ryegrass in that year. In both 1992-1993 and 1993-1994 growing seasons, annual ryegrass had the highest percent cover compared to the other treatments.

Fresh and dry cob yields of sweet corn were not affected by date of seeding nor type of cover crop underseeded. Early underseeded cover crop appeared to compete with sweet corn for nitrogen as compared to late underseeding. Despite low dry matter production which may be attributed to different growth habits, annual ryegrass and alsike clover look promising soil cover crops because they gave higher percentage of soil cover.

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Chapter One

INTRODUCTION

1.1. The importance of cover crops underseeded in sweet corn in Delta.

Delta municipality is part of South Coastal British Columbia and has some of Canada's most productive land in agriculture. The major cash crops grown in Delta are sweet corn, vegetables and potatoes and many are harvested late in the season. Present farming in Delta is far below its potential crop production. This can be attributed to a number of factors, e.g. declining soil organic matter and soil compaction. Over the past two decades the Delta farming community has switched from dairy farming to intensive vegetable production. As a result, organic matter inputs have decreased since crops such as peas, beans and potatoes return little crop residue. Declining soil productivity has been compensated by heavy fertilization (Bomke, personal communication, 1991). However, heavy usage of fertilizers can be decreased if farmers use grasses and legumes for underseeding (cover crops). Legumes act as cover crops, and fix nitrogen from the air, which may became available to subsequent crops. Agricultural crop production practices in Delta have intensified soil degradation processes such as soil erosion and compaction. Soil compaction occurs because the local farmers in the valley often till wet soils in early spring and late fall as required for spring seeded crops. In addition the winter precipitation causes leaching of soil nutrients and soil erosion. Underseeding with cover crops may reduce nutrient leaching during winter. The introduction of different cover crops like red clover, crimson clover, alsike clover, fall rye and annual ryegrass as relay cropping in the farms in South Coastal climatic region, encompasses many important considerations. For instance cover crop establishment could be carried out during the drier months of the year and thus reduce soil compaction. The presence of cover crops in the systems will help to reduce soil compaction and erosion. Cover crops as a green manure are an alternative source of soil organic matter. The climate in Delta is exceptional with respect to precipitation and temperature. Because of the mild temperature, cover crops generally remain vegetative over the winter months and recommence growth in early spring. On average Delta, B.C. receives about 1000 mm of precipitation per annum, which is about half of that in the eastern parts of the lower Fraser Valley. The longest frost-free period in Canada, extends from April 15 to October 21 (Temple, 1992). The soils in Delta are inherently fertile, heavy textured and deep; consequently the soil has a good water retention capacity and a potential to sustain crop production on a year-round basis.

Agronomic information pertaining to cover crop underseeding in sweet corn is lacking locally; however, information from other regions with similarities in climate is available in the literature. Such available information, however, may not be directly applicable under Delta, B.C conditions because differences in soil conditions and slight climatic differences may have considerable consequences. Therefore, the success of cover crops in sweet corn in Delta would demand that information be developed locally. The research work reported in this thesis investigated the establishment and evaluation of cover crops in sweet corn production.

1.2 Objectives

1. To investigate the biomass production of three species of clover and two grasses underseeded with sweet corn.

2. To investigate the effects of cover crop type and date of seeding on sweet corn yield and the nitrogen content of both the cover crops and the sweet corn.

3. To investigate the effectiveness in providing soil cover prior to winter of underseeding sweet corn with five cover crops at two different dates.

Chapter Two

LITERATURE REVIEW

2.1. Historical background of cover crops.

Cover cropping is the practice of growing pure or mixed stands of annual or perennial herbaceous plants to cover the soil of croplands for part or all of the year. The plants may be left to cover the top soil or incorporated into the soil by tillage as green manure. In the history of agriculture, legumes and animal manure have been the major source of soil nitrogen. Although animal wastes, nonsymbiotic fixation, and atmospheric fixation can be significant sources of nitrogen, a large fraction can be attributed to legumes through symbiotic fixation. The importance of green manure can be traced back to early Mediterranean civilization, as early as the writings of Xenophen, who lived from 434 to 355 B.C. (Wedderbuan and Collingwood, 1976). In a review of historic agricultural practices, Semples (1928), cited several writers who had discussed the use of legumes for soil improvement. There is evidence in literature that bean crops were used as green manure by farmers in Macedonia and Thessely as early as 373 B.C. Comparisons among different types of legumes for soil improvement have also been reported (Smith *et al.* 1987). According to Pieters (1927), Chinese Civilization had known the importance of legumes in increasing crop production for more than 2000 years. Using legumes in crop rotation is among the oldest agricultural management practices used to enhance soil fertility and crop production. Ancient Roman and Greek writers documented the importance of faba bean, vetch and other leguminous species as cover crops and rotation crops with grains (Smith *et al.* 1987). From the above discussion, it can be seen that the modern agricultural practice of green manuring is an ancient invention.

At the beginning of modern agricultural science, Lawes and Gilbert conducted experiments at Rothamsted to measure and understand the significant contributions of legumes to soil fertility (Russell, 1966). By the 1930s, the mechanism by which legumes improve soil nitrogen availability, nitrogen fixation, and organic nitrogen mineralization, had become reasonably well understood (Waksman and Starkey, 1931; Fred *et al.*, 1932). In early American agriculture it is difficult to determine how widely green manuring and cover cropping were practised. According to Pieters and Mckee (1929), these practises were known but not common in the colonial era. As soil fertility was depleted, the value of legume green manures should have become more apparent, but perhaps this problem was more commonly solved by long-term pasture rotations and application of animal manure to grain crops. The use of green manure and cover crops had yet not been appreciated, for example in 1936, which was suggested as the heyday of green manuring, there were 55 million hectares of cropped land in 12 southern states but only 0.8 million were seeded to winter cover crops (Pieters and McKee, 1938). Although there was 5.9 million hectares of green manure crops in the Southeast in 1940, the acreage declined significantly after that time (Rogers and Giddens, 1957). The decline can be attributed to the widespread availability of synthetic nitrogen fertilizer and the economic advantage of its use in continuous grain crop production systems.

After World War II, agronomists did not completely ignore winter cover crops but, for the most part, farmers did. A lot of research was conducted between 1940 and 1965 (Nelson, 1944; Evans *et al.*, 1954; Beale *et al.*, 1955; Kamprath *et al.*, 1958; Benoit *et al.*, 1962) but the practice was rather limited. From the historical background, it would certainly be difficult to claim that legume cover crops and legume intercropping are new ideas. However, during the last 10 years both researchers and producers have shown tremendous interest in this old practice. This can be explained by three major factors: (i) Large increases in the cost of fossil fuels and the related increase in the price of nitrogen fertilizer experienced in the 1970s and early 1980s. Although the costs of both commodities have recently stabilized or even decreased, the perception remains that over the long-term these are likely to become more expensive or more limited in supply. (ii) Increased concern about soil erosion and the more general concern about the effects of agricultural practices on environmental quality. (iii) Rapid adoption of no-tillage and conservation tillage practices by crop producers in many regions of United States and throughout the world.

2.2. Resources for underseeding cover crops

2.2.1. Light

Light is an important resource and an inadequate supply becomes a limiting factor in achieving optimum yields. Therefore, successful mixed cropping systems may reduce competition for light. This can be minimized through various possibilities such as planting the dominant crop in double rows, orientation of rows in east-west direction, increasing leaf inclination of the dominant crop, and growing shade tolerant crops. Willey (1979) conducted experiments at the International Crop Research Institute For The Semi-Arid Tropics and found that in a pearl millet- groundnut intercropping system, the much slower development of the groundnut canopy was apparent as it intercepted only 45% of incident light at 40 days after sowing as sole crop as compared to 80% by pearl millet at this growth stage. The interception in intercrop was intermediate between the sole crops. Pendleton *et al.* (1963), who studied intercropped maize-soybean sensitivity to reduced light intensity reported that east-west direction of rows reduced shading of groundnuts and led to yield increases. Other plant species like cocoyam, yam, cassava and cowpea can adapt to low light conditions (Steiner, 1984).

2.2.2. Water and Nutrient use

It is believed that mixed cropping systems make better use of soil resources than sole crops because component crops can exploit different layers. Several authors have shown greater uptake of nutrients by intercrops than by sole crops (Liboon and Harward, 1975; De 1980, Natarajan and Willey, 1980). Reddy and Willey (1981) reported Land Equivalent Ratios (LER) values of 1.25, 1.28 and 1.26 for uptake of N, P and k respectively at final harvest in pearl-millet/groundnut intercrop and attributed higher yield of intercrop to those factors.

The water use efficiency has also been studied in intercrops by some workers.

Baker and Norman (1975) while studying sorghum-pigeonpea intercrop found that better water use was probably a common cause of increased yields in the semi-arid tropics where water is a limiting production factor.

2.2.3. Effect of cover crops in underseeding on plant population

Plant population refers to both the concepts of number of plants per unit area and the spatial arrangements to accommodate that population. It is generally reported that the total optimum population of mixed crops may be higher than that of sole crops. Willey (1979) confirmed these results in maize/bean mixed cropping. Results from mixed cropping in India indicated that in a mixed cropping system comprising of an 80-90 day cereal and 150-180 day pigeonpea, optimum plant population could be increased to full sole crop optimum of each crop (Freyman and Venkateswarlu, 1977). Similar results were reported from cassava/legume mixed cropping (Thung and Cock, 1979). Component populations generally have a direct bearing on the yield contributed by each in mixed cropping. This relationship however, is influenced by the relative competitiveness. Willey (1979), reported that component crops become relatively more competitive if they form a larger proportion of the trial population.

Planting patterns or spatial arrangements are of equal importance to the relative population proportions in the mixed cropping because of competition for light, water and mineral nutrients. In general where a shorter crop is susceptible to shading, planting mixed cropping in multiple rows, alternate rows, or in some grouping has given higher yields than mixed intercropping (Dalal, 1977; Willey, 1979). In cereal based intercropping systems in India, De (1980) showed that maize, sorghum or millet could be grouped in closer rows without any adverse effect on yield, leaving larger spaces for shade sensitive species like groundnut, and in this way achieve highest LERS. He also found no adverse effect on dominant crops by reducing inter-plant spacing within the rows.

In the intercropping systems, where cover crops have been used as underseedings, it is reported that the cover crops had no effect on the yields of the dominant crops. For example, Palada *et al.* (1983) working at Rodale Research Centre, found no reduction in grain yields in corn underseeded with legumes. Nanni and Baldwin (1987) in Ontario found that different clover species underseeded in corn did not affect the corn grain yield. Mt. Pleasant (1982), working in New York, saw that corn yields were not affected by red clover intercrop during establishment provided that corn was 0.5 to 0.30 m high at the time of cover crop establishment. Wall *et al.* (1991) working at Guelph, concluded that intercropping silage corn with red clover can provide soil erosion protection without sacrificing silage corn yields.

2.3. Effects of underseeded cover crops on insects and diseases

Cover cropping systems constitute agricultural systems diversified in time and space. There is evidence that this vegetational diversity often results in significant reductions of insect pest problems (Altieri *et al.* 1978). Research on the effects of cover crops on weeds, pathogens and nematodes has started to emerge, and studies indicate that their populations change in response to diversification of cropping systems (Egunjobi, 1984). The effects of intensive systems on pests and weeds can neither be generalized nor predicted because of the enormous variety of systems utilized throughout the world. As the temporal and spatial dimensions of vegetation diversity change, so does the magnitude of the effects on pest population (Perrin and Philips, 1978).

For the majority of cover crops, the residue remains on the soil surface following herbicide application, increasing the overall diversity in the agroecosystem. The most pronounced effects are seen early in the season prior to, or immediately following, herbicide application. Several studies have shown that there is an increase in the arthropod fauna, most notably soil predators, herbivores, and decomposers, with the use of cover crops. It has also been observed that with different types of cover crops there is an increase in arthropod diversity. House and Alzugary (1989) found that hairy vetch supported higher below ground arthropod densities and more diverse fauna than crimson clover or wheat.

Smith *et al.* (1988) in Ohio, found that potato leafhopper populations in soyabeans were consistently lower when rye cover crop residues remained on the soil surface. Highest numbers of potato leafhoppers were found in rye-free plots or where rye was plowed in. This negative impact on potato leafhoppers from the presence of grassy residues corresponds to studies with alfalfa (Lamp *et al.* 1984a; Lamp *et al.* 1984b; Oloumi-Sadeghi *et al.* 1989) and soybeans relay-intercropped into winter wheat (Hammond, 1990) where lower leafhopper populations were found in mixed grass/legume systems. Potato leafhopper population was found to be lower in mixed grass and legume in an experiment where soybean was relay-intercropped into winter wheat. Grasses are not hosts for potato leafhopper but induce behavioral changes in the leafhopper (by a mechanism that is not completely understood) which in turn reduces leafhopper numbers. These changes apparently can occur whether the grass is living or, in the case of cover crops, dead or dying from a recent herbicide application.

Smith *et al.* (1988) found that numbers of Japanese beetles and bean leaf beetles were slightly higher in the rye cover crop plots. The impact that cover crops have on soil and foliar arthropods depends not only on the types of arthropods and cover crops and main crop agroecosystem but also on the type (grass versus legume) and management of the cover crops.

Knowledge of influence of the cover crop on the arthropods may assist the farmer in better management of their cropping systems. Steiner (1984) has given a list of cases where component crops have been used successfully in controlling pests in a wide variety of crop combinations. The mechanisms that have played a role are reported to be visual effects on insects, impediments in dispersal of larval stages of insects, increased abundance of natural enemies and feeding inhibition. Despite this broad situation, the pest incidence/damage may also be influenced by crop species or variety and location interactions. Natural ecosystems can be regarded as models for pest management strategies in agroecosystems. Some rural societies simulate forest conditions in their farms to obtain the beneficial effects of forest structures. Farmers in Central America imitate the structure and species diversity of tropical forests by planting a variety of crops with different growth habit. By keeping diversity at the highest possible level, small scale farmers have minimized the threat of unstable condition (such as pests) while obtaining a stable source of income and nutrition and maximizing returns under low levels of technology. Taylor (1977) reported that in maize/cowpea combination, the stalk borer (*Chilpartellus*) damage in maize was 50 to 60 percent less than in the case of the maize sole crop. However, pod damage in cowpea by Maruca, was the same in both the intercrop and sole crop in variety Tvu4557, but was reduced by nearly 50% in intercrop as compared to the sole crop for variety Ife brown. Chad and Sharma (1977) reported significant reduction of borers (*Chilpartellus*) in maize incidence in intercropped (maize/beans) as compared to sole crop.

Altieri (1978) observed that populations of several important bean pests were reduced in maize/bean crop combinations due to increases in predator populations. However, Steiner (1984) reported that dry season planting of maize with cotton increased the abundance of boll worm (*Helothesis armergia*) in cotton as the pest could multiply on maize and migrate to cotton without being checked by enemies.

2.4. Effect of cover crop in underseeding on weed control

Weeds are a major limiting factor in crop production and have a significant influence on yields as well as the area that farmers can cultivate. Most farmers are concerned with reducing negative impacts of weeds on crop production and the losses that they suffer from weeds. Often they cannot kill or effectively suppress the weeds. Presently, farmers in the United States spend more than $6.2 billion annually controlling weeds in crop production and pastureland. This includes an estimated $3.6 billion used for nearly 200 million kilograms of herbicide (Shaw, 1982; Pimental and Levitan, 1980). About 50% of all tillage operations in the United States are carried out specifically for weed control (McWhorter and Chandler, 1982), and one to three cultivations are common in many row crop production systems (Zimdahl, 1981).

Over the last several decades, farmers in Canada and United States have used more herbicides in weed control. This has made tillage operations shift towards reduced or minimum tillage systems (Koskinen and McWhorter, 1986). More reliance on herbicide has resulted in increased farm sizes and a decreases in crop diversity within farms (USDA, 1973). A large number of researchers and farmers look at herbicides as a main ingredient for effective weed control and increased profit. Despite the current emphasis on herbicides in North American agriculture, several factors (e.g. environmental cleanliness, quality of produce and herbicide resistant etc.) have recently led to a reappraisal of their use. Secondly some farmers are faced with financial difficulties and are led into consideration that farm profitability might be increased by reducing inputs such as herbicide, if less costly alternatives were available (Papendick, 1987; Francis and King, 1988). Lastly, researchers and farmers have become increasingly aware that full-time farms can operate profitably with little or no use of herbicides (Thompson and Thompson, 1984).

Based on experience of farmers and research results, we can see that some biological and physical practices may reduce heavy dependence on herbicides and potentially improve farm profits and environmental quality. These practices include using allelopathic cover crops, intercropping, and crop rotation. Cover cropping in row crop production that combines short-term crop rotation has a potential in reducing use of herbicides for weed control in conservation tillage. Cover crops are generally established prior to the fall to provide a dense soil cover during winter and spring, and to suppress weed germination and establishment.

2.5. Legume cover crops in underseeding

Different legume species are available in many different parts of the world. Some of these legume species are used to feed livestock as in grazing or silage, green chop and hay. Many of these species have played a significant role in soil conservation tillage practices. Generally speaking, the diverse climatic and soil conditions across both temperate and tropical regions necessitate this diversity in legume resources. Therefore, no specific species is dominant in a particular region. Red clover (*Trifolium pratense* L.) is one of the most important legumes grown in United States and Canada because of its winter hardiness and fixation of substantial amounts of nitrogen and significant biomass production. The total area covered in both countries is 5 million hectares of land (Smith *et al.* 1985). Red clover is grown for pasture, hay, improvement of soil structure in a four year crop rotation.

White clover (*Trifolium repens* L.) is another important legume cover crop in temperate regions (Carlson *et al.* 1985). White clover is a legume grown by farmers and ranchers in many different parts of the United States annually.

Other important legumes are crimson clover (*Trifolium incarnatum* L.), vetch (*Vicia* spp), rose clover (*Trifolium hirum* L.) and alsike clover (*Trifolium hybridum).* Other species are important in many different parts of United States. As an example, Roter and Kretschemer, have a large program involving over 4,000 accessions of tropical legumes in Florida (Pederson and Knight, 1984).

Biologically, most legume species are annuals or biennials. Their adaptation ranges from semi-temperate for hairy vetch and crimson clover to temperate for winter pea, sweet clover and alfalfa. Dry matter production of these legumes ranges from 2.3 t/ha for sweet clover to 10 t/ha for hairy vetch and alfalfa (Palada *et al.* 1982).

Most legume cover crops cannot tolerate dry and acid soil conditions, while some are known to be tolerant to shade and field traffic, which are ideal characteristics of intercropping. Resistance to severe winter frost is important if the legumes are grown for soil nitrogen. Winter survival and spring regrowth seem to be fair with selected species. In spring 1978, research was conducted in many different parts of the United States to observe the crop establishment and growth characteristic of six legume sod species (Palada *et al.* 1982). These species were medium red clover, crownvetch, short vetch, Nolan improved Louisiana white clovers, strawberry clover and sweet clover. The legumes were seeded without companion crops and managed as if they were grown for hay production. Strawberry clover and crownvetch were totally destroyed by tillage operations, while short white clover and Nolan improved Louisiana white clover showed significant resistance. Of the six species, only medium red clover and short white clover survived the winter. This research helped to identify species that are suitable for overseeding and interplanting.

If the cover crop used is a legume or a mixture including a legume, it can provide the additional benefit of contributing a substantial amount of biologically fixed nitrogen to subsequent crops. In association with appropriate *Rhizobium* bacteria, legumes are capable of fixing atmospheric nitrogen, which becomes available to other plants through mineralization. Certain species of legumes are genetically more efficient than others at fixing nitrogen. Given well-inoculated leguminous plants, the amount of biologically fixed nitrogen supplied by a particular legume cover crop is affected mainly by the amount of growth of the legumes, particularly the aboveground growth. According to Allison (1957), average values for N_2 fixation by legume crops are usually in the range of about 60 to 110 kg/ha, but more than 225 kg/ha of N may be fixed by certain legumes. The amount of nitrogen produced is a function of the dry matter yield and the nitrogen content of the legume. Therefore, any factor limiting dry matter production by the legume decreases the amount of nitrogen produced. Results with legumes have shown that about 80% of the nitrogen is contained in the above-ground portion of the cover crops. Van Doren, (1979) observed that it did not matter whether the legume stand was weedy as long as there was a reasonable population of vigorous legume plants in the stand. Several factors affect the amount of nitrogen produced by the legumes. Slow growth in the spring resulting from cold and dry weather or from some other environmental factor may severely limit nitrogen production by legumes. Killing legume stands too early will limit the nitrogen production by the legume cover crop. Legumes that are poorly adapted to some specific localities will perform poorly in fixing and providing nitrogen to the subsequent crop if grown in these localities.

Bomke *et al.* (1993), while investigating the effect of a wide range of fall-seeded cover crops on nitrogen cycling in the South Coastal region of British Columbia, found that by spring plow-down time only crimson and red clovers and the low yielding forage kale had nitrogen concentrations in excess of 2%, the approximate level required for net nitrogen mineralization for the succeeding summer crop. Although red clover had the highest nitrogen concentration, its vigor and dry matter accumulation were so low that it was not expected to make a significant contribution to available nitrogen during the subsequent growing season.

2.6. Nonlegume cover crops in underseeding

The value of nonlegumes as cover crops has been recognized for many years. Generally speaking, nonlegume cover crops are classified into two major families Graminaceae and Cruciferae. In the Graminaceae family, the majority of research has centred on the use of cereal rye (*Secale cereale* L.), although many other grasses such as barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum*) have been successfully used (Hargrove and Frye, 1987). Most of the remaining nonlegume cover crops are members of the genus *Brassica* and include such crops as mustard (Chapman *et al.*, 1949). The ability of nonlegumes to prevent nitrogen leaching is related to their ability to develop rapidly and their dry matter production under cool conditions. Grasses have been used extensively as cover crops because they are hardy under a wide range of environmental conditions.

The ability of cover crops to improve soil structure and to take up and conserve residual nitrogen prior to the winter rainy period is directly related to their ability to accumulate biomass (Bomke *et al.* 1993). However, non leguminous cover crops like cereals and annual ryegrass, which had total nitrogen concentrations at plowdown time of 0.9 to 1.3% may immobilize soil available nitrogen in direct proportion to their dry matter yields.

A field study was conducted on the Atlantic coastal plains of Maryland in which corn (*Zea mays* L.) was fertilized with 336 kg N/ha and an unfertilized rye cover crop was planted in early October (Meisinger *et al.* 1990). The corn was intentionally over-fertilized to ensure a large pool of fall $N0_3$-N to test the capacity of the rye to use residual nitrogen. Shallow groundwater wells 1.5 m deep, were installed in replicate plots in November before recharge season, and water well samples of recent percolation drainage into these wells were collected throughout the winter and spring. The average $N0_3$-N concentration below the no-cover controls was 17 ppm, while the concentration below the rye cover was 12 ppm. Therefore, the rye cover crops reduced the concentration of NO_3 entering shallow groundwater by 29%. It was not possible to measure drainage volumes in the study, but it is clear that the rye cover crop had a beneficial impact on groundwater quality.

Other researchers monitored during fall and winter the soil $N0_3$ content in fields seeded with cover crops (Neilsen and Jensen 1985; Staver *et al.* 1990). In the studies, it was observed that there was a marked reduction in the size of the mobile $N0_3$-N pool below grass cover crops.

In the State of Maryland, a rye cover crop reduced the NO_3-N content below the 0-30 cm soil surface layer from 58 to 13 N kg/ha during the winter. Neilsen and Jenson (1985) in Denmark found that, an annual ryegrass cover crop reduced the NO_3-N pool in 100 cm of soil by 33 kg N/ha, which represented a 62% reduction in potentially leachable nitrogen. From the above studies, it can be seen that grass cover crops are effective in reducing the mass and concentration of the leachate NO_3. The somewhat smaller percent reduction in the NO_3 concentration stems from the fact that as cover crops take up N the mass of potentially leachable N decreases; but the NO_3 concentration in the soil solution may not decrease. Because of simultaneous use of NO_3 and water by cover crops a larger percentage reduction could be expected in the mass compared with the concentration of N lost. Among the grass cover crops studied so far, it seems that cereal rye is best in many environments for the improvement of water quality.

2.7. Effects of cover crop underseeding on soil properties

2.7.1. Accumulation of organic carbon and nitrogen

It can be stated as common knowledge that legumes and grasses in rotations will increase soil organic matter, or at least maintain it at relatively higher levels than under row crops. Increased organic matter could be beneficial to crop growth by enhancing soil physical and chemical properties, water retention capacity and nutrient reservoirs.

Kamprath *et al.* (1958) in North Carolina measured the effects of oats or hairy vetch winter covers with conventionally tilled corn and various nitrogen fertilizer rates on changes in soil carbon and nitrogen over eight years at four sites in North Carolina. In general, soil organic matter declined without cover crops but tended to increase with either vetch or oats plus nitrogen fertilizer. Touchton *et al.* (1984) in Georgia concluded that winter legumes caused no measurable changes in soil carbon or nitrogen, but research data indicated strong trends for a relative increase with crimson clover or common vetch. Hargrove (1986) measured soil carbon and nitrogen before and after three years of no-tillage grain sorghum with several different winter cover treatments in Georgia. He found that organic matter declined in winter fallow treatments but was generally maintained or declined less with cover crops. The differences were consistent only above 15 cm soil depth. There was little evidence that soil organic matter accumulation was highly sensitive to type of cover crop or residue used. Legumes result similiar soil organic carbon contents as equivalent quantities of higher C:N materials, such as grass or wheat straw. Larson *et al.* (1972) added into the soil different crop residues for 11 consecutive years. For a given mass of a residue, soil carbon accumulation was comparable for legumes, straw, and even sawdust. Soil nitrogen increases were also surprisingly similar for all materials except sawdust an extremely low N substrate. Kamprath *et al.* (1958) observed no consistent differences in soil carbon and nitrogen between hairy vetch and oats if adequate fertilizer nitrogen was supplied for good crop growth. Hargrove (1986) found that rye covers resulted in just as much soil nitrogen accumulation as crimson clover, and at least as much soil carbon, even though the nitrogen content of the crop residue of the former is less than a quarter of the latter. This indicates that the retention of both organic carbon and organic nitrogen in the soil is independent of crop residue. However, hairy vetch, which contained slightly more carbon and nitrogen, than crimson clover, resulted in significantly greater soil carbon and nitrogen. Beale *et al.* (1955) observed more soil nitrogen after 10 years with minimum tillage cover crops than moldboard plowed cover crops. Such observations may reflect greater loss of soil organic matter with greater tillage, and not relatively less effect of cover crop residue on soil organic matter in plowed systems than minimum tillage systems. Utomo (1986) in Kentucky observed that there was a greater difference between organic carbon in hairy vetch and winter fallow treatments for no-tillage than for conventional tillage. Vetch had a small effect in conventional tillage, but a significant effect in no-tillage.

2.7.2. Soil aggregation and aggregate stability

Many of the effects of legumes on soil physical properties are exemplified by their effect upon soil aggregation and aggregate stability. Tisdall and Oades (1982) indicated that soil aggregation is influenced by three types of agents: (1) transitory materials, such as polysaccharides, that are usually products of microbial activity, (2) temporary effects through binding action of fungal hyphae and plant roots, and (3) persistent effects resulting from the action of polyvalent cations and strongly adsorbed organic polymers. They concluded that total quantity of soil organic matter present has a major influence on aggregation and aggregate stability. Therefore, use of legume cover crops in a cropping system could affect aggregation through changes in soil organic matter content and microbial activity. Because of the relative narrow C:N ratio of legume residues, microbial biomass may be temporarily increased, increasing aggregation due to hyphal binding. On the other hand, grass roots are usually more fibrous than those of legumes, hence aggregation resulting from root binding may be greater under grasses than under legumes. Strickling (1950) observed these same effects of cropping systems on soil organic matter and aggregation. In general, the water-stable aggregates (greater than 0.25 mm) were closely related to soil organic matter content. Aggregation in soil in continuous bluegrass was much greater than that for any other treatments. For cultivated soils, aggregation was greatest for a rotation containing two years of alfalfa-grass hay. Continuous ryegrass was intermediate and continuous corn was very low in aggregation; however, lowest values were reported for corn and soybean hay.

2.7.3. Soil Water and Temperature Regimes

Legumes in crop rotations have some effects on the soil water and temperature regimes. Legume cover crops lower soil temperature by acting as mulch (live or dead). The insulating effect of legume residues on the soil surface is no different from the nonlegume residues. Utomo *et al.* (1987) found that soil temperatures under no-till hairy vetch residue and corn stover were respectively 1.5° and 1.2°C lower than for clean, cultivated corn. The main effect of legumes on reducing temperature and potential evaporation rates results from the fact that legume cropping systems often provide more ground cover than occurs under normal cultivation. However, a living mulch of legumes reduces soil water content, thereby reducing the heat sink in the soil.

The effects of legume cover crops on soil water were discussed by Hargrove and Frye (1987). They found that when used as a cover crop, legumes utilized stored soil water during the noncrop period of the grain crop with which the cover crop was associated. This can have a positive, negative, or no effect on the following grain crop. In poorly drained soils, when excessive precipitation was received during the noncrop period, use of legume cover crop reduced soil water content, thereby reducing the adverse effect of the excess water on crop growth. The cover crop also reduced the likelihood of nutrients and pesticides leaching into ground water. For drier climates, however, legume cover crops can reduce soil water content to such an extent that the following grain crops suffer. For example, Koerner and Power (1987) showed that under Eastern Nebraska conditions hairy vetch, if not properly managed as a winter cover crop, reduced soil water storage and increased competition, reducing yield of the following corn crop.

In the wheat growing regions of the northwestern United States, various legumes are frequently grown in different types of rotation with winter wheat. Elliot et al. (1987) showed water storage at wheat seeding time varied with the legume used. Water storage was decreased most with a spring pea rotation, and least with red clover or hairy vetch in rotation. Legume dry matter production and amount of nitrogen fixed by the legume generally increased, except for spring pea. These results indicated that legume species differ significantly in their water requirements as well as in nitrogen fixation.

In drier regions, use of legumes in crop rotations is often restricted because of water availability. Haas *et al.* (1976) showed that deep rooted legumes such as alfalfa or sweet clover, when grown in rotation with wheat in North Dakota, frequently depleted soil water reserves to 2 m or greater. As a consequence, the following grain crops had no subsoil reserve of soil water, and yields for the first several years after plowing up the sod suffered accordingly. Brown (1964) came to a similar conclusion after summarizing long term data from legume based rotations at a number of locations throughout the north American Great Plains.

2.8. Effect of underseeding on socio-economic aspects

Although increased productivity is one of the major advantages of mixed cropping, there are equally important socio-economic considerations which induce farmers to adopt these cropping systems in preference to sole cropping. Norman (1977) and Francis and Sanders (1987) reported that mixing maize with legumes gave comparable returns to sole crops.

The crop mixtures are also considered as a risk minimization mechanism. Rao and Willey (1980) studied stability of mixtures as compared to sole crops by determining the probability of crop failure. In no case did mixtures show a higher probability of a return below the sole crop mean. In northern Guinea, savanna mixtures showed a much reduced risk of crop failure. Jodha (1977) reported that intercropping is predominant in low rainfall/high risk areas. Similar observation were made by Dichel (1981) in Southern

Guinea, where risk of crop failure is high due to lack of rain. Farmers there grow mixtures of drought resistant crops in order to have some yield in dry years.

Another important economic factor that has influenced perpetuation of crop mixture is diversified and continuous food supply over prolonged periods. Steiner (1984) considered this as important in humid areas, where storage of harvested produce is difficult.

In south coastal British Columbia as with other regions of a similar climate, the heavy precipitation can leach most of the residual nitrogen after harvest. The use of cover crops as nitrogen scavengers can alleviate the problem particularly if they follow a crop associated with moderate levels of nitrogen mineralization after harvest, such as early potatoes, beans and peas (Temple, personal communication). Clearly there is a need to develop innovative methods to increase organic matter inputs in order to increase crop yields and reduce agrochemical costs. Successful practices must be easily incorporated into the current cropping systems and compatible with profitable farming.

Chapter Three

MATERIALS AND METHODS

3.1. Site Description

The two year (1992-1993) and (1993-1994) field study was carried out in Delta Municipality, approximately 30 km south of Vancouver, British Columbia in cooperation with John Malenstyn, Jowkema farms. Delta was chosen as the location for the study because of its proximity to UBC and the availability of a farmer willing to cooperate in the study. Sweet corn variety 'Jubilee', the crop chosen for the study, is grown in the region mainly for canning and freezing. The soil classified as a Crescent silty clay loam, Orthic Gleysol, whose parent material is deltaic alluvial deposits (Luttmerding, 1981). The climatic data was provided by Environment Canada, Delta Ladner Weather Station.

Drainage is the major problem in the study area. The 1992 experiment was conducted on a field with surface drainage to a ditch, while the 1993 experiment was conducted on a site with subsurface drains. The preceding crop on the former site in 1991 was potato and on the latter site peas in 1992.

3.2. Experimental layout

The experiment was conducted as a split plot, randomized complete block design with 12 treatment combinations and four replicates. Main plots were two dates of cover crop planting, shortly after emergence or sidedressing time (~30 cm), and subplots were comprised of an unseeded control plus five different cover crops seeded under sweet corn. Main plots measured 8 m x 48 m and sub-plots 8 m x 8 m.

During the 1992-1993 growing season, the dates for the early and late underseeding of cover crop were 29/5/92 and 22/6/92, whereas during the 1993-1994 growing season, the respective dates were 24/6/1993 and 20/7/1993 respectively.

Two weeks before planting, a preemergence herbicide vernolate (surpass) was applied at a rate of 5.5 l/ha. Planting of sweet corn was done by the farmer at the of 60,000 plants/ha using a row width of 1.0 m. The seeding rates of cover crops used in both years were: crimson clover (12 kg/ha), red clover (12 kg/ha), alsike clover (7 kg/ha), annual ryegrass (20 kg/ha) and fall rye (80 kg/ha). The red clover, annual ryegrass and fall rye cultivors were Pacific double cut, aubade and Danko, respectively, while common seed was used for crimson and alsike clovers. Red clover and alsike clover seeds were inoculated with the appropriate *Rhizobium* just before planting and broadcast seeded by hand. In the 1992-1993 growing season, urea was side banded by hand alone the corn rows at the rate of 104 kg N ha^{-1} and cover crops were broadcast by hand. In the 1993-1994 growing season, the experiment was repeated and ammonium nitrate applied at the rate of 102 kg N ha^{-1} when the sweet corn was 30 cm in height.

3.3. Field Sampling

Weed identification was done in July and August by locating randomly within each plot. The weeds were clipped at ground level and separated into grasses and broad leaves for identification. During the study, the four centre rows of the experimental plots were hand weeded. Soil samples for site characterization were collected just prior to the first date of underseeding cover crops in sweet corn. Six composite soil cores were taken randomly within each plot at one depth (0-20 cm) using an Oakfield 2.5 cm diameter sampling probe. The soil samples were placed in labelled polythene bags and transferred in a cooler to the laboratory where they were stored in refrigerators at 4^0 C. NH_4 and NO_3-N were extracted within 24 hours. Four bulk density samples were taken in each site at the time soils were sampled for chemical characterization. A cylindrical core (7.3 cm diameter, 7.6 height) was inserted vertically on the soil surface. The core was then dug out using a spade, the excessive soil was trimmed. The bulk density was determined by oven drying the samples at 105^0C for 48 hours.

The sweet corn ear leaves were sampled immediately after silking, (R stage) for analysis of the nitrogen status. Twenty ear leaves were randomly selected from four center rows of each plot on 30/7/1992 and 27/8/1993. During the growing season, establishment of cover crops was assessed by two methods. The first was through field observation, which involved rating the cover crops on the following scale: F (fast), S (slow), M (medium), (Temple, 1991). The second assessment was percentage of ground cover estimated by stretching a string with 25 points along the inner six rows (Laften *et al.*, 1981).

3.4. Crop harvest

Harvest of the experimental plots was done by hand, using machetes. Samples were taken from 1 meter lengths of the two centre rows of each plot. Fresh weights of stalks and cobs were obtained. Following weighing in the field, three stalks were randomly subsampled from each plot for dry weight determinations of both stalks and cobs after being dried at 65°C.

About two weeks before harvesting, the sweet corn plants were topped by a contractor in order to facilitate combine harvesting. The process of topping involved the removal of the top 50 cm of the plants and that portion of the crop was not included in the total stalk weight recorded at harvests on 28/9/92 and 27/9/93.

Cover crops were sampled randomly from a 0.5 m^2 quadrat on every plot by clipping at ground level. Assessments of cover crops were done at two different times in spring 1993 (1992-1993 growing season) and fall 1993 (1993-1994 growing season). Spring cover crop sampling was done on 3 March 1993 because the soil was too wet on November 1992 to sample without serious disturbance. However, in November 1993 the soil was not wet. The sample were taken on 2 November 1993, before the field had been cultivated. A 1994 spring assessment was not made because the farmer inadvertently cultivated the site before it could be done.

3.5. Laboratory methods

3.5.1. Plant analysis

Sweet corn and cover crop plant samples were taken to the Totem field laboratory for drying at 65°C in a forced air oven for 72 hours. After dry weight determination, cover crop plant material was ground using a stainless steel Wiley mill to pass a 2 mm sieve. Samples of 0.5 g were digested following the procedure outlined by Parkinson and Allen (1975) and total N concentration was determined colorimetrically using a Technicon Autoanalyzer II (Technicon, 1974).

3.5.2. Soil analysis

Soil samples were mixed in their respective polythene bags before extraction. Soil water contents of the samples were determined by oven drying a 30 g subsample of soil at 105^{0}C for 24 hours and reweighing (Gardner, 1986). Bulk density samples were treated in a similar manner.

Field moist 10 g samples were extracted for NH_4-N and $N0_3$-N by shaking with 100 mL of 2 M KCl four one hour (Keeney and Nelson, 1982). After settling, the supernatant was filtered through Whatman No.42 filter paper. Two drops of toluene were added to extracts stored in 60 mL bottles at 2 ^{0}C awaiting analysis. NH_4-N and NO_3-N concentrations were determined colorimetrically using a Technicon Autoanalyzer II, coupled with a cadmium reduction column for $N0_3$-N (Technicon, 1977). The soil samples used to describe the study site (Appendix 1) were extracted using the Kelowna extractant (0.015 M NH_4F+0.25M HOAC) and available nutrients in the soil determined by procedures outlined by Gough (1991).

3.6. Statistical analysis

Data from each growing season were subjected to analysis of variance following procedures outlined by Little and Hills (1978) using a computer program Proc. GLM (SAS Institute, 1988). Orthogonal contrasts were used to partition main effects and interaction sums of squares into single degree of freedom contrasts. Statistical significance was determined at the probability level of 5%. Duncan's multiple range test was used to compare means following a significant F-value.

Chapter Four

RESULTS AND DISCUSSION

4.1. Weather and soil conditions

Results of soil nutrient analysis conducted on samples taken from the two experimental sites are presented in (Appendix 1) and are interpreted by using the soil interpretations recommended by the British Columbia Ministry of Agriculture (Gough, 1991). Soil pH is relatively low. Soil organic matter and total nitrogen concentrations at both sites were low. The concentrations of phosphorus, potassium and magnesium were very high. The bulk density of the soil 0-20 cm layer was found to be about 1.2 Mg/m^3.

Mean monthly air temperatures (°C) and precipitation (mm) during 1992-1993 and 1993-1994 seasons are presented in Appendices 2 and 3, respectively.

The average precipitation from 1951-1980 was 1133 mm (Appendix 2,3). In the 1992 growing season, sweet corn was planted in May. Cover crops were underseeded in May (Early) and June (Late). The amounts of precipitation in the months of May and June 1992 were 15.8 and 96.4 mm, respectively. May precipitation was lower than the average of 1951-1980 (30 years) which was 51.6 mm, while June precipitation was higher than the 30 year average of 45.2 mm. In the winter months (December-March) of 1992, average precipitation was lower than average of 30 years.

In 1993, sweet corn was planted in June. Cover crops were underseeded in June

(Early) and July (Late). The amount of precipitation in the months of June and July 1993 were 72.2 and 34.2 mm, respectively. June precipitation was higher than the 30 year average (45.2 mm). July precipitation close to the long average term of 32.0 mm. In the fall of 1993, average precipitation was lower than that of 30 year average.

4.2. 1992-1993 and 1993 and 1994 Experimental Results

Analysis of variance tables for soil, sweet corn and cover crop variables are presented in Appendices 4-19.

4.2.1. Cob yield of sweet corn

Fresh cob yield of sweet corn is the most important attribute that determines its economic return. The data in Table 1 show that date of planting of cover crops in sweet corn had no significant effect on fresh or dry cob yield. The data in Table 2 indicate that the five different cover crops underseeded in sweet corn in both growing seasons did not have any significant effect on the fresh yield of the sweet corn.

The data for dry cob yield of sweet corn in both 1992-1993 and 1993-1994 growing seasons also show that there were no statistically significant differences among the five cover crops (Table 2).

Table 1. Effects of date of planting cover crops on fresh and dry cob yield of sweet corn in 1992-1993 and 1993-1994 growing seasons.

Treatments	Fresh cob yield (t/ha)		Dry cob yield (t/ha)	
	1992/93	1993/94	1992/93	1993/94
Early planting	14.5[a]	14.2[a]	3.3[a]	3.1[a]
Late planting	16.3[a]	17.9[a]	3.5[a]	3.7[a]
C.V.(%)	14.5	12.9	21.1	18.0

Note: means within a column with the same superscript are not significantly different ($P > 0.05$).

Table 2. Fresh and dry cob yield of sweet corn underseeded with five cover crops in 1992/93 and 1993/94 growing seasons.

Treatments	Fresh cob yield (t/ha)		Dry cob yield (t/ha)	
	1992/93	1993/94	1992/93	1993/94
Unseeded	15.6[a]	16.6[a]	3.5[a]	3.4[a]
Crimson clover	15.5[a]	15.5[a]	3.3[a]	3.3[a]
Alsike clover	14.6[a]	15.9[a]	3.2[a]	3.3[a]
Red clover	15.6[a]	17.3[a]	3.3[a]	3.1[a]
Fall rye	15.1[a]	14.8[a]	3.1[a]	3.4[a]
Annual ryegrass	15.8[a]	16.4[a]	3.8[a]	3.8[a]
C.V.(%)	14.5	12.9	21.1	18.0

Note: means within a column with the same superscript are not significantly different ($P>0.05$).

The results presented above on fresh and dry cob yield of sweet corn clearly point out that legume and grass cover crops underseeded with sweet corn had no effect on sweet corn yield. This agrees with findings from other researchers working with cover crops underseeded or overseeded in corn. For example, Palada *et al.* (1982) reported that there was no reduction in grain yields in corn which was overseeded with legumes. Nanni and Baldwin (1987) found that different clover species underseeded in corn did not have an effect on corn grain yield. Mt. Pleasant (1982) noted that corn yields were not affected by red clover intercrop during the establishment provided that corn was 0.15 to 0.30 m in height at the time of cover crop establishment. Wall *et al.* (1991) reported that intercropping silage corn with red clover can provide soil erosion protection without significant effect on silage corn yields.

4.2.2. Stalk yield of sweet corn

Early planting of the cover crops significantly reduced the fresh or dry stalk yield of sweet corn (Table 3). Early planted cover crops may have competed with sweet corn for the mineral nutrients required for the stalk formation, while this may not be the case with the late planted cover crops. Ear-leaf N concentration was less in corn with early underseeding as compared to late underseeding (Table 5). This is because, establishment of the early planted cover crops was closer to the vegetative establishment of the sweet corn.

Table 4 indicates that the type of underseeded cover crop had no effect on both fresh and dry sweet corn stalk yield in the 1992-1993 growing season. In the 1993-1994 growing season however, the effect of red clover on fresh stalk yield was significantly higher than fall rye and annual ryegrass.

During the 1993/1994 growing season, the red clover was affected by powdery mildew disease in August and there was no biomass harvested. The above ground biomass, which would have otherwise persisted until winter returned back to the soil during the corn growing season. This may have supplied some nutrients particularly nitrogen to the soil in the plots underseeded with red clover. Consequently, the supplied nutrients could have been taken up by the sweet corn. This could possibly explain the higher sweet corn stalk yield in the red clover treatment as compared to the two non-legumes and crimson clover.

Table 3. Effects of date of planting cover crops on fresh and dry stalk yield of sweet corn in 1992-1993 and 1993-1994 growing seasons.

Treatments	Fresh stalk yield (t/ha)		Dry stalk yield (t/ha)	
	1992/93	1993/94	1992/93	1993/94
Early planting	42.4[b]	29.9[b]	6.6[b]	5.1[b]
Late planting	50.8[a]	41.2[a]	7.6[a]	6.2[a]
C.V.(%)	13.7	11.9	12.8	12.6

Note: means within a column with the same superscript are not significantly different ($P > 0.05$).

Table 4. Fresh and dry stalk yield of sweet corn underseeded with five cover crops in 1992/93 and 1993/94 growing seasons.

Treatments	Fresh stalk yield (t/ha)		Dry stalk yield (t/ha)	
	1992/93	1993/94	1992/93	1993/94
Unseeded	43.7[a]	36.5[ab]	6.7[a]	5.8[ab]
Crimson clover	47.6[a]	34.2[b]	7.4[a]	5.5[b]
Alsike clover	46.8[a]	35.6[ab]	7.3[a]	5.7[ab]
Red clover	45.2[a]	39.9[a]	6.8[a]	6.3[a]
Fall rye	47.0[a]	33.3[b]	7.2[a]	5.42[b]
Annual ryegrass	49.2[a]	33.9[b]	7.3[a]	5.3[a]
C.V.(%)	13.7	11.9	12.8	12.6

Note: means within a column with the same superscript are not significantly different ($P > 0.05$).

4.2.3. Ear leaf nitrogen of sweet corn

From Table 5, there was no significant difference in the ear leaf N concentration in the sweet corn early and late underseeded with the cover crops for the 1992-1993 growing season. In the 1993-1994 growing season the ear leaf N concentration of the sweet corn early underseeded was significantly lower than the ear leaf N concentration in the sweet corn late underseeded. This difference may be due to the fact that early planting of cover crops was closer to the vegetative establishment of the sweet corn and hence competition for N.

From Table 6, it can be observed that there was no difference due to cover crop in the ear leaf N concentration in the 1992-1993 growing season. It can also be seen that the ear leaf nitrogen concentrations were below the critical nitrogen range (28-35 g/kg) for maxiumn yield (Tisdale *et al.*1993). In the 1992-1993 growing season, the preceding crop was potato which may have depleted the N from the soil. In the 1993-1994 growing season, the sweet corn/fall rye had the lowest ear leaf N concentration. The reason could be possibly be due to the effect of the preceding crop (peas) planted at the experimental site prior to the 1993-1994 growing season. Overall 1993-94 ear leaf N concentration appeared to be higher than in 1992-93. Since peas are a legume there is a possibility that pea residue provided more N to the subsequent crop in the 1993-1994 growing season.

Table 5. Effects of date of planting cover crops on ear leaf nitrogen concentration of sweet corn in 1992-1993 and 1993-1994 growing seasons.

Treatments	Ear leaf nitrogen (g/kg)	
	1992/93	1993/94
Early planting	22[a]	23[a]
Late planting	21[a]	28[b]
C.V.(%)	11.9	5.9

Note: means within a column with the same superscript are not significantly different ($P > 0.05$).

Table 6. Ear leaf nitrogen concentration of sweet corn underseeded with five cover crops in 1992/93 and 1993/94 growing seasons.

	Ear leaf nitrogen (g/kg)	
Treatments	1992/93	1993/94
Unseeded	21[a]	26[a]
Crimson clover	21[a]	25[ab]
Alsike clover	22[a]	26[a]
Red clover	21[a]	26[a]
Fall rye	22[a]	24[b]
Annual ryegrass	21[a]	26[a]
C.V.(%)	11.9	5.9

Note: means within a column with the same superscript are not significantly different ($P>0.05$)

4.2.4. Dry matter production, nitrogen concentration and nitrogen uptake of cover crops.

4.2.4.1. Effect of date of planting

In the 1992-1993 growing season the fall rye did not establish and crimson clover was grazed by migratory birds. There was no difference in 1992-1993 between early and late planting of cover crops in sweet corn on cover crop dry matter production, nitrogen concentration, and nitrogen uptake (Table 7).

From the foregoing, it can be seen that there was more precipitation at planting (cover crops) time during 1993-1994 than 1992-1993. This might have resulted in better germinations for the 1993-1994 cover crops than the 1992-1993 crops; resulting in slightly higher yields for the 1993-1994 cover crops than the 1992-1993 cover crops, as can be seen in Table 7 and 8.

In 1993-1994, the effects of early and late planting of cover crops in sweet corn, dry matter production and nitrogen concentration were not significant (Table 8). However, nitrogen uptake by cover crops in early planting was 19% higher than late planting.

Table 7. Cover crop yield and nitrogen concentration and uptake at two planting dates (29 May 1992 and 22 June 1992) for 1992-1993 growing seasons sampled on 3 March 1993.

Treatments	Dry Matter (t/ha)	N Conc. g/kg	N Uptake (kg/ha)
Early planting	2.3[a]	25[a]	59.2[a]
Late planting	2.2[a]	25[a]	55.7[a]
C.V.(%)	20.2	9.5	15.7
Alsike clover	2.1[b]	32[a]	66.6[b]
Red clover	2.7 [a]	31[a]	83.6[a]
Annual Ryegrass	2.0[b]	11[b]	22.1[c]
C.V.(%)	20.2	9.5	15.7

Note: means within column with the same superscript are not significantly different($P > 0.05$).

4.2.2.4. Cover crop dry matter production, nitrogen concentration and nitrogen uptake.

In the 1992-1993 growing season, red clover produced the highest dry matter yield by spring 1993 (Table 7). It was found to have 28 and 35% more dry matter than alsike and annual ryegrass respectively. Nitrogen concentrations in alsike and red clover were 190 and 180% higher than in annual ryegrass. Red clover and alsike clover N concentrations were not significantly different. Nitrogen contents in red clover and alsike clovers were significantly higher than annual ryegrass. This may be due to of the ability of legumes to fix nitrogen. Red clover had the highest nitrogen uptake. It was found to have 26% and 278% more nitrogen than alsike and annual ryegrass respectively. Both biomass production and nitrogen concentration of the cover crops obtained in this study compare very well with those obtained in the screening trials of the cover crops conducted by Temple (1992) and Bomke *et al.*(1993).

During the first year of the study, the main problem encountered was how to control weeds successfully and get the cover crops established. Weeds found in the experiment in both years were redroot pigweed *(Amaranthus retroflexus),* lambsquarter *(Chenopodium album),* common chickweed *(Stellaria media),* common groundsel *(Senecio vulgaris),* common pepper-grass *(Lepidium densiflorium),* shepherd's purse *(Capsella bursa-pastoris),* and corn spurry *(Spergula arvensis).* Where weeds were successfully controlled, the cover crops did not compete with nor reduce the yields of the sweet corn. Fall rye did not establish well in 1992-1993 and produced virtually no biomass in fall or spring, while crimson clover did well in the fall, but could not survive wet overwinter conditions on the site.

Dry matter production of crimson clover in the fall (November) following the 1993 growing season was significantly higher than annual ryegrass but not alsike clover or fall rye (Table 8). Data on dry matter of red clover was not included in this analysis, because the plants were infected by powdery mildew and there was no biomass to be harvested. Crimson clover produced more dry matter than annual ryegrass. Crimson and alsike clovers N content were significantly higher than grasses. The N uptake by crimson clover was 29, 87 and 139% higher than that by alsike, fall rye and annual ryegrass respectively.

Table 8. Cover crop yield and nitrogen concentration and uptake at two planting dates (24 June 1993 and 20 July 1993) for 1993-1994 growing seasons sampled on 2 November 1993.

Combination Treatments	Dry Matter (t/ha)	N Conc. (g/kg)	N Uptake (kg/ha)
Early planting	2.9[a]	21[a]	61.2[a]
Late planting	2.5[a]	19[a]	49.3[b]
C.V.(%)	17.5	14.1	25.0
Crimson clover	3.1[a]	27[a]	81.1[a]
Alsike clover	2.6[ab]	24[a]	62.7[b]
Fall rye	2.7[ab]	16[b]	43.4[c]
Annual ryegrass	2.5[b]	14[b]	33.9[c]
C.V.(%)	17.5	14.1	25.0

Note: means within a column with the same superscript are not significantly different ($P>0.05$).

4.2.5. Ground Cover (percent cover)

Some cash crops like sweet corn in Delta are harvested late in the growing season. It is therefore advantageous to plant cover crops as relay crops so that they can establish and become beneficial to the soil. Some cover crops, e.g. clover, establish too slowly for late fall seeding. At time of harvesting, the farmers are so busy that they are not able to plant the cover crops. Many of the cover crops when planted late, after the third week of September, are subjected to intense grazing by migratory birds. Underseeding cover crops may be more effective as far as soil conservation is concerned than planting cover crops after the cash crops has been harvested.

Winter annual cover crops provide plant cover and root mass during winter and spring, which effectively reduce the soil erosion during wet winter seasons. Table 9 shows both the mode of establishment and percent soil cover of the five different cover crops underseeded in sweet corn. In the 1992-1993 growing season, annual ryegrass had the highest percent cover. It was found to be 10 and 40 % more than alsike and red clover respectively. In the 1993-1994 growing season, annual ryegrass had the highest percent cover. It was found to be 20, 20 and 40 % more than fall rye, alsike and crimson clover respectively.

Table 9. Establishment and percent cover assessed in spring 1993 for year and fall 1993 for year 2 of different cover crops in sweet corn.

Treatments	Establishment	% Cover
1992-1993		
Crimson clover	M	*
Alsike clover	S	80
Red clover	M	50
Fall rye	F	*
Annual ryegrass	F	90
1993-1994		
Crimson clover	M	60
Alsike clover	S	80
Red clover	M	*
Fall rye	F	80
Annual ryegrass	F	100

* = No stand   F (fast), M (medium), S (slow)

Chapter Five

CONCLUSIONS

1. The study revealed that the fresh and dry cob yields of sweet corn were not affected by date of seeding nor type of cover crop underseeded.

2. Early underseeded cover crops appear to reduce corn stalk yields and compete with sweet corn for nitrogen. However, late underseeding of cover crops does not compete for nitrogen. This study has shown that late planting of cover crops in sweet corn increases ear leaf nitrogen concentration relative to early seeding.

3. In both experiments annual ryegrass and alsike clover were promising to use as soil cover during winter. Their percent covers were higher than that of other cover crops. This is may due to the different types of growth habit.

RECOMMENDATIONS

The findings reported here emerged from an experiment which was conducted for two seasons at two locations. In order to make definite conclusions, it would be essential to repeat these investigations over a number of seasons at different locations. This programme should include different farms in Fraser Valley in order to have more realistic information under actual farm situations.

Nonetheless some of the salient implications of the present study with regard to future work are indicated below:

1. It is suggested that a study on the residual effect of underseeded cover crops on nitrogen uptake of the subsequent crops should be made.

2. Studies should be emphasized on weed control in underseeding cover crop research since weeds were a major problem during the present experiments.

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Appendix 1: Some chemical properties of composite soil samples taken from plots 29 May 1992 and 24 June 1993.

Soil Parameter	29/May/1992 0-20 depth (cm)	24/June/1993 0-20 depth (cm)
pH (H_2O)	5.5	5.9
Organic matter (%)	2.6	2.8
NH_4-N (mg/kg)	0.2	0.4
$N0_3$-N (mg/kg)	0.9	1.6
Total N (%)	0.1	0.1
Phosphorus (mg/kg)	97.0	135.0
Potassium (mg/kg)	270.0	448.0
Magnesium (mg/kg)	223.8	173.8
Calcium (mg/kg)	1675.0	1750.0
Sodium (mg/kg)	28.8	14.8

Appendix 2: Mean monthly air temperatures (^0C) and precipitation (mm) during the 1992-1993 growing season compared with the mean data for the 1951-1980 period.

	Precipitation (mm)			Temperature (^0C)		
Month	1951-1980	1992	Deviation from mean	1951-1980	1992	Deviation from mean
January	153.8	281.4	16.0	2.5	5.8	3.3
February	114.7	87.8	-26.9	4.6	6.6	2.0
March	101.0	25.9	-75.1	5.8	8.5	2.7
April	59.6	126.2	66.6	8.8	10.6	1.8
May	51.6	15.8	-35.8	12.2	13.6	1.4
June	45.2	96.4	51.2	15.1	17.2	2.1
July	32.0	42.0	10.0	17.3	18.4	1.1
August	41.1	23.2	-17.9	17.1	17.8	0.7
September	67.1	48.2	-18.9	14.2	13.9	0.3
October	114.0	109.1	-4.9	10.0	11.3	1.3
November	150.1	168.3	18.2	5.9	6.4	0.5
December	182.4	117.8	-64.6	3.9	1.9	2.0

Appendix 3: Mean monthly air temperatures (^0C) and precipitation (mm) during the 1993-1994 growing season compared with the mean data for the 1951-1980 period.

	Precipitation (mm)			Temperature(^0C)		
Month	1951-1980	1993	Deviation from mean	1951-1980	1993	Deviation from mean
January	153.8	103.4	50.4	2.5	-0.4	2.1
February	114.7	11.4	-103.3	4.6	3.5	-1.1
March	101.0	115.2	14.2	5.8	7.4	1.6
April	59.6	126.9	67.3	8.8	10.0	1.2
May	51.6	100.8	49.2	12.2	14.7	2.5
June	45.2	72.2	27.0	15.1	15.9	0.8
July	32.0	34.3	2.3	17.3	16.4	-0.9
August	41.1	19.0	-22.1	17.1	17.6	0.5
September	67.1	2.1	-65.0	14.2	14.8	0.6
October	114.0	73.1	-40.9	10.0	11.4	1.4
November	150.1	6.1	-87.0	5.9	4.5	-1.4
December	182.4	162.3	-20.1	3.9	4.5	0.6

Appendix 4: Analysis of variance for fresh cob yield of sweet corn underseeded with five different cover crops in 1992 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	23.520	2.35	0.252
Date	1	38.880	3.88	0.143
MP error (a)	3	10.011		
Cover crop	5	1.672	0.34	0.887
1 vs 2+3+4+5+6	1	0.353	0.07	0.792
2+3+5 vs 4+6	1	0.641	0.13	0.722
2 vs 3+5	1	0.880	0.18	0.677
3 vs 5	1	4.000	0.80	0.377
4 vs 6	1	2.481	0.50	0.485
Date*cover crop	5	4.559	0.92	0.483
(d1/d2)*(c1/23456)	1	0.254	0.05	0.823
(d1/d2)*(c235/46)	1	0.345	0.07	0.794
(d1/d2)*(c2/35)	1	0.255	0.05	0.822
(d1/d2)*(c3/5)	1	20.250	4.08	0.053
(d1/d2)*(c4/6)	1	1.690	0.34	0.564
SP error (b)	30	4.969		
Corrected Total	47	114.760		

Appendix 5. Analysis of variance for fresh cob yield of sweet corn underseeded with five different cover crops in 1993 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	16.067	3.99	0.1438
Date	1	171.839	42.66	0.007
MP error (a)	3	4.028		
Cover crop	5	6.075	1.41	0.248
5 vs 1+2+3+4+6	1	2.436	0.57	0.458
1+2+3 vs 4+6	1	3.760	0.87	0.357
1 vs 2+3	1	7.130	1.66	0.208
2 vs 3	1	7.563	1.76	0.195
4 vs 6	1	9.486	2.21	0.148
Date*cover crop	5	2.415	0.56	0.729
(d1/d2)*(c5/12346)	1	8.694	2.02	0.165
(d1/d2)*(c123/46)	1	2.197	0.51	0.480
(d1/d2)*(c1/23)	1	0.005	0.00	0.973
(d1/d2)*(c2/3)	1	1.000	0.23	0.633
(d1/d2)*(c4/6)	1	0.176	0.04	0.841
SP error (b)	30	4.301		
Corrected Total	47	247.172		

Appendix 6: Analysis of variance for dry cob yield of sweet corn underseeded with five different cover crops in 1992 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	0.3460	0.81	0.567
Date	1	0.5830	1.36	0.327
MP error (a)	3	0.428		
Cover crop	5	0.455	0.90	0.494
1 vs 2+3+4+5+6	1	0.118	0.23	0.632
2+3+5 vs 4+6	1	0.346	0.68	0.415
2 vs 3+5	1	0.002	0.00	0.955
3 vs 5	1	0.047	0.09	0.762
4 vs 6	1	1.762	3.48	0.072
Date*cover crop	5	0.425	0.84	0.532
(d1/d2)*(c1/23456)	1	0.029	0.06	0.813
(d1/d2)*(c235/46)	1	0.192	0.38	0.524
(d1/d2)*(c2/35)	1	0.068	0.13	0.716
(d1/d2)*(c3/5)	1	1.672	3.30	0.079
(d1/d2)*(c4/6)	1	0.166	0.33	0.571
SP error (b)	30	0.506		
Corrected Total	47	7.144		

Appendix 7. Analysis of variance for dry cob yield of sweet corn underseeded with five different cover crops in 1993 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	1.631	2.46	0.239
Date	1	4.774	7.21	0.075
MP error (a)	3	0.662		
Cover crop	5	0.360	1.41	0.453
5 vs 1+2+3+4+6	1	0.029	0.97	0.782
1+2+3 vs 4+6	1	1.108	0.08	0.094
1 vs 2+3	1	0.011	2.98	0.867
2 vs 3	1	0.124	0.03	0.568
4 vs 6	1	0.527	0.33	0.243
Date*cover crop	5	0.533	1.42	0.240
(d1/d2)*(c5/12346)	1	0.305	1.44	0.372
(d1/d2)*(c123/46)	1	0.250	0.82	0.419
(d1/d2)*(c1/23)	1	0.019	0.67	0.823
(d1/d2)*(c2/3)	1	0.869	0.05	0.137
(d1/d2)*(c4/6)	1	1.224	2.34	0.076
SP error (b)	30	0.372		
Corrected Total	47	13.627		

Appendix 8: Analysis of variance for fresh stalk yield of sweet corn underseeded with five different cover crops in 1992 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	169.966	4.25	0.133
Date	1	846.216	21.16	0.019
MP error (a)	3	39.993		
Cover crop	5	29.813	0.73	0.607
1 vs 2+3+4+5+6	1	82.204	2.01	0.166
2+3+5 vs 4+6	1	24.691	0.60	0.443
2 vs 3+5	1	12.886	0.32	0.579
3 vs 5	1	9.970	0.24	0.625
4 vs 6	1	19.316	0.47	0.497
Date*cover crop	5	44.138	1.08	0.391
(d1/d2)*(c1/23456)	1	60.964	1.49	0.232
(d1/d2)*(c235/46)	1	26.017	0.64	0.431
(d1/d2)*(c2/35)	1	3.451	0.08	0.773
(d1/d2)*(c3/5)	1	130.131	3.18	0.085
(d1/d2)*(c4/6)	1	0.126	0.00	0.956
SP error (b)	30	40.867		
Corrected Total	47	1540.749		

Appendix 9. Analysis of variance for fresh stalk yield underseeded with different cover crops in 1993 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	72.744	34.49	0.008
Date	1	1521.564	721.48	0.000
MP error (a)	3	2.109		
Cover crop	5	46.848	2.61	0.045
5 vs 1+2+3+4+6	1	7.975	0.44	0.510
1+2+3 vs 4+6	1	86.100	4.79	0.037
1 vs 2+3	1	66.505	3.70	0.064
2 vs 3	1	72.750	4.02	0.054
4 vs 6	1	1.410	0.08	0.781
Date*cover crop	5	11.804	0.66	0.658
(d1/d2)*(c5/12346)	1	4.888	0.27	0.606
(d1/d2)*(c123/46)	1	1.240	0.07	0.795
(d1/d2)*(c1/23)	1	31.688	1.76	0.194
(d1/d2)*(c2/3)	1	19.141	1.07	0.310
(d1/d2)*(c4/6)	1	2.066	0.12	0.737
SP error (b)	30	17.959		
Corrected Total	47	1966.291		

Appendix 10: Analysis of variance for dry stalk yield of sweet corn underseeded with five different cover crops in 1992 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	0.633	4.25	0.133
Date	1	10.056	21.16	0.019
MP error (a)	3	0.489		
Cover crop	5	0.656	0.73	0.607
1 vs 2+3+4+5+6	1	1.822	2.01	0.166
2+3+5 vs 4+6	1	0.063	0.60	0.443
2 vs 3+5	1	0.502	0.32	0.579
3 vs 5	1	0.797	0.24	0.625
4 vs 6	1	0.096	0.47	0.497
Date*cover crop	5	1.049	1.08	0.391
(d1/d2)*(c1/23456)	1	1.468	1.49	0.232
(d1/d2)*(c235/46)	1	1.126	0.64	0.431
(d1/d2)*(c2/35)	1	0.049	0.08	0.773
(d1/d2)*(c3/5)	1	1.995	3.18	0.085
(d1/d2)*(c4/6)	1	0.608	0.00	0.956
SP error (b)	30	0.830		
Corrected Total	47	22.239		

Appendix 11: Analysis of variance for dry stalk yield underseeded with five different cover crops in 1993 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	1.410	4.41	0.127
Date	1	15.675	49.07	0.006
MP error (a)	3	0.319		
Cover crop	5	1.071	2.12	0.090
5 vs 1+2+3+4+6	1	0.113	0.22	0.639
1+2+3 vs 4+6	1	2.356	4.67	0.039
1 vs 2+3	1	1.505	2.98	0.094
2 vs 3	1	1.278	2.53	0.122
4 vs 6	1	0.106	0.21	0.651
Date*cover crop	5	0.482	0.96	0.460
(d1/d2)*(c5/12346)	1	0.006	0.01	0.915
(d1/d2)*(c123/46)	1	0.227	0.45	0.508
(d1/d2)*(c1/23)	1	1.135	2.25	0.144
(d1/d2)*(c2/3)	1	0.846	1.68	0.205
(d1/d2)*(c4/6)	1	0.198	0.39	0.436
SP error (b)	30	0.504		
Corrected Total	47	27.231		

Appendix 12: Analysis of variance for ear leaf nitrogen status of sweet corn 1992 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	0.627	1.74	0.329
Date	1	0.159	0.44	0.554
MP error (a)	3	0.360		
Cover crop	5	0.045	0.72	0.615
1 vs 2+3+4+5+6	1	0.006	0.10	0.751
2+3+5 vs 4+6	1	0.002	0.03	0.862
2 vs 3+5	1	0.055	0.89	0.354
3 vs 5	1	0.128	2.05	0.163
4 vs 6	1	0.032	0.52	0.477
Date*cover crop	5	0.036	0.58	0.713
(d1/d2)*(c1/23456)	1	0.135	2.17	0.151
(d1/d2)*(c235/46)	1	0.003	0.04	0.838
(d1/d2)*(c2/35)	1	0.000	0.00	0.977
(d1/d2)*(c3/5)	1	0.041	0.66	0.424
(d1/d2)*(c4/6)	1	0.003	0.04	0.843
SP error (b)	30	0.062		
Corrected Total	47	1.694		

Appendix 13: Analysis of variance for ear leaf nitrogen status of sweet corn 1993 growing season.

Source of variation	df	MS	F-value	Probability
BLock	3	0.017	0.34	0.798
Date	1	3.456	69.63	0.004
MP error (a)	3	0.050		
Cover crop	5	0.042	1.86	0.132
5 vs 1+2+3+4+6	1	0.068	3.00	0.094
1+2+3 vs 4+6	1	0.021	0.90	0.349
1 vs 2+3	1	0.005	0.24	0.629
2 vs 3	1	0.001	0.06	0.805
4 vs 6	1	0.116	5.09	0.032
Date*cover crop	5	0.031	1.36	0.269
(d1/d2)*(c5/12346)	1	0.009	0.39	0.536
(d1/d2)*(c123/46)	1	0.055	2.41	0.131
(d1/d2)*(c1/23)	1	0.039	1.72	0.199
(d1/d2)*(c2/3)	1	0.019	0.83	0.369
(d1/d2)*(c4/6)	1	0.032	1.83	0.242
SP error (b)	30	0.023		
Corrected Total	47	3.976		

Appendix 14. Analysis of variance of cover crop biomass planted on 29 May and 22 June 1992 growing season. Cover crop was sampled on 3 March 1993.

Source of variation	DF	MS	F-value	Probability
Block	3	0.665	4.88	0.113
Date	1	0.052	0.38	0.580
MP error (a)	3	0.136		
Cover crop	2	1.095	5.13	0.025
3 5/6	1	0.785	3.68	0.079
3/5	1	1.404	6.58	0.025
Date*Cover crop	2	0.088	0.41	0.670
(d1/d2)*(c3 5/6)	1	0.130	0.61	0.450
(d1/d2)*(c3/5)	1	0.046	0.22	0.650
SP error (b)	12	0.213		
Corrected Total	23	4.614		

Appendix 15. Analysis of variance for cover crop biomass planted on 24 June and 20 July 1993 growing season. Cover crop was sampled on 24 November 1993.

Source	df	MS	F-value	Probability
Block	3	0.313	1.09	0.474
Date	1	1.272	4.42	0.126
MP error (a)	3	0.289		
Cover crop	3	0.456	2.02	0.148
1+2 vs 4+6	1	0.466	2.06	0.169
1 vs 2	1	0.766	3.38	0.082
4 vs 6	1	0.137	0.60	0.447
Date*Cover crop	3	0.125	0.55	0.653
(d1/d2)*(c12/46)	1	0.104	0.46	0.507
(d1/d2)*(c1/2)	1	0.060	0.27	0.613
(d1/d2)*(c4/6)	1	0.212	0.94	0.346
SP error (b)	18	0.226		
Corrected Total	31	4.426		

Appendix 16: Analysis of variance of cover crop nitrogen concentration underseeded in sweet corn in 1992 growing seasons.

Source of variation	df	MS	F- value	Probability
Block	3	0.186	6.75	0.077
Date	1	0.001	0.03	0.874
MP error (a)	3	0.028		
Cover crop	2	11.388	210.19	0.000
3 5/6	1	22.770	420.25	0.000
3/5	1	0.006	0.12	0.737
Date*cover crop	2	0.004	0.08	0.922
(d1/d2)*(c3 5/6)	1	0.005	0.10	0.762
(d1/d2)*(c3/5)	1	0.004	0.07	0.801
SP error (b)	12	0.054		
Corrected Total	23			

Appendix 17. Analysis of variance of cover crop nitrogen concentration underseeded in sweet corn 1993 growing season.

Source of variation	df	MS	f-Value	Probability
Block	3	0.014	0.27	0.843
Date	1	0.112	2.17	0.237
MP error (a)	3	0.051	0.64	0.598
Cover crop	3	3.012	37.69	0.000
1+2 vs 4+6	1	8.496	106.34	0.000
1 vs 2	1	0.276	3.45	0.080
4 vs 6	1	0.263	3.29	0.087
Date*Cover crop	3	0.158	1.97	0.154
(d1/d2)*(c12/46)	1	0.000	0.00	0.946
(d1/d2)*(c1/2)	1	0.040	0.50	0.488
(d1/d2)*(c4/6)	1	0.432	5.41	0.032
SP error (b)	18	0.080		
Corrected Total	31	12.934		

Appendix 18: Analysis of variance for nitrogen uptake by cover crop planted 29 May and 22 June 1992 growing season. Cover crop biomass was sampled on 3 March 1993.

Source of variation	df	MS	F-value	Probability
Block	3	200.242	5.30	0.102
Date	1	74.836	1.98	0.254
MP error (a)	3	37.779		
Cover crop	2	8078.237	99.98	0.000
3 5/6	1	15001.834	185.67	0.000
3/5	1	1154.640	14.29	0.003
Date*Cover crop	2	32.706	0.40	0.676
(d1/d2)*(c3 5/6)	1	48.642	0.60	0.453
(d1/d2)*(c3/5)	1	16.769	0.21	0.657
SP error (b)	12	80.796		
Corrected Total	23	16729.029		

Appendix 19: Analysis of variance of nitrogen uptake by cover crop planted on 24 June and 20 July 1993. cover crop biomass was sampled on 24 November 1993.

Source of variation	df	MS	f-value	Probability
Block	3	171.676	2.53	0.233
Date	1	1124.210	16.57	0.027
MP error (a)	3	67.851		
Cover crop	3	3517.294	18.44	0.000
1+2 vs 4+6	1	8835.525	46.32	0.000
1 vs 2	1	1362.164	7.14	0.016
4 vs 6	1	354.192	1.86	0.190
Date*cover crop	3	117.073	0.61	0.615
(d1/d2)*(c12/46)	1	141.751	0.74	0.400
(d1/d2)*(c1/2)	1	127.295	0.67	0.425
(d1/d2)*(c4/6)	1	82.174	0.43	0.520
SP error (b)	18	190.734		
Corrected Total	31	16091.939		