AN ABSTRACT OF THE THESIS OF

Segundo Nova Angustia for the degree of Master of Science in Horticulture presented on October 25, 1995. Title: Impact of Cover Crops on Weed Abundance and Nitrogen Contribution in Broccoli, *Brassica oleracea* var. *italica*, Production Systems in the Maritime Pacific Northwest.

Abstract approved: ______________________
John M. Luna

Field experiments were conducted in 1994 and 1995 at the OSU Vegetable Research Farm near Corvallis, OR. The objectives were to evaluate nitrogen (N) accumulation and contribution from selected cover crops, to determine optimum N fertilizer rates in combination those selected cover crops for broccoli production, and to evaluate the impact of cover crops on weed abundance. Two cereal and legume cover crop cultivars were evaluated as sole crops and as mixtures. These included 'Monida' oats (*Avena sativa* L.), cereal rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth), Austrian peas (*Pisum sativum* L. ssp. *arvense* (L.) Poir.), cereal rye plus hairy vetch, cereal rye plus Austrian peas, 'Monida' oats plus hairy vetch, or 'Monida' oats plus Austrian peas. A fallow treatment was used as a control. Cover crops were arranged in a randomized block design with nine treatments and four replications. After the cover crops were flailed-mowed and incorporated, 'Hybrid Excelsior' broccoli was direct-seeded. Then, four N rates (0, 90, 180, and 270 kg/ha) were applied within each cover crop treatment in a split plot design. A 60 cm strip was left between each four rows of broccoli for the weed study.

Nitrogen accumulation from the cover crops varied between years. Hairy vetch as a sole crop accumulated as much as 131 kg N/ha in 1994, but only 55

kg N/ha in 1995. 'Monida' oats accumulated an average of 22 kg N/ha in 1994, but produced 56 kg N/ha in 1995. The mixture of cereal rye plus hairy vetch was consistent in both years with a total N accumulation of 93 and 94 kg N/ha in 1994 and 1995, respectively.

In 1994, broccoli yields following hairy vetch and Austrian peas as a sole crop plus 90 kg N/ha were statistically equivalent to those following fallow and 180 kg N/ha. Also, broccoli yields following the mixtures of 'Monida' oats plus Austrian peas and cereal rye plus hairy vetch with 90 kg N/ha were equivalent to those of broccoli following the fallow at 180 kg N/ha. In 1995 again, broccoli yields following hairy vetch plus 90 kg N/ha were statistically equivalent to those following fallow and 180 kg N/ha.

In both years the cereals, 'Monida' oats and cereal rye as a sole crops significantly reduced weed emergence and weed biomass when compared to the fallow control. In 1994, 'Monida' oats reduced hairy nightshade (*Solanum sarrachoides* Sendtner) emergence by 59%, shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.) by 97%, and common groundsel (*Senecio vulgaris* L.) by 82% compared to the fallow control. Cereal rye reduced hairy nightshade by 48%, shepherdspurse by 95%, and common groundsel by 64%. The legume cover crops, however, appeared to stimulate shepherdspurse emergence. Austrian peas increased shepherdspurse emergence by 18% and hairy vetch by 45% compared to the fallow control.

The N coming from the legumes likely stimulated weed growth. This legume N effect was apparent in the increased weed biomass in the cover crop mixtures.

In the 1995 experiment, 'Monida' oats reduced total weed density by 54% and cereal rye by 44% compared with the fallow. The legumes increased the germination of nightshade and Persian speedwell (*Veronica persica* Poir).

Impact of Cover Crops on Weed Abundance and Nitrogen Contribution in Broccoli, *Brassica oleracea* var. *italica*, Production Systems in the Maritime Pacific Northwest.

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Chapter 1

Introduction and Literature Review

Cover Crop Contributions to Farming Systems

Cover crops are non-harvested legumes, cereals, or other crops that are usually grown to improve or conserve soil quality (Power and Biederbeck, 1991). Cover crops have also been shown to improve water infiltration, reduce runoff and water erosion, and improve soil fertility by adding organic matter and N through symbiotic biological fixation (Folorunso et al., 1992). Fall-planted winter-annual cover crops can reduce ground-water contamination from nitrate leaching (Jackson et al., 1993; Smukalski et al., 1991). Cover crops can also contribute to the management of insect pests, weeds, and plant pathogens (Hoyt and Hargrove, 1986; Luna, 1993; Lal et al., 1991). Not all of these effects are related to the use of a specific cover crop, but many do occur at the same time.

Although growing cover crops has many advantages, problems do exist. Additional farming operations needed to establish and incorporate the cover crops increase production costs (Keeney, 1982). Cover crops can cause delays in planting, increase nutrient immobilization, create a source of pest problems, and reduce soil moisture (Jackson et al., 1993; Luna, 1993; Shennan, 1992). In addition, the availability of organic N in the plowed-down cover crop for subsequent crops is difficult to predict. Some of the N may become mineralized too late in the growing season to be used by the following summer crops (Keeney, 1982).

Cover crops can be grown as perennials or annuals. Perennial cover crops, such as grass sods, are commonly used in perennial cropping systems such as tree fruits, caneberries and grapes. Annual cover crops are usually used in annual cropping systems such as vegetable and grain crops.

There are two different groups of annual cover crops according to their planting season: the first group is the winter annual cover crops such as cereal rye (*Secale cereale* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), ryegrass (*Lolium* spp.), hairy vetch (*Vicia villosa* Roth.), Austrian peas (*Pisum sativum* spp. *arvense* (L.) Poir. or *Pisum arvense* L.), and crimson clover (*Trifolium incarnatum* L.). They are commonly planted in the fall and killed in the spring before planting a summer cash crop. The second group of cover crops are the warm-season annuals, such as buckwheat (*Fagopyrum esculentum* Moench) and sudangrass (*Sorghum bicolor* var. *sudanese*). These are used to fill openings in crop rotations during summer fallow periods.

Legume cover crops such as clovers, vetch, and Austrian peas have long been grown because of their ability to fix N through a symbiotic relation with *Rhizobia* bacteria living in root nodules. If winter legumes are used to provide a significant component of the N requirement for a summer cash crop, assessing how much N the legume provides and whether the release period of inorganic N from the decomposing residue coincides with the crop's N demand is important (Shennan, 1992; Wagger, 1989; McVay et al., 1989; Morse and Seward, 1986).

According to Bruce et al. (1992) and Karlen et al. (1992), effective use of cover crops requires examination of the entire set of crop production objectives in relation to soil and climate. The quantity and quality of biomass input affect the results as does whether the cover crop is incorporated as a green manure crop or allowed to remain on the surface as a mulch.

Cover crops may be a single species or mixtures that will give specific benefits and that will integrate with the whole farming system. In many situations, optimum benefits can be obtained by using mixtures of species, such as grasses and legumes (Ingels et al., 1994). A study in Massachusetts found that oats mixed with either hairy vetch or Austrian winter peas were the best cover crops for no-till sweet corn (Lyman and Sarrantonio, 1993). Also, cereal rye mixed with hairy vetch has been successfully managed as mulch for no-till corn (Shennan, 1992; Sullivan et al., 1990).

Cover crops and Nitrogen Management

Fall-planted grass cover crops, such as cereal rye, oats, barley, and ryegrass, have extensive and fibrous root systems that allow them to reduce leaching of excess soil N, thereby increasing the recycling of nutrients (Lyman and Sarrantonio, 1993).

There is evidence that fall-planted cover crops can "scavenge" significant amounts of soil N, accumulating it in the above-ground biomass to be recycled through the soil system the following growing season when incorporated as a green manure crop (Meissinger et al., 1991). In an on-farm demonstration project using cover crops in Marion County, nitrate analyses were done on soil samples taken at 30-cm intervals to a 1.5-m depth. The cereal rye and barley cover crops clearly reduced soil nitrate levels compared to the fallow plots (Luna and McGrath, 1993). In another study conducted by Luna and McGrath at the North Willamette Research and Extension Center at Aurora, OR, they found that Galt and Steptoe barley, Owens and Stevens wheat (*Triticum aestivum* L.), annual ryegrass, crimson clover and common vetch (*Vicia sativa* L.) cover crops reduced soil nitrate levels in the spring compared to a fallow control (unpublished data).

In a Maryland study, Shipley (1990) examined the ability of winter cover crops to assimilate residual corn fertilizer N and reduce nitrate N losses through leaching. Labeled N (^{15}N-depleted) was applied to corn at rates of 0, 168, and 336 kg N/ha. Cover crop treatments after corn harvest were hairy vetch, crimson clover, cereal rye, or annual ryegrass, and a weed/fallow control containing mostly common chickweed (*Stellaria media* (L.) Vill). The cover crops were harvested three times the following spring and dry matter yields and percentage ^{15}N were determined. The average cover crop uptake of applied N (kg N/ha) in mid-April after 336 kg N/ha treatment was 48 for cereal rye, 29 for annual ryegrass, 9 for hairy vetch, 8 for crimson clover, and 6 for the native weed cover. These results show that grass cover crops conserved the most N. Cereal rye recovered more N through mid-April because of its growth ability in cool weather.

Nitrogen Contribution of Cover Crops

Various methods to measure legume N contributions to subsequent crops have been used. Total N accumulation by successive crops is the most simple and inexpensive method but does not account for residual soil N; therefore, legume N merits are often overestimated (La Rue and Patterson, 1981). Changes in soil N and the N response of following non-legume crops are also used to estimate legume N contribution (Lynd et al., 1984, and Hargrove, 1986).

Another method that has been used most extensively in N_2 fixation research is the acetylene reduction assay of nitrogenase activity. This method gained rapid acceptance because it is simple, sensitive, and less expensive compared with the $^{15}N_2$ method of studying N_2 fixation and can be used to study N_2 fixation under field conditions (Bremner and Hauck, 1982).

A commonly used method of estimating the N contribution of cover crops has been to determine the N fertilizer equivalency values. These values are usually estimated by comparing crop yields following a legume cover crop with fertilizer response functions obtained following a bare fallow period, a nonlegume cover crop, or fallow plus residue from previous crops. This method of estimating N contribution has been criticized for greatly overestimating the N contribution of legumes when compared with estimates obtained from N^{15} tracer experiments (Shennan, 1992). The addition of organic residues can also affect soil microbial biomass and various indicators of microbial activity, and hence presumably affect the rates of N mineralization and immobilization of existing soil N in the organic fraction (Shennan, 1992). Although this N-equivalency method does not accurately assess actual N contribution from cover crops, it serves as an integrative method of assessing the total systems effects on increasing N availability in the soil.

In a study examining cover crop contribution to corn silage yield, Sullivan et al. (1990) report that the most cover crop N was produced by hairy vetch or a mixture of hairy vetch and bigflower vetch (*Vicia grandiflora* W. Koch var. Kitailbeliana). Cereal rye growing in association with hairy vetch had lower carbon to N (C:N) ratios than did pure cereal rye. The C:N ratios for legumes were unchanged when the cover crops were allowed additional growth time, suggesting that a later kill date would permit additional biomass accumulation without sacrificing residue/mulch quality. Uptake of N by corn is related to increased N production by cover crops and low C:N ratios. There were no differences in corn silage yield between using greatest N rates, 140 and 210 kg/ha, and corn following a vetch cover crop with no N fertilizer.

According to Hoyt and Hargrove (1986), legume cover crops influence nutrient availability in following crops by increasing soil organic carbon, total N, exchangeable cations, and increasing pH. A winter cover rotation enhances nutrient retention in an agricultural system. Essential plant nutrients are incorporated into the biomass during the winter, then decompose and become available to the summer crop.

Samson et al. (1991) found that corn yields after non-fertilized hairy vetch were equivalent to those using 112 kg N/ha. Also, he found that corn after red clover (*Trifolium pratense* L.), crimson clover, and oilseed radish (*Raphanus sativus* 'Renova') produced yields equivalent to those with 79 kg N/ha. In an experiment estimating response curves of legume N contribution to no-till corn (*Zea mays* L.), Tyler et al. (1987), using 0, 56, 112, 178, and 224 kg N/ha and chemically killed wheat residue, vetch, Austrian winter peas, and crimson clover, found that corn yield following killed vetch was greater at all N rates than that with the cereal. Also, they found a similar response with Austrian winter peas and crimson clover.

Shurley (1987) compared the effects of winter cover crop, including hairy vetch, bigflower vetch, cereal rye, and corn residues, on no-till corn yields. From 1980 to 1983, each treatment received three levels of N, 0, 50, and 100 kg/ha. From 1984 to 1986, the N rates were 0, 84, and 168 kg/ha. Bigflower vetch and hairy vetch were shown to provide as much as 56 kg/ha of N. Corn yields following a combination of bigflower vetch or hairy vetch along with 168 kg/ha of N were 430 to 616 kg/ha greater than corn residue with the same amount of N. The net returns using bigflower vetch and hairy vetch at the higher rates of N were about the same as the residue treatment even though three of the seven years during the study were dry years.

In a Kentucky study, Utomo et al. (1989) examined the role of cover crops in providing N for corn under no-tillage and conventional tillage. Winter cover crop treatments of hairy vetch, cereal rye, and corn residues were combined factorially with N rates of 0, 85, and 170 kg N/ha in the two tillage systems. Grain yield without N on the vetch treatment was essentially equal to yields with 170 kg N/ha on the cereal rye or corn residue treatments. However, results suggested that to obtain maximum corn yields N fertilization should be reduced little, if any, with a hairy vetch cover crop.

Holderbaum et al. (1990) evaluated effects of various harvest management schedules on total N contribution of legume cover crops, subsequent corn grain and silage yields, and total forage production in a Maryland study. A crimson clover cover crop was subjected to no harvest, spring silage harvest with clippings removed, and simulated pasture harvest with clippings from multiple harvests removed or returned. A no-cover control treatment was included. No-tillage corn was grown in the cover crop residues, and two fertilizer N rates 0, and 90 kg/ha were applied in a split-block design to each harvest management treatment. Corn grain, silage yield, and corn N uptake were consistently greater with crimson clover than with no cover, regardless of harvest management, and were generally greater when the cover was left in place than after removal of the cover. There were positive N fertilizer responses regardless of harvest management treatments. The reduction in corn silage yields when the cover crop was harvested and removed was less than the cover crop herbage dry matter yield, resulting in greater total forage production when cover crop was harvested as forage.

Blevins et al. (1989) examined the N fertilizer equivalency of hairy vetch, bigflower vetch, and cereal rye to no-tillage corn and grain sorghum (*Sorghum bicolor* (L.) Moench). A fallow treatment, consisting of stalk residue only, was used as a comparison in this Kentucky study. Fertilizer N rates for corn were 0, 50 or 100 kg N/ha for 1980 to 1983 and 0, 85 or 170 kg N/ha for 1984 to 1987. Hairy vetch produced the most cover crop dry matter with the greatest percentage of N. During 1980 to 1983, corn grain yields were significantly greater with the vetch treatments than with cereal rye or fallow treatments at the 0 and 50 kg N/ha rates with tendency toward greater yields at the 100 kg N/ha rates. During 1984 to 1987, corn yields from the vetch treatments were significantly greater than from the other cover treatments at all N levels. Grain sorghum yields, like corn yields, were greater with the vetch treatments than with the cereal rye or fallow treatments, although the bigflower vetch treatment did not yield significantly more than the fallow treatment at the 170 kg N/ha rate. The estimated fertilizer-N equivalency of the hairy vetch-N in the corn experiment was 75 kg N/ha and bigflower vetch was 65 kg N/ha. Fertilizer N equivalency values in the grain sorghum experiment were estimated to be 125 kg N/ha for hairy vetch and 135 kg N/ha for bigflower vetch.

In another Kentucky study, Munawar et al. (1988) examined the effects of tillage systems, N fertilizer rates, and cover crop management on soil temperature, soil moisture, and corn yields. Tillage treatments were chisel-plow tillage, conventional tillage, disk tillage, and no-tillage. Nitrogen fertilizer at rates of 0, 70, 150, or 250 kg N/ha was broadcast on the soil surface. Cereal rye on one half of each split plot was killed three weeks before corn planting time, while the other half was allowed to grow until the corn was planted. Corn yields were significantly greater with early-killed cereal rye than with late-killed cereal rye in both years. Soil temperature tended to be slightly greater under the late-killed cereal rye mulch in 1986 with no significant difference in 1987. Soil moisture content for the early-killed cereal rye treatment was significantly greater than for late-killed cereal rye treatment because of the transpirational losses from the growing cereal rye.

In Ontario, Raimbault et al. (1989) conducted an experiment to evaluate corn response to cereal rye cover crop management and spring tillage system. One factor studied was cereal rye treatments consisting of no cereal rye, cereal rye harvested as whole plant silage in the spring, and cereal rye biomass left on the soil surface in the spring. The second factor involved spring tillage treatments before corn planting of no-till, tandem disking twice, or moldboard plowing plus secondary tillage with a tandem disk. The cereal rye cover crop had a significant adverse effect on the corn crop planted immediately after cereal rye kill or cereal rye harvest. Also, removal or retention of the cereal rye residue has no consistent effect on the subsequent corn crop. Raimbault et al. (1989) suggest that an allelopathic effect resulting from the cereal rye crop may be one plausible explanation for the reduction in corn silage yield.

Hargrove (1986) conducted a field experiment in which four legumes: crimson clover, subterranean clover (*Trifolium subterraneum* L. 'Mt. Barker'), hairy vetch, and common vetch, cereal rye, and a fallow treatment and four N rates (0, 28, 56, and 112 kg N/ha) were applied to no-till sorghum. Sorghum yields following a legume cover crop averaged 3.91 Mg/ha, regardless of N rate. With the fallow or rye, the maximum yield was 3.95 Mg/ha, which was not significantly different from the average yield following the legume, and was obtained with 99 kg N/ha.

In a Kentucky study, Ebelhar et al. (1984) examined N from legume cover crops for no-tillage corn. Winter annual legume cover crop treatments of hairy vetch, bigflower vetch, and crimson clover were compared with a cover of corn residue and a cover crop of cereal rye. Three N fertilizer treatments (0, 50, and 100 kg N/ha) were combined with the cover crops. Corn yields following hairy vetch with no N fertilizer were about 2.5 Mg/ha more than corn yields when following corn residue or rye cover crop. These authors estimated that 90 to 100 kg/ha of biologically fixed N fertilizer equivalency was supplied by the hairy vetch.

Cover Crops for Vegetable Crop Production Systems

In a California study, Jackson et al. (1993) examined the effects of winter cover crops to minimize nitrate losses in intensive lettuce production. Oilseed radish, white senf mustard (*Brassica hirta* 'Martigena'), white mustard (*Brassica alba*), phacelia (*Phascelia tanacetifolia* 'Phaci'), rye, and annual ryegrass cover crops were compared to a fallow treatment. They found that the soil nitrate concentrations were reduced by them. Nitrate concentrations after spring rains were lower in soils left fallow during winter. Furthermore, they found that the subsequent lettuce (*Lactuca sativa* L.) crop was not affected by cover crop treatment.

Abdul-Baki and Teasdale (1993) compared four cover treatments, hairy vetch, subterranean clover, paper, and black polyethylene with bare ground for tomato (*Lycopersicon esculentum* Mill.) production in Maryland. Hairy vetch and clover were cut near the soil surface, and then mowed above the bed's surface to achieve a uniform cover over the beds. Tomato yield with a hairy vetch mulch was more than double the yield of the control (nonmulched) plants. Tomato yield following the clover mulch treatment was significantly greater than that of the control plants, but only 65% of the tomato yield with hairy vetch. Also, the plants grown under hairy vetch and clover showed more vegetative growth, even though they received only 50% of the commercial fertilizer applied to plants in the other three treatments. The greater vegetative growth may have contributed to the high yield under these treatments.

In an Alabama study, Doss et al. (1981) examined interactions of a rye cover crop with different tillage methods on growth and yield of tomatoes. Marketable tomato yields tended to decrease as the amount of tillage increased.

Also, these authors found that marketable tomato yields tended to be greater on no-rye plots than on rye plots, with yields averaging 2.2 MT/ha greater for no-rye plots.

In a Massachusetts experiment, Mangan et al. (1990) used three cover crops (hairy vetch and cereal rye, cereal rye alone, and fallow) and two rates of inorganic N (0 kg/ha and 112 kg/ha) with broccoli. The addition of inorganic N resulted in a significant increase in the yield of broccoli heads. There were no statistical differences between broccoli yields using hairy vetch with no inorganic N and cereal rye with 112 kg/ha of inorganic N. Also, the yield with no cover crop was greater than with cereal rye alone.

Foulds et al. (1990) examined the effects of interseeded legume cover crops on broccoli yield. White clover (*Trifolium repens* L.), red clover, sweet clover (*Melilotus officinalis* Lam.), crimson clover, and hairy vetch were broadcast on existing broccoli fields over a two years period, from 1989 to 1990. Hairy vetch and crimson clover produced the most N and biomass. However, none of the interseeded cover crops reduced broccoli yields.

In a Virginia study, Morse and Seward (1986) examined three cover crops, hairy vetch, Austrian winter peas, and cereal rye, and four rates of N (0, 30, 60, and 90 kg/ha) in 1983 and 60, 120, and 180 kg/ha in 1984 with broccoli and cabbage (*Brassica oleracea*, Capitata group). The results indicate that Austrian winter peas and hairy vetch did not differ in the amount of dry matter produced, but the Austrian winter peas produced the greatest N levels. The head numbers and yield per hectare of broccoli and cabbage were not affected by tillage systems.

In a Massachusetts study, Schonbeck et al. (1993) studied the yield effects on broccoli and cabbage of hairy vetch and rye as a sole crop, hairy vetch plus rye, and a fallow treatment. Cover crops of hairy vetch as a sole crop and the mixture of hairy vetch plus rye produced greater broccoli and cabbage yields than the rye as a sole crop and the fallow. Rye as a sole crop was found to reduce yield.

Grenoble et al. (1989) examined the effects of tillage methods and soil cover crops on yield and leaf elemental concentrations of snap bean (*Phaseolus vulgaris* L.) in a Pennsylvania study. No-tillage, strip-tillage, and conventional tillage were compared in combination with red clover, rye, and a fallow treatment. Beans yields were greater with conventional tillage. Also, beans yielded better with either cover crop than with the fallow treatment.

Cover Crops and Weed Management

Cover crops can provide considerable weed suppression through the release of allelopathic chemical compounds (Putnam, 1990; Barnes and Putnam, 1983). Commonly, plants will interact in a negative manner with their neighboring plants, when the emergence or growth of one or both are inhibited. This adverse effect on plants in an association is called interference (Muller, 1969). According to Muller (1969) and Szezepanski (1977), interference can be divided into three categories: (1) competition, in which a plant reduces the level of some necessary factor in the habitat to the detriment of some other plants in the same habitat (Muller, 1969), (2) allelopathy is a form of plant interference that occurs when one plant, through living or decaying tissue, interferes with the growth of another plant through a chemical inhibitor (Zimdahl, 1993; Szezepanski, 1977), and (3) allelomediation, which is a type of interference where a plant possesses some chemical properties which makes it poisonous or unpalatable to animals, thus lending advantage to another (Szezepanski, 1977).

Barnes and Putnam (1983) found that cereal rye residues reduced early season biomass of common lambsquarters (*Chenopodium album* L.) by 98%, large crabgrass (*Digitaria sanguinalis* (L.) Scop.) by 42%, and common ragweed (*Ambrosia artemisiifolia* L.) by 90%. Also, they found in greenhouse studies that cereal rye root leachates reduced tomato dry weight by 25-30%, which is an additional evidence of the allelopathic effect of cereal rye on other plant species.

Furthermore, Putnam et al. (1983) found 90% weed suppression using cereal rye, wheat, and barley.

White et al. (1989) found that cotton (*Gossypium hirsutum*) and pitted morningglory (*Ipomoea lacunosa* L.) emergence and dry weight decreased approximately 60% to 80% when these plants were grown under greenhouse conditions in the presence of increasing amounts (0.8 to 6.7 mg debris/g soil) of field-grown crimson clover or hairy vetch debris incorporated into the soil medium. Corn dry weight increased 20 to 75% when legume debris was placed on the soil surface. Germination and seedling growth of corn, Italian ryegrass (*Lolium multiflorum* Lam.), cotton, pitted morningglory, and wild mustard (*Sinapis arvensis* L.) decreased progressively, with species-dependent variation, when exposed to increasing concentrations (8.3 to 33.3 g debris/L) of aqueous crimson clover and hairy vetch extract. Mustard and ryegrass germination and growth were almost completely inhibited by the greater concentration extracts of both legumes.

Liebl and Worsham (1983) reported that wheat has a phytotoxic compound that reduced the germination and root length of some weeds. This compound, ferulic acid, inhibits the germination of pitted morningglory by 23%, large crabgrass by 100%, and prickly sida (*Sida spinosa* L.) by 85%.

In a Michigan study, Smeda and Putnam (1988) determined the effect of 'Wheeler' rye, wheat, and barley cover crops on weed suppression and their influence on strawberry (*Fragaria* x *ananassa* Duch) yields. Rye and wheat provided greater early season weed suppression than barley. Strawberry fruit yields were not reduced by any of the cover crops.

Although weed suppression by cover crop residue is frequently attributed to allelopathy, physical alterations of the seed environment may be important also (Teasdale and Mohler, 1993). Cover crop mulches can aid in the reduction of herbicide use by providing a non-chemical means of reducing the impact of weed interference on a given crop (Moore et al., 1994). Cover crop mulch systems have been referred as a weed suppresser by competition by live cover crop, physical barrier of weed emergence, and allelopathic potential (Barnes and Putnam, 1981, and Else and Ilnicki, 1989).

Worsham (1984) found that when full-season soybeans (*Glycine max* (L.) Merr.) and sunflower (*Helianthus annuus* L.) were no-till planted into killed green cereal rye the common lambsquarters growth was reduced 99 percent; redroot pigweed (*Amaranthus retroflexus* L.) growth was reduced 96 percent, and ragweed growth in 92 percent, in comparison with tilled plots with no mulch. Also, he found that when tobacco (*Nicotiana tabacum* L.) was planted no-till into killed cereal rye, the early season pigweed growth was reduced 51 percent, common lambsquarters 41 percent, and ragweed growth 73 percent, compared with tilled plots with no mulch.

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Chapter 2

Nitrogen Contribution from Cereal and Legume Cover Crops to Broccoli, *Brassica oleracea* var. *italica*, Production

Abstract

Field experiments were conducted in 1994 and 1995 at the OSU Vegetable Research Farm near Corvallis, OR. The objectives were to evaluate N accumulation and contribution from selected cover crops and to determine optimum N fertilizer rates in combination with those selected cover crops for broccoli production. Two cereal and legume cover crop cultivars were evaluated as a sole crops or as mixtures. They included 'Monida' oats (*Avena sativa* L.), cereal rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth), Austrian peas (*Pisum sativum* L. ssp. *arvense* (L.) Poir.), cereal rye plus hairy vetch, cereal rye plus Austrian peas, 'Monida' oats plus hairy vetch, and 'Monida' oats plus Austrian peas. A fallow treatment was used as a control. Cover crops were arranged in a randomized block design with nine treatments and four replications. After the cover crops were flailed-mowed and incorporated, 'Hybrid Excelsior' broccoli was direct-seeded. Then, four N rates (0, 90, 180, and 270 kg/ha) were randomized within each cover crop treatment.

Nitrogen accumulation from the cover crops varied between years. In 1994, hairy vetch as a sole crop accumulated as much as 131 kg N/ha, while in 1995, accumulated only 55 kg N/ha. 'Monida' oats accumulated an average of 22 kg N/ha in 1994, but produced 56 kg N/ha in 1995. The mixture of cereal rye plus hairy vetch was consistent in both years with a total N accumulation of 93 and 94 kg N/ha in 1994 and 1995 respectively.

In 1994, broccoli yields following hairy vetch and Austrian peas as a sole crop plus 90 kg N/ha were statistically equivalent to those following the fallow with 180 kg N/ha. Also, broccoli yields following the mixtures of 'Monida' oats plus Austrian peas and cereal rye plus hairy vetch with 90 kg N/ha were equivalent to those of broccoli following the fallow at 180 kg N/ha. In 1995 again, following hairy vetch plus 90 kg N/ha broccoli yields were equivalent to the fallow with 180 kg N/ha.

Introduction

In the maritime Pacific Northwest, an extensive variety of vegetable crops are produced for processing and fresh market. Oregon ranked fourth among the states in production of fresh market and processing vegetables, accounting for 3.6 percent of the 1990 U. S. production (Agriculture and Fisheries Statistics 1990-1991).

In the Willamette Valley of Western Oregon, an increasing number of vegetable growers are interested in growing cover crops because they may play a significant role in increased soil productivity. Cover crops may be used for both N capture and N contribution. Although many studies have demonstrated a role of legumes in N contribution (Stivers and Shennan, 1991; Hoyt and Hargrove, 1986; Ebelhar et al., 1984; Doran and Smith, 1991; Torbert and Reeves, 1991), there is no work reported in the Pacific Northwest that enables growers to adjust N fertilizer rates according to N contribution from cover crops. Without accounting for N from cover crops, growers using full rates of N fertilizer may be loading the soil with more N than the crop can use. This may result in residual soil nitrate at the end of the growing season, increasing the risk of nitrate loss to surface and groundwater during the rainy winter season.

The following experiment was designed to evaluate cover crop and N effects in broccoli production in western Oregon. The specific objectives of this experiment were the following: (1) to evaluate relative biomass production and N accumulation from selected cover crop species and mixtures and (2) to determine optimum N fertilizer rates in combination with selected cover crops for maximum broccoli yield.

Materials and Methods

Field studies were conducted in 1994 and 1995 at the Oregon State University Vegetable Research Farm located near Corvallis. The soil is a Chehalis silt clay loam. The field used in 1994 was cropped to strawberry in 1992-93 and was fallow during the summer of 1993. The field used in 1995 was cropped to a barley plus hairy vetch cover crop during 1993-94 and buckweat cover crop during the summer of 1994.

Cover Crops

Two cereals and two legume cultivars were evaluated either as sole crops or as mixtures, including: cereal rye, 'Monida' oats, Austrian peas, hairy vetch, cereal rye plus Austrian peas, cereal rye plus hairy vetch, 'Monida' oats plus Austrian peas, 'Monida' oats plus hairy vetch. A fallow treatment without a cover crop was used as a control. These four cover crop cultivars were selected for varying characteristics. Hairy vetch is a cold tolerant winter-annual legume with a well-documented capacity to fix biological N (Blevins et al., 1990; Shennan, 1992; Lyman and Sarrantonio, 1993; Holderbaum et al., 1990; Hargrove, 1986; Frye and Blevins, 1989). Austrian peas is one of the most commonly grown cover crops in the Willamette Valley of Oregon and also has a proven capacity to fix N (Shennan, 1992; Lyman and Sarrantonio, 1993). Cereal rye is also quite cold-tolerant, establishes quickly in fall (Sullivan et al., 1990; Lyman and Sarrantonio, 1993), and is commonly used by vegetable growers. 'Monida' oats, a spring variety, was selected because of its delayed maturity in the spring, which results in a greater leaf to stem ratio than other cereals (Luna, unpublished data).

The experimental design was a randomized block design with nine cover crop treatments and four replications. Cover crop plot size was 16.6 m long by

4.7 m wide. There was 1 m between each cover crop plot and 4.5 m between two replications. A split plot design was established to evaluate N and cover crop interactions, and the details of this design will be described in a later section.

1994 Experiment.

Cover crops were planted on October 7, 1993, using a grain drill on 20-cm centers. Cover crop seeding rates (kg/ha) were: cereal rye 100, 'Monida' oats 100, Austrian peas 90, hairy vetch 28, cereal rye plus Austrian peas 56/56, cereal rye plus hairy vetch 56/22, 'Monida' oats plus Austrian peas 56/56 'Monida' oats plus hairy vetch 56/22. The legumes were inoculated with *Rhizobium leguminosarum* at an approximate rate of 4 g/kg of seeds by mixing the *Rhizobium* with the cover crop seed before planting.

Biomass sampling and cover crop incorporation. Cover crop above-ground biomass was sampled by clipping cover crops at the soil surface in a 0.50 m by 0.50 m (0.25 m^2) quadrat at two randomly selected locations within each cover crop treatment on March 29 and April 26, 1994. Grasses, legumes, and weeds were separated into their respective species and placed in paper bags. Samples were taken to the laboratory and oven-dried at 60°C for 48 to 60 hours and weighed. Cover crop tissue subsamples were ground and analyzed for total N using the Kjeldahl method (Bremner, 1965).

Cover crops were flail-mowed on May 2. A cover crop disk was used to incorporate the above-ground cover crop biomass and the broccoli seedbed was prepared using a Lely Roterra® (power harrow).

1995 Experiment

The cover crop experiment was moved to a nearby plot in 1995. Previous crops were hairy vetch and barley cover crop in 1993-94 and buckwheat cover crop during the summer of 1994. A seedbed was prepared using an offset disc and a Lely Roterra®. Cover crops were planted on October 5, 1994, using a grain drill with 20 cm row spacing. Cover crop seeding rates (kg/ha) were: cereal rye 106, 'Monida' oats 121, Austrian peas 91, hairy vetch 26, cereal rye plus Austrian peas 58/58, cereal rye plus hairy vetch 67/26, 'Monida' oats plus Austrian peas 61/61, and 'Monida' oats plus hairy vetch 63/25. The legumes were inoculated with *Rhizobium leguminosarum*, as in the 1994 experiment. Cover crop seeding rates differed from 1994 due to calibration error. After planting, irrigation was applied to assure a good seed germination.

Biomass sampling and cover crop incorporation. On March 28 and April 25, 1995, cover crop above-ground biomass was sampled and processed as described for the 1994 experiment. In addition, weed tissue subsamples were ground and analyzed for total N using the same procedures as for the cover crops.

In the 1995 study, excessive soil moisture from abnormally rainy weather precluded the use of the disc harrow to incorporate the cover crop. Instead, the cover crop treatments were flail-mowed, then incorporated into the soil using a tractor-mounted rotovator to approximately 12 cm deep, followed by two passes of the Lely Roterra® to prepare a seedbed for broccoli planting.

Broccoli Experimental Design

After the cover crops were flailed and incorporated, a split plot, randomized block design was established, where each cover crop plot represented the main plot and four N fertilizer rates (0, 90, 180, and 270 kg/ha) within each cover crop plot, the subplots. Each main plot size was 16.6 m long by 4.7 m wide; N fertilizer rate subplot size (within cover crops) was 8.3 m by 2 m. There was 1 m between cover crop treatments.

1994 Experiment

The broccoli cultivar 'Hybrid Excelsior' was direct-seeded with a Gaspardo® planter on May 24, 1994. There was 30 cm between two rows of broccoli and 70-cm between each pair of rows of broccoli. Broccoli seeds were treated with a fungicide mixture of captan and benomyl. A 0-34-15 (N-P_2O_5-K_2O) fertilizer was banded 5 cm to the side of the row and 5 cm deep at planting time at a rate of 314 kg/ha to provide phosphorus and potassium based on soil sample and Oregon State University (OSU) Central Analytical Laboratory recommendations. Plots were irrigated to provide sufficient moisture for broccoli germination. After the stand was established, irrigation was applied to assure optimum crop growth. On May 27, three days after planting, chlorpyrifos insecticide was sprayed using backpack sprayer, at a rate of 1.2 kg a.i./ha as a preventive control of symphylans (*Scutigerella immaculata*) and cabbage root maggot (*Delia brassicae*). On May 31, seven days after planting, 50 kg N/ha was applied as urea (46-0-0) to all treatments except for the 0 kg N/ha treatment. The fertilizer was applied to the soil surface between the pairs of broccoli rows, followed by irrigation to move the fertilizer into the soil. On July 5, the remaining N for the N-rate treatments was applied in a similar manner between the pairs of broccoli rows after the last cultivation, 42 days after planting, followed by irrigation.

In order to control cabbage flea beetle (*Phyllotreta cruciferae*), carbaryl was applied at 0.4 kg a.i./ha with a tractor-mounted boom sprayer at 3-leaf stage, on June 15, 22 days after planting.

The broccoli was thinned to approximately 20 cm between plants when they were about 10-15 cm tall, leaving a plant population of approximately

80,000 plants per hectare. Weed control was achieved by mechanical cultivation and hand-hoeing. The main weeds controlled were: hairy nightshade (*Solanum sarrachoides* Sendtner), common groundsel (*Senecio vulgaris* L.), shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.), and common lambsquarters (*Chenopodium album* L.).

Diazinon, at a rate of 2.7 kg a.i./ha, was applied to control cabbage root maggot on broccoli roots on July 12, 52 days after broccoli planting. This product was applied as a drench at the base of the plants with approximately 4,500 liters of water/ha, as a rescue treatment. Also, diazinon at a rate of 0.6 kg a.i./ha was applied to control cabbage aphid (*Brevicoryne brassicae*) on July 15, 55 days after broccoli planting. On August 10, 78 days after planting, a second application of carbaryl at 0.5 kg a.i./ha was made to control cabbage flea beetles.

1995 Experiment

The broccoli cultivar 'Hybrid Excelsior' was direct-seeded with a Gaspardo® planter on May 17, 1995. At planting time, a 0-45-0 fertilizer at 210 kg/ha was applied to provide phosphorus requirements using the same procedures as in 1994. On May 24, seven days after planting, the first application of N fertilizer was made. The remaining N for the N-rate treatments was applied on June 28 in a similar manner as in 1994.

On May 26, nine days after planting, rotenone insecticide was applied to control cabbage flea beetle at a rate of 0.1 kg a.i./ha with a tractor-mounted boom sprayer. A second application of rotenone (0.1 kg a.i./ha) was made on June 8, 22 days after planting, to control cabbage flea beetle.

The broccoli was thinned to approximately 20 cm between plants when they were approximately 10-15 cm high. Weed control was achieved by mechanical cultivation and hand-hoeing as in 1994. The main weeds controlled were: common purslane (*Portulaca oleracea* L.), hairy nightshade, and redroot pigweed (*Amaranthus retroflexus* L.).

Diazinon at a rate of 3.8 kg a.i./ha, was applied as a soil drench to the base of the plants with approximately 5,850 liters of water per hectare to control cabbage root maggots on broccoli roots on June 30, 45 days after broccoli planting. *Bacillus thuringiensis* var. Kurstaki (potency of 52,863 Spodoptera Units) was applied at a rate 4.7 l formulation/ha to control diamondback moth (*Plutella xylostella*) and cabbage looper (*Trichoplusia ni*) on July 17, 62 days after planting.

Broccoli Yield Estimation

Broccoli heads were harvested on August 17, August 22, and August 30, for the 1994 experiment and August 8, 14, and 18 for the 1995 experiment. A 5.9 m section of the interior two rows within the four-row broccoli plots was harvested, with a total area of 11.8 m^2. Grading criteria were obtained from Norpac Foods, Inc., a major broccoli processor in Western Oregon. Broccoli heads were separated into three categories grade # 1, grade # 2, and cull. Grade # 1 heads are fresh, tender, and have good characteristic color, compact, firm heads, and are free from damage, insects, diseases, pittiness, scars, discoloration, or mechanical damage. Grade # 2 heads are usable but not grade # 1 quality and are not culls. Heads may be affected to a small degree by over-maturity, yellow buds, insect or mechanical damage. Cull heads are over-mature, with insect damage, or more than 25 aphids per head. Total fresh weights were recorded for each grade category. Ten broccoli heads were randomly selected from each sample and head length and width measurements were made. The percentage of broccoli heads with hollow stem was also recorded.

The yield data were analyzed using GLM procedures (SAS, 1990). Mean separation was made using F-protected LSD with an F-distribution at a .05 probability level.

Nitrogen fertilizer equivalence contribution by cover crops was calculated by comparing the broccoli yield in the fallow at the N fertilizer rate where no further significant yield increase is obserbed with the broccoli yield under the cover crop treatments at the different N fertilizer rates.

Temperature, relative humidity, and rainfall data were obtained from the meteorological monitoring equipment at the Oregon State University (OSU) Lewis Brown Farm and are given in the Appendices, Figs. A-1 to A-6. This location is approximately 2 miles from the Vegetable Research Farm where this research was conducted.

Results

1994 Experiment

Cover crop biomass and nitrogen contribution. Cover crop dry matter biomass production increased dramatically from March 29, to April 26, 1994, (Tables 2.1 and 2.2). On the March 29 sampling date, dry matter biomass of 'Monida' oats as a sole crop and the cover crop mixtures did not differ statistically, and was greater than the biomass production of the other cover crop treatments. Hairy vetch produced the lowest biomass with an average of 1,043 kg/ha, but that did not differ significantly from Austrian peas with an average of 1,299 kg/ha, cereal rye with an average of 1,538 kg/ha, and the mixture of cereal rye plus hairy vetch with an average of 1,787 kg/ha (Table 2.1). On April 26, six days before the cover crops were killed, the mixture of cereal rye plus Austrian peas produced the greatest dry matter biomass with an average of 5,896 kg/ha, but that did not differ significantly from the mixture of 'Monida' oats plus Austrian peas, 'Monida' oats plus hairy vetch, and cereal rye. Austrian peas as a sole crop produced smallest dry matter biomass with an average of 2,980 kg/ha; however, that did not differ significantly from hairy vetch, 'Monida' oats, cereal rye as a sole crop, and the mixture of cereal rye plus hairy vetch (Table 2.2).

For both cover crop sampling dates, legume cover crops in pure stands and in mixtures accumulated the greatest amount of above-ground N (Tables 2.1 and 2.2). On March 29, Austrian peas as a sole crop and the mixture of cereal rye plus Austrian peas accumulated the greatest amount of N with an average of 46 kg/ha; however, that did not differ significantly from hairy vetch as a sole crop with an average of 42 kg N/ha or cereal rye plus hairy vetch with an average of 35 kg N/ha. 'Monida' oats as sole crop produced the least amount of N with an average of 20 kg N/ha, but that did not differ significantly from the cereal rye as sole crop with an average of 23 kg N/ha and the mixture of 'Monida' oats with Austrian peas and hairy vetch, and cereal rye with hairy vetch (Table 2.1).

On April 26, hairy vetch accumulated the greatest quantity of N (131 kg N/ha), but that did not differ significantly from Austrian peas as a sole crop and the cover crop mixtures (Table 2.2). 'Monida' oats as a sole crop accumulated the smallest amount of N with an average of 22 kg N/ha, but that did not differ significantly from the cereal rye as a sole crop which accumulated an average of 39 kg N/ha (Table 2.2). The legumes showed a rapid increase in the amount of N accumulated from March 29 to April 26. Hairy vetch N accumulation increased by more than three times, from 42 kg N/ha on March 29, to 131 kg N/ha on April 26. Austrian peas N accumulation nearly doubled, from 46 kg N/ha on March 29 to 86 kg N/ha on April 26 (Fig. 2.1). Cereal rye as a sole crop increased from 23 kg N/ha on March 29 to 39 kg N/ha on April 26, whereas 'Monida' oats as a sole crop increased just 2 kg N/ha from March 29 to April 26, 1994 (Fig. 2.1).

1995 Experiment

Cover crop biomass and nitrogen contribution. On the March 28, 1995, 'Monida' oats as a sole crop produced the greatest amount of dry matter biomass with an average of 3,650 kg/ha, but this production did not differ significantly from that of the mixtures of 'Monida' oats plus Austrian peas with an average of 2,633 kg/ha and 'Monida' oats plus hairy vetch with an average of 3,513 kg/ha. On April 25, sampling, cereal rye as a sole crop yielded the greatest amount of dry matter biomass with an average of 6,597 kg/ha, but this did not differ significantly from that of the 'Monida' oats as a sole crop with an average of 6,487 kg/ha and the mixtures. Hairy vetch as a sole crop yielded the lowest amount of dry matter biomass with an average of 1,481 kg/ha, but this did not differ significantly from the Austrian peas as a sole crop with an average of 1,750 kg/ha (Table 2.4). The legumes as a sole crop yielded the lowest amount of dry matter biomass at both sampling dates (Tables 2.3 and 2.4), perhaps because of the severe competition with Persian speedwell (*Veronica persica* Poir), during the winter and spring.

On March 28, the mixture of cereal rye plus hairy vetch accumulated the greatest amount of N with an average of 49 kg/ha; however, that did not differ significantly from 'Monida' oats as a sole crop with an average of 49 kg N/ha and the mixture of 'Monida' oats plus hairy vetch with an average of 47 kg N/ha (Table 2.3). Moreover, that did not differ significantly from cereal rye plus Austrian peas with an average of 43 kg N/ha, cereal rye as a sole crop and the mixture of 'Monida' oats plus Austrian peas, both, with an average of 35 kg N/ha. Hairy vetch as a sole crop accumulated the least amount of N with an average of 12 kg N/ha, but that did not differ significantly from Austrian peas as a sole crop with an average of 23 kg N/ha.

On April 25, again the mixture of cereal rye plus hairy vetch accumulated the greatest quantity of N of 94 kg N/ha, although that did not differ significantly from the sole crops and the mixture of cereal rye plus Austrian peas, and 'Monida' oats plus hairy vetch (Table 2.4). The mixture of 'Monida' oats plus

Austrian peas produced the least amount of N with an average of 45 kg N/ha, but that did not differ significantly from the sole crops and the mixture of cereal rye plus Austrian peas, and 'Monida' oats plus hairy vetch. The legumes as a sole crop did not accumulate as much N as the previous year, likely because of the poor stand due to a competition with Persian speedwell, as mentioned earlier. However, hairy vetch N accumulation increased by about five times, from 12 kg N/ha on March 28, 1995, to 55 kg N/ha on April 25. Austrian peas total N accumulation increased nearly three-fold during this period, from 23 kg N/ha on March 28 to 67 kg N/ha on April 25 (Fig. 2.2). Cereal rye as a sole crop nearly doubled the N accumulation from 35 kg N/ha on March 28 to 75 kg N/ha on April 25, and 'Monida' oats as a sole crop increased just 5 kg N/ha from March 28 to April 25, 1995 (Fig. 2.2).

Nitrogen Contribution from Weeds

A more complete description of the cover crop effect on weeds is included in Chapter 3. The discussion here will focus on N contribution from weeds in the cover crops. Because all cover crop treatments significantly reduced weed biomass compared to the fallow, the fallow treatment accumulated the greatest amount of N from the weeds, with an average of 42 kg N/ha (Fig. 2.3). Weeds in 'Monida' oats as a sole crop produced the lowest amount of N with an average of 6 kg N/ha, but this did not differ significantly from weed biomass in cereal rye as a sole crop and the mixtures. Weed biomass in legumes was intermediate between the cereal cover crops and the fallow, with Austrian peas as a sole crop producing an average of 25 kg N/ha, significantly similar to 20 kg N/ha from weeds in the hairy vetch as a sole crop (Fig. 2.3).

Land Equivalency Ratios for Biomass and Nitrogen

The land equivalency ratio (LER), or relative yield total, has been used to compare the relative performance of crops grown in polycultures with those grown as sole crops (Vandermeer, 1989a). The calculated LER value indicates the relative land area for crops grown as monocultures to give a yield equivalent to crops grown as polycultures at the same management level (Vandermeer, 1989a). The formula used to calculate the LER is:

$$LER = [(P_1/M_1) + (P_2/M_2)]$$

Where P_1 and P_2 equal the yield for the first and second crop in mixture and M_1 and M_2 equal the yield for the first and second crop in a monoculture.

The LER values for the cover crops biomass and N accumulation from the monoculture and the intercrops were calculated using the relative yield (biomass or N) of the cover crops in intercrops divided by its yield in monoculture (Vandermeer, 1989b).

LER values were calculated using the mean values from the four replications, therefore statistical comparisons for LER values were not made.

LER for 1994 experiment. There was a clear advantage for both above-ground cover crop biomass and N accumulation for all the cover crop mixtures (LER > 1). In the April 26 sampling date, the mixtures of 'Monida' oats plus Austrian peas produced a LER of 1.64 for dry matter biomass accumulation and cereal rye plus Austrian peas produced a LER of 1.60 (Table 2.5).

The 'Monida' oats plus Austrian peas mixture also produced the greatest LER value (2.06) for N accumulation (Table 2.6). These results may be due to the relatively small biomass produced by Austrian peas as a pure stand (2,980 kg/ha) and the low N accumulated from the 'Monida' oats (22 kg N/ha) and cereal rye (39 kg N/ha). However, these results are similar to those found for Sullivan (1990) using cereal rye plus hairy vetch.

LER for 1995 experiment. In the April 25 sampling date, there was a slight advantage in above-ground cover crop dry matter biomass accumulation for the mixture of cereal rye with the two legumes and the mixture of 'Monida' oats plus hairy vetch, but the mixture of 'Monida' oats plus Austrian peas did not perform as well as the sole crops (LER < 1.0) (Tables 2.7 and 2.8). Cereal rye plus hairy vetch produced the greatest LER value for above-ground biomass accumulation (1.32) and for the above-ground N accumulation (1.40) (Tables 2.7 and 2.8). 'Monida' oats plus Austrian peas produced the lowest LER value for cover crop dry matter biomass accumulation (0.80) and for above-ground N accumulation (0.77) (Tables 2.7 and 2.8). Also, the mixture of cereal rye plus Austrian peas produced a LER less than 1. In the 1995 experiment, both legumes performed poorly in the mixtures, compared to 1994, and this would affect the calculated LER values.

Broccoli Yield for the 1994 Experiment

Broccoli Grade # 1

There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to broccoli grade # 1 yield ($p=.44$), therefore, data were pooled and analyzed by main effects. The greatest yield of broccoli grade # 1, with an average of 15,062 kg/ha was obtained following hairy vetch as a sole crop, but that did not differ significantly from those obtained following Austrian peas as a sole crop and the mixture of cereal rye plus hairy vetch (Table 2.9). The smallest broccoli grade # 1 yield, with an average of 8,792 kg/ha was obtained following 'Monida' oats as a sole crop, but did not differ significantly from those obtained following cereal rye as a sole crop and the mixture of 'Monida' oats plus hairy vetch (Table 2.9). Broccoli yield following the fallow treatment was equivalent to yields obtained following the cover crop mixtures and the cereal rye as a sole crop. As the N rates increased, the broccoli grade # 1 yield increased (Table 2.10).

Although there was no statistically significant interation between cover crops and N fertilizer rates in the overall experiment, it is important to note that there was no significant increase in grade # 1 yield above 180 kg N/ha in the hairy vetch, Austrian peas, and the cover crop mixtures (Fig. 2.4).

Broccoli Grade # 2 and Cull

There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to broccoli grade # 2 yield (p=.97). There was no significant difference among cover crop treatments; therefore, data were summarized by nitrogen effects. The greatest broccoli grade # 2 yield was obtained with the 90 kg N/ha treatment with an average of 1,497 kg/ha (Table 2.11). The least broccoli grade # 2 yield was obtained with the highest N fertilizer rate (270 kg N/ha) with an average of 434 kg/ha, but that did not differ significantly from the 180 kg N/ha treatment (Table 2.12). Broccoli cull yields were less than 0.5% of the total broccoli production in all cover crops and N treatment combinations (data not shown).

Nitrogen Fertilizer Equivalency for the 1994 Experiment

Because there was no significant increase in yield detected between the 180 and 270 kg N/ha rates in the fallow, the 180 kg N/ha yield were chosen to evaluate N fertilizer equivalency contribution of the cover crops. Total broccoli yields following hairy vetch, Austrian peas plus the application of 90 N/ha, were statistically equivalent to the yields obtained following the fallow with the application of 180 kg N/ha (Table 2.13). Also, broccoli yields following the mixture of cereal rye plus hairy vetch with 90 kg N/ha and 'Monida' oats plus

Austrian peas were equivalent to those of broccoli after the fallow at 180 kg N/ha (Table 2.13). These results indicate that these cover crop treatments crop produced an equivalent N fertilizer value of 90 kg/ha.

Broccoli Head Diameter, Weight, and Hollow Stem, 1994

Broccoli head diameter. There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to broccoli head diameter (p=.17), therefore, data were pooled and analyzed by main effects. The legume cover crops produced greater broccoli head diameter than did the cereal cover crops, but statistically similar to that from the mixtures (Table 2.14). Increasing N rates up to 180 kg N/ha increased the head diameter, but no significant increase was observed at the greatest N rate (Table 2.15).

Broccoli head weight. There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to broccoli head weight (p=.41), therefore, data were pooled and analyzed by main effects. Head weight exhibited similar trends to that of broccoli diameter, with the legume cover crop and the cereal rye plus hairy vetch mixture producing significantly greater head weight than the cereal cover crops (Table 2.14). The legumes also produced significantly larger head weights than did the fallow treatment. Head weight increased as the N rates increased (Table 2.15).

Broccoli with hollow stem. There was no statistically significant interaction between cover crop treatments and N fertilizer in relation to the percentage of broccoli heads with hollow stem (p=.11), therefore, data were pooled and analyzed by main effects. The legume cover crops produced highest percentage of broccoli heads with hollow stem, significantly greater than following the cereals or the fallow (Table 2.14). This is apparently related to the N contribution from these legumes and the correspondingly large head diameter.

The lowest percentage of broccoli heads with hallow stem with 15 percent was obtained following the mixture of 'Monida' oats plus hairy, but it was not statistically different from the 'Monida' oats and cereal rye in pure stands, the mixture of cereal rye plus hairy vetch, and the fallow (Table 2.14).

As the N rates increased, the percentage of broccoli heads with hollow stem increased (Table 2.15). This physiological disorder can impact the quality of broccoli for fresh market because the hollow stem area is visible at the base of the stem. This effect on the appearance quality of the produce is noticeable at the display counter, thus affecting the marketability of broccoli. Hollow stem does not, however, represent a serious problem for broccoli that is used for processing (Hipp, 1973; Jim Schwab, Norpac Foods Inc., personal communication).

Broccoli Yield for the 1995 Experiment

Broccoli Grade # 1

There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to broccoli grade # 1 yield (p=.49), therefore, data were pooled and analyzed by main effects. The greatest yield of broccoli grade # 1, with an average of 13,213 kg/ha was obtained following hairy vetch as a sole crop, but that did not differ significantly from Austrian peas as a sole crop with an average of 11,660 kg/ha (Table 2.9). The smallest broccoli grade # 1 yield, with an average of 6,370 kg/ha was obtained following 'Monida' oats as a sole crop, but did not differ significantly from cereal rye as a sole crop with an average of 8,142 kg/ha (Table 2.9). The broccoli yield at the fallow treatment was equivalent to those obtained following the Austrian peas as a sole crop and the mixtures of cereal rye with both legumes and the mixture of 'Monida' oats plus hairy vetch. As the N rates increased, the broccoli grade # 1 yield increased (Table 2.10).

When examining the effects of increasing N fertilizer from 180 kg/ha to 270 kg/ha for each individual cover crop treatment (as was done for the 1994 data), six of the nine cover crop treatments showed a significant increase in yields (Fig. 2.5). Only 'Monida' oats, hairy vetch, and Austrian peas showed a non-significant yield increase at the highest N fertilizer rate (Fig. 2.5), however the relatively low p-values (0.16, 0.10, and 0.11 respectively) suggests an N-fertilizer effect in these treatments as well. Therefore, these analyses support the general N-fertilizer response as shown in Table 2.10.

Broccoli Grade # 2 and Cull

The greatest broccoli grade # 2 yield was at all combinations of cover crop treatments and 90 kg N/ha, except Austrian peas producing the greatest broccoli grade # 2 yield at the 90 kg N/ha rate. The fallow plus 90 kg N/ha produced the greatest broccoli grade # 2 yield, with an average of 3,688 kg/ha and 'Monida' oats and cereal rye as sole crop and the mixture of 'Monida' oats plus Austrian peas and cereal rye plus Austrian peas did not produce any broccoli grade # 2 (Fig. 2.6). Broccoli cull yields were less than 5% of the total broccoli production in all cover crops and N treatment combinations (data not shown).

Nitrogen Fertilizer Equivalency for the 1995 Experiment

As in 1994, total broccoli yields did not increase significantly in the fallow treatment at the largest N rate, therefore the 180 kg N/ha rate was chosen for the N fertilizer equivalency analysis. Total broccoli yields, following hairy vetch plus the application of 90 kg N/ha, were statistically equivalent to the yields obtained from the fallow with the application of 180 kg N/ha (Table 2.16). These results indicate that hairy vetch produced an equivalent N fertilizer value of 90 kg/ha.

Broccoli Head Diameter, Weight, and Hollow Stem

Broccoli head diameter. There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to broccoli head diameter (p=.98), therefore, data were pooled and analyzed by main effects. Head diameter following the fallow and Austrian peas were significantly greater than those following the cereals, but statistically similar to those following hairy vetch and the cover crop mixtures (Table 2.17). There was not significant increase in the broccoli head diameter from 0 kg N/ha to 90 kg N/ha, but there was up to 180 kg N/ha (Table 2.18).

Broccoli head weight. There was no statistically significant interaction between cover crop treatments and N fertilizer rates in relation to weight of the broccoli heads (p=.33), therefore, data were pooled and analyzed by main effects. As in 1994, the legumes produced significantly greater head weights than the cereal cover crops, however, there was no significant increase over the fallow (Table 2.17). The cover crop mixtures all produced similar weight to the fallow and Austrian peas. As the N rates increased, the head weight increased (Table 2.18).

Broccoli with hollow stem. There was no statistically significant interaction between cover crop treatments and N fertilizer in relation to the percentage of broccoli heads with hollow stem (p=.78). Therefore, data were pooled and analyzed by main effects. The percentage of broccoli heads with hollow stem following hairy vetch cover crop was greater than following the cereals, but significantly similar to that following the other cover crop treatments (Table 2.17). There was no significant difference between the legumes and the fallow. As with the trends for head diameter and weight, the N rates increased, the percentage of broccoli heads with hollow stem increased (Table 2.18).

Discussion

There was a year by year variation in the amount of N accumulation from the cover crops. In 1994, hairy vetch and Austrian peas as a sole crop produced as much as 131 and 86 kg N/ha respectively, while in 1995, produced just 55 and 67 kg N/ha. That was due to the poor growth of the legumes in 1995 in contrast to the greater amount of dry matter produced by the legumes in 1994. 'Monida' oats accumulated 22 kg N/ha in 1994, however accumulated 56 kg N/ha in 1995. The mixture of cereal rye plus hairy vetch was consistent in both years with a total N accumulation of 93 and 94, respectively, kg N/ha in each year.

Hairy vetch as a sole crop produced up to 90 kg N/ha N fertilizer equivalent in both years, supporting the finding by Holderbaum et al. (1990), Hargrove (1986), Utomo et al. (1990), McVay et al. (1989), Ebelhar et al. (1984), Morse and Seward (1986), Tyler et al. (1987), and Wagger (1989) using other crops.

The greatest broccoli yields were obtained following hairy vetch as a sole crop in both years of the study, across N rates supporting the study of Blevins et al. (1990) reporting that corn grain yields after hairy vetch cover crop were greater than other legumes or cereal cover crops.

Broccoli following 'Monida' oats cover crop seems to experience some delay in growth, and produced smaller plants, especially in the lowest N treatments. 'Monida' oats may be producing some allelopathic compounds that could affect broccoli germination and/or growth and these effects are reflected in weed suppression (see Chapter 3). That effect may be related to the finding by Huber and Abney (1986) and Mason-Sedun et al. (1986) that decomposing plant residues left on the soil surface may produce phytotoxins which may be harmful to germination and/or plant growth.

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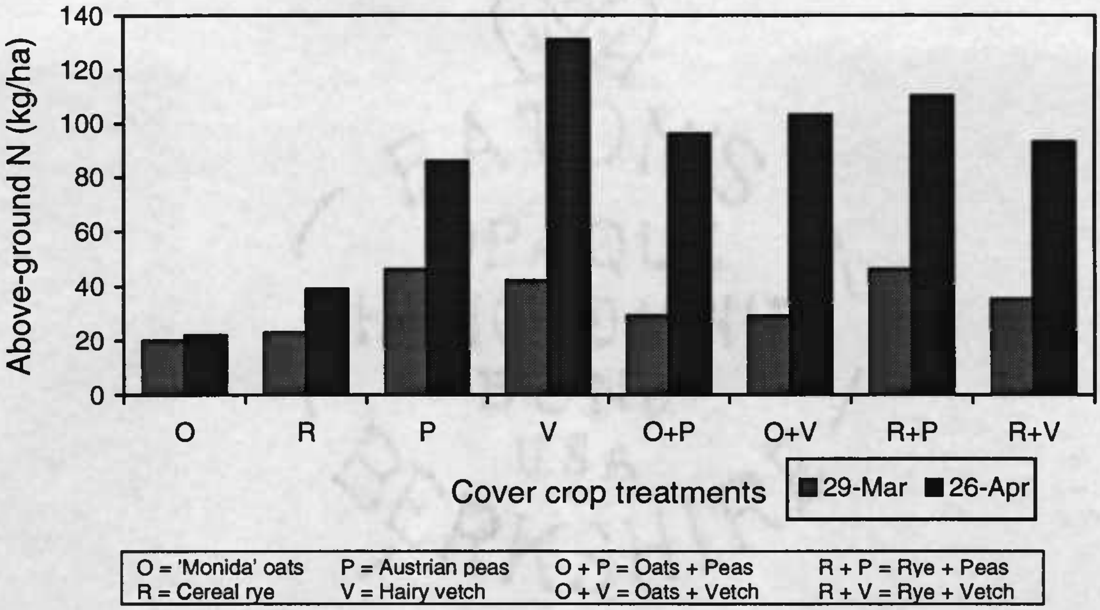

Figure 2.1. Effects of spring growth on cover crop nitrogen accumulation, 1994.

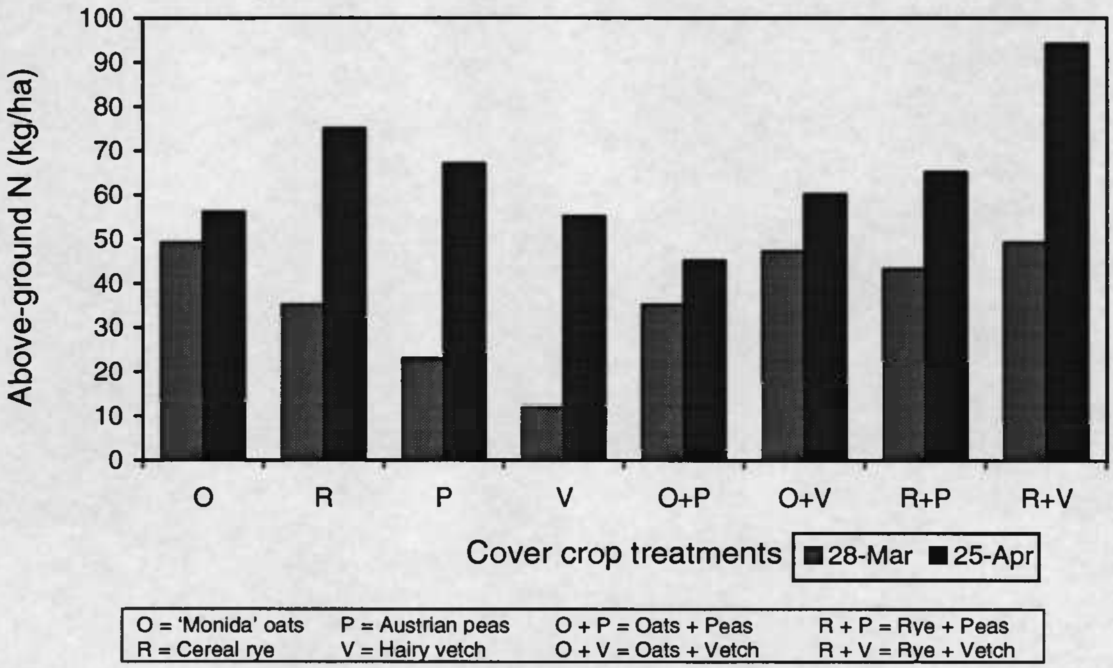

Figure 2.2. Effects of spring growth on cover crop nitrogen accumulation, 1995.

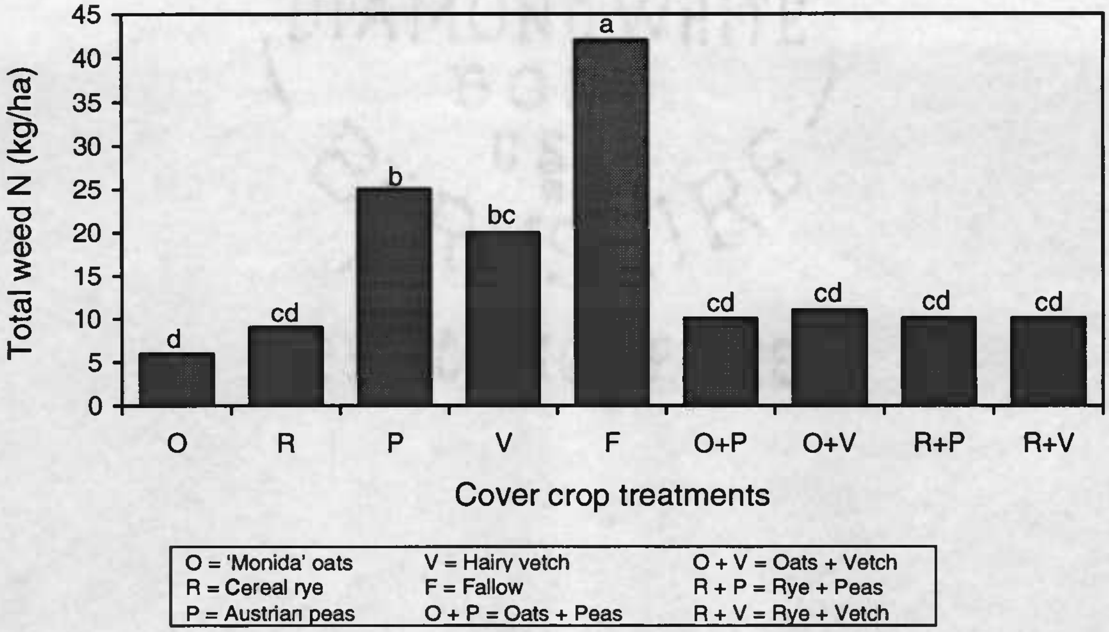

Figure 2.3. Total of nitrogen contribution from weed dry matter biomass within the cover crops, April 25, 1995. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, $\alpha = .05$).

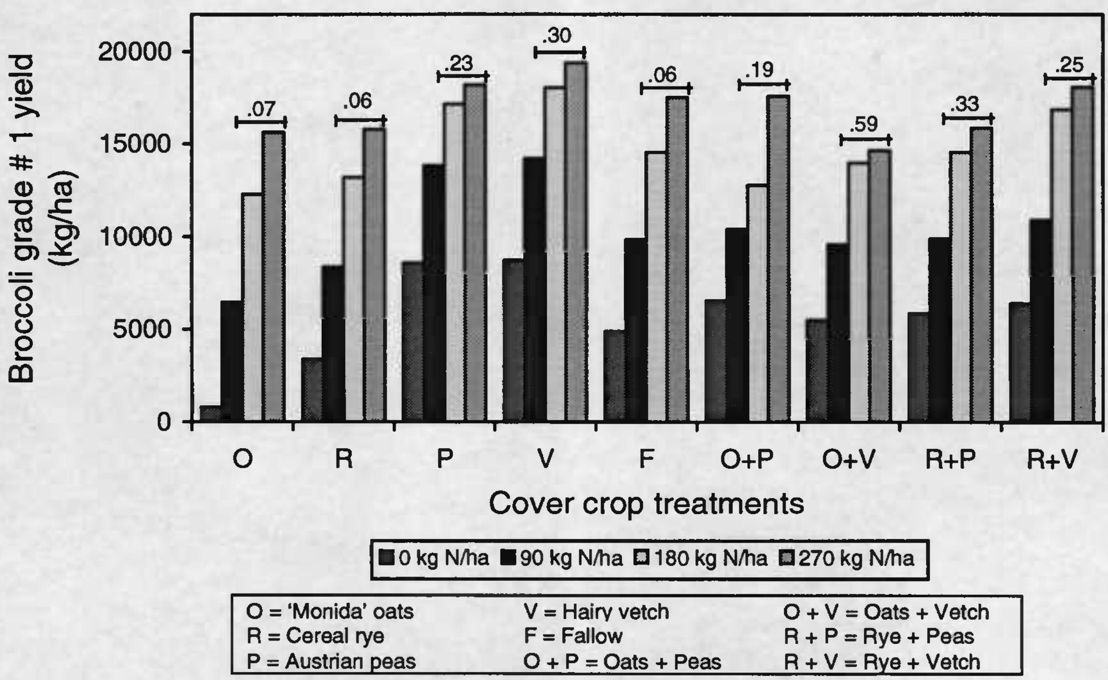

Figure 2.4. Effects of cover crops and N fertilizer rates on broccoli grade # 1 yield, 1994. Values above the bars indicate p-values for statistical significance for differences in yield in the highest two N rates, using Student's t-test.

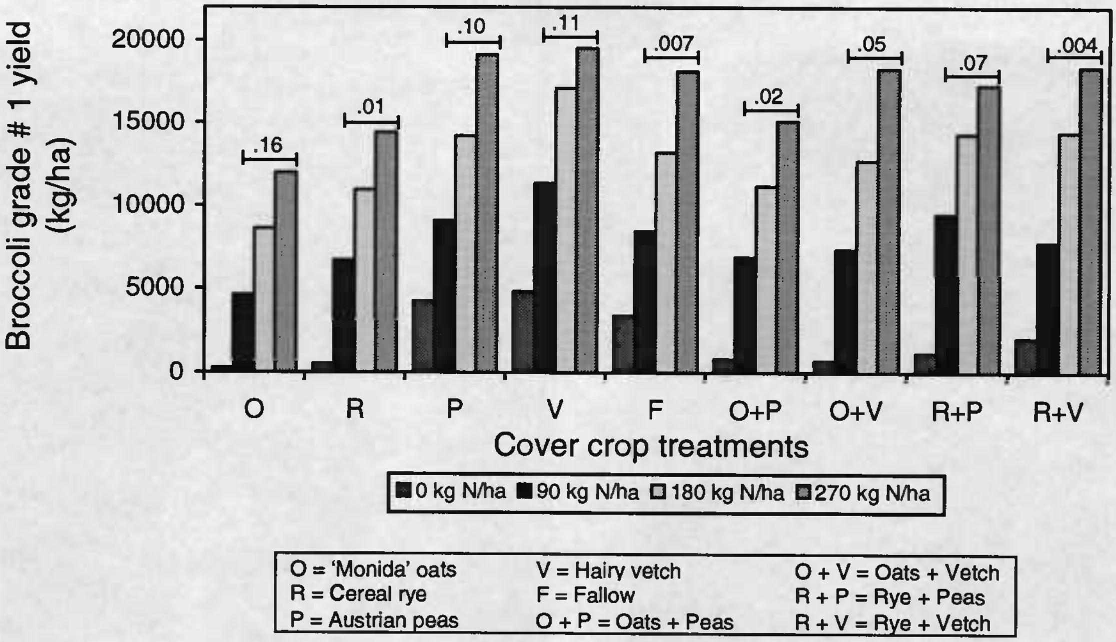

Figure 2.5. Effects of cover crops and N fertilizer rates on broccoli grade # 1 yield, 1995. Values above the bars indicate p-values for statistical significance for differences in yield in the highest two N rates, using Student's t-test.

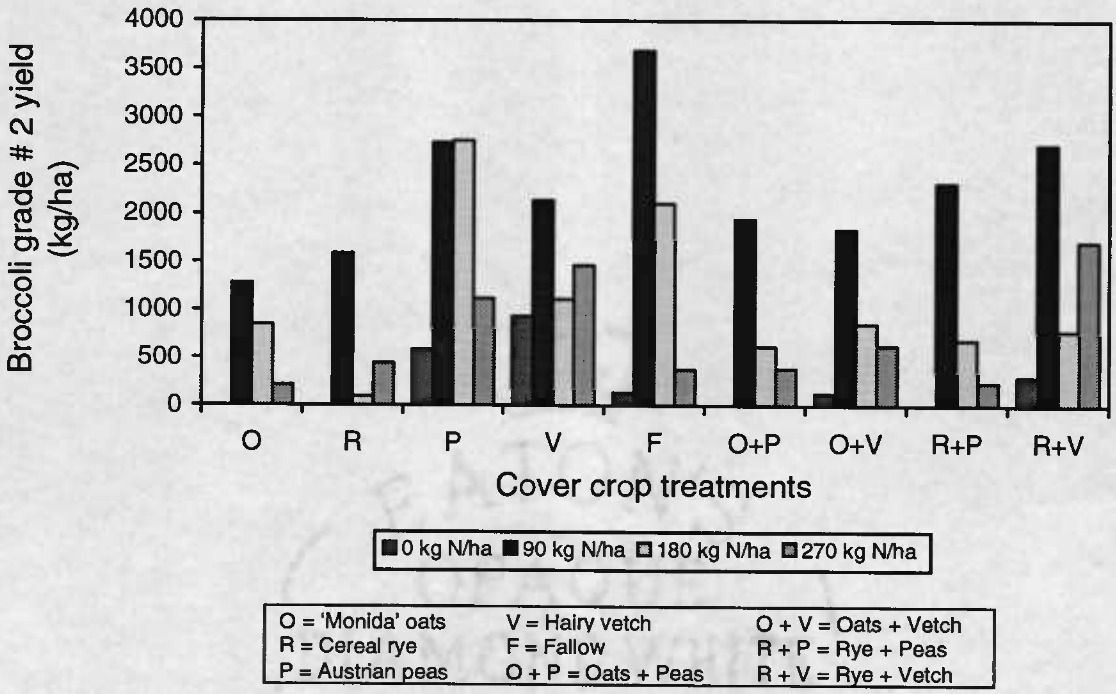

Figure 2.6. Effects of cover crops and N fertilizer rates on broccoli grade # 2 yield, 1995.

Table 2.1. Above-ground dry matter biomass and nitrogen accumulation by cover crops, March 29, 1994.

Cover crop treatments	Total biomass (kg/ha)	Percent nitrogen	Total nitrogen (kg/ha)
'Monida' oats	2,370 a*	0.84	20 c
Cereal rye	1,538 bc	1.50	23 c
Austrian peas	1,299 bc	3.54	46 a
Hairy vetch	1,043 c	4.03	42 ab
Mixtures			
'Monida' oats + Austrian peas	2,000 ab	1.45	29 bc
'Monida' oats	1,595	1.00	16
Austrian peas	405	3.21	13
'Monida' oats + hairy vetch	2,551 a	1.14	29 bc
'Monida' oats	2,297	0.87	20
Hairy vetch	254	3.54	9
Cereal rye + Austrian peas	2,080 ab	2.21	46 a
Cereal rye	1,413	1.63	23
Austrian peas	667	3.45	23
Cereal rye + hairy vetch	1,787 abc	1.96	35 abc
Cereal rye	1,206	1.16	14
Hairy vetch	581	3.61	21

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$. Individual components of the mixtures are not included in the analysis.

Table 2.2. Above-ground dry matter biomass and nitrogen accumulation by cover crops, April 26, 1994.

Cover crop treatments	Total biomass (kg/ha)	Percent nitrogen	Total nitrogen (kg/ha)
'Monida' oats	3,917 bc*	0.56	22 b
Cereal rye	4,428 abc	0.88	39 b
Austrian peas	2,980 c	2.89	86 a
Hairy vetch	3,863 bc	3.39	131 a
Mixtures			
'Monida' oats + Austrian peas	5,733 ab	1.67	96 a
'Monida' oats	3,490	0.80	28
Austrian peas	2,243	3.03	68
'Monida' oats + hairy vetch	5,516 ab	1.87	103 a
'Monida' oats	3,291	0.73	24
Hairy vetch	2,225	3.55	79
Cereal rye + Austrian peas	5,896 a	1.87	110 a
Cereal rye	3,494	1.06	37
Austrian peas	2,402	3.04	73
Cereal rye + hairy vetch	4,302 bc	2.16	93 a
Cereal rye	2,183	0.92	20
Hairy vetch	2,119	3.45	73

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$. Individual components of the mixtures are not included in the analysis.

Table 2.3. Above-ground dry matter biomass and nitrogen accumulation by cover crops, March 28, 1995.

Cover crop treatments	Total biomass (kg/ha)	Percent nitrogen	Total nitrogen (kg/ha)
'Monida' oats	3,650 a*	1.29	49 a
Cereal rye	1,927 c	1.83	35 ab
Austrian peas	540 d	4.23	23 bc
Hairy vetch	251 d	4.62	12 c
Mixtures			
'Monida' oats + Austrian peas	2,633 abc	1.33	35 ab
'Monida' oats	2,493	1.18	29
Austrian peas	140	4.13	6
'Monida' oats + hairy vetch	3,513 ab	1.34	47 a
'Monida' oats	3,385	1.17	41
Hairy vetch	128	4.28	6
Cereal rye + Austrian peas	1,990 c	2.16	43 ab
Cereal rye	1,725	1.77	31
Austrian peas	265	4.05	12
Cereal rye + hairy vetch	2,407 bc	2.04	49 a
Cereal rye	2,204	1.76	39
Hairy vetch	203	4.59	10

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$. Individual components of the mixtures are not included in the analysis.

Table 2.4. Above-ground dry matter biomass and nitrogen accumulation by cover crops, April 25, 1995.

Cover crop treatments	Total biomass (kg/ha)	Percent nitrogen	Total nitrogen (kg/ha)
'Monida' oats	6,487 a*	0.86	56 ab
Cereal rye	6,597 a	1.13	75 ab
Austrian peas	1,750 b	3.87	67 ab
Hairy vetch	1,481 b	3.70	55 ab
Mixtures			
'Monida' oats + Austrian peas	4,312 a	1.04	45 b
'Monida' oats	3,986	0.90	35
Austrian peas	326	3.13	10
'Monida' oats + hairy vetch	5,030 a	1.19	60 ab
'Monida' oats	4,526	0.91	42
Hairy vetch	505	3.42	18
Cereal rye + Austrian peas	5,361 a	1.21	65 ab
Cereal rye	4,855	1.06	48
Austrian peas	506	3.28	17
Cereal rye + hairy vetch	6,002 a	1.57	94 a
Cereal rye	5,229	1.19	64
Hairy vetch	774	3.84	30

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$. Individual components of the mixtures are not included in the analysis.

Table 2.5. Total dry matter accumulation and land equivalency ratios (LER) of cover crop mixtures, April 26, 1994.

	Biomass (kg/ha)			
Cover crop treatments	Total	Cereal	Legume	LER
'Monida' oats + Austrian peas	5,733	3,490	2,243	1.64
'Monida' oats + hairy vetch	5,516	3,291	2,225	1.42
Cereal rye + Austrian peas	5,896	3,494	2,402	1.60
Cereal rye + hairy vetch	4,302	2,183	2,119	1.04

Table 2.6. Total N accumulation and land equivalency ratios (LER) of cover crop mixtures April 26, 1994.

	Total Nitrogen (kg/ha)			
Cover crop treatments	Total	Cereal	Legume	LER
'Monida' oats + Austrian peas	96	28	68	2.06
'Monida' oats + hairy vetch	103	24	79	1.69
Cereal rye + Austrian peas	110	37	73	1.80
Cereal rye + hairy vetch	93	20	73	1.07

Table 2.7. Total dry matter accumulation and land equivalency ratios (LER) of cover crop mixtures, April 25, 1995.

	Biomass (kg/ha)			
Cover crop treatments	Total	Cereal	Legume	LER
'Monida' oats + Austrian peas	4,312	3,986	326	0.80
'Monida' oats + hairy vetch	5,030	4,526	504	1.04
Cereal rye + Austrian peas	5,361	4,855	506	1.03
Cereal rye + hairy vetch	6,002	5,229	774	1.32

Table 2.8 Total N accumulation and land equivalency ratios (LER) of cover crop mixtures April 25, 1995.

	Total Nitrogen (kg/ha)			
Cover crop treatments	Total	Cereal	Legume	LER
'Monida' oats + Austrian peas	45	35	10	0.77
'Monida' oats + hairy vetch	60	42	18	1.08
Cereal rye + Austrian peas	65	48	17	0.89
Cereal rye + hairy vetch	94	64	30	1.40

Table 2.9. Effects of cover crops on broccoli grade # 1 yield (averaged over N fertilizer rates), 1994 and 1995.

	Broccoli yield (kg/ha)	
Cover crop treatments	1994	1995
'Monida' oats	8,792 e*	6,370 d
Cereal rye	10,155 de	8,142 cd
Austrian peas	14,402 ab	11,660 ab
Hairy vetch	15,062 a	13,213 a
Fallow	11,703 cd	10,805 b
'Monida' oats + Austrian peas	12,240 bcd	8,503 c
'Monida' oats + hairy vetch	10,796 cde	9,767 bc
Cereal rye + Austrian peas	11,537 cd	10,555 b
Cereal rye + hairy vetch	13,052 abc	10,675 b

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.10. Effects of N fertilizer rates on broccoli grade # 1 yield (averaged over cover crop treatments), 1994 and 1995.

	Broccoli yield (kg/ha)	
Nitrogen treatments	1994	1995
0 kg N/ha	5,628 d*	2,005 d
90 kg N/ha	10,477 c	7,973 c
180 kg N/ha	14,835 b	12,962 b
270 kg N/ha	16,944 a	16,922 a

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.11. Effects of cover crops on broccoli grade # 2 yield (averaged over N fertilizer rates), 1994.

Cover crop treatments	Broccoli yield (kg/ha)
'Monida' oats	689 a*
Cereal rye	470 a
Austrian peas	896 a
Hairy vetch	1,389 a
Fallow	819 a
'Monida' oats + Austrian peas	1,059 a
'Monida' oats + hairy vetch	953 a
Cereal rye + Austrian peas	512 a
Cereal rye + hairy vetch	1,210 a

*Means followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.12. Effects of N fertilizer rates on broccoli grade # 2 yield (averaged over cover crop treatments), 1994.

Nitrogen treatments	Broccoli yield (kg/ha)
0 kg N/ha	962 b*
90 kg N/ha	1,497 a
180 kg N/ha	661 bc
270 kg N/ha	434 c

*Means followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.13. Cover crops and N fertilizer rate treatments with statistically equivalent total broccoli yield compared to fallow plus 180 kg N/ha (F-protected LSD, $\alpha = .05$), 1994.

Cover crop treatments	N Rate (kg/ha)	Yield means (kg/ha)
Fallow	180	15,052
Austrian peas	90*	15,649
Hairy vetch	90	16,323
'Monida' oats + Austrian peas	90	13,211
Cereal rye + hairy vetch	90	12,432

* Indicates that cover crops are providing 90 kg/ha of N fertilizer equivalent.

Table 2.14. Effects of cover crop treatments on broccoli head diameter, weight, and the percentage of heads with hollow stem (averaged over N fertilizer rates), 1994.

Cover crop treatments	Head diameter (cm)	Head weight (kg)	Heads with hollow stem (%)
'Monida' oat	11.6 b*	0.17 d	17 cde
Cereal rye	11.6 b	0.16 d	16 de
Austrian peas	13.1 a	0.22 ab	31 ab
Hairy vetch	12.9 a	0.23 a	38 a
Fallow	12.3 ab	0.18 cd	22 bcde
'Monida' oat + Austrian peas	12.2 ab	0.19 bcd	27 abcd
'Monida' oat + hairy vetch	12.3 ab	0.17 d	15 e
Cereal rye + Austrian peas	12.4 ab	0.18 cd	28 abc
Cereal rye + Hairy vetch	12.9 a	0.21 abc	26 bcde

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.15. Effects of N fertilizer rates on broccoli head area and head weight, and percentage of broccoli heads with hollow stem (averaged over cover crop treatments), 1994.

Nitrogen treatments	Head diameter (cm)	Head weight (kg)	Heads with hollow stem (%)
0 kg N/ha	9.9 c*	0.11 d	2 d
90 kg N/ha	11.9 b	0.18 c	16 c
180 kg N/ha	13.8 a	0.22 b	36 b
270 kg N/ha	13.9 a	0.24 a	44 a

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.16. Cover crops and N fertilizer rate treatments with statistically equivalent total broccoli yield compared to fallow plus 180 kg N/ha (F-protected LSD, $\alpha = .05$), 1995.

Cover crop treatments	N Rate (kg/ha)	Yield means (kg/ha)
Fallow	180	15,909
Hairy vetch	90*	13,665

* Indicates that cover crops are providing 90 kg/ha of N fertilizer equivalent.

Table 2.17. Effects of cover crop treatments on broccoli head diameter, weight, and the percentage of heads with hollow stem (averaged over N fertilizer rates), 1995.

Cover crop treatments	Head diameter (cm)	Head weight (kg)	Heads with hollow stem (%)
'Monida' oat	10.8 c*	0.22 c	7 bc
Cereal rye	11.3 bc	0.24 c	5 c
Austrian peas	13.6 a	0.28 ab	12 ab
Hairy vetch	12.4 abc	0.30 a	15 a
Fallow	13.8 a	0.28 ab	10 abc
'Monida' oat + Austrian peas	11.4 abc	0.25 bc	10 abc
'Monida' oat + hairy vetch	11.8 abc	0.25 bc	10 abc
Cereal rye + Austrian peas	12.1 abc	0.25 bc	9 bc
Cereal rye + Hairy vetch	12.4 abc	0.26 bc	10 abc

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 2.18. Effects of N fertilizer rates on broccoli head area and head weight, and the percentage of broccoli heads with hollow stem (averaged over cover crop treatments), 1995.

Nitrogen treatments	Head diameter (cm)	Head weight (kg)	Heads with hollow stem (%)
0 kg N/ha	9.4 b*	0.15 d	0.4 d
90 kg N/ha	9.5 b	0.24 c	4.0 c
180 kg N/ha	14.2 a	0.29 b	12.8 b
270 kg N/ha	15.5 a	0.34 a	21.4 a

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Chapter 3

Effect of Cereal and Legume Cover Crops on Weed Germination and Growth in Broccoli, *Brassica oleracea* var. *italica*

Abstract

Field experiments were conducted in 1994 and 1995 at the OSU Vegetable Research Farm near Corvallis, OR. The objectives were to evaluate the competitive effects of selected cereal and legume cover crops on weed biomass within the cover crop and to evaluate the effects of cover crops on weed germination, density, and biomass in a succeeding broccoli crop. Two cereal and legume cover crop cultivars were evaluated as sole crops and as mixtures. They included 'Monida' oats (*Avena sativa* L.), cereal rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth), Austrian peas (*Pisum sativum* L. ssp. *arvense* (L.) Poir.), cereal rye plus hairy vetch, cereal rye plus Austrian peas, 'Monida' oats plus hairy vetch, 'Monida' oats plus Austrian peas. A fallow treatment was used as a control. Cover crops were arranged in a randomized block design with nine treatments and four replications. After the cover crops were flailed-mowed and incorporated, 'Hybrid Excelsior' broccoli was direct-seeded. A 60-cm strip was left between each four rows of broccoli for the weed study. For the 1995, experiment, four N rates (0, 90, 180, and 270 kg/ha) were split within each weed strip treatment.

In 1994 both cereals, 'Monida' oats and cereal rye as a sole crop, significantly reduced weed emergence when compared to the fallow control. 'Monida' oats reduced hairy nightshade (*Solanum sarrachoides* Sendtner), emergence by 59%, shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.) by 97%, and common groundsel (*Senecio vulgaris* L.) by 82% compared to the

fallow control. Cereal rye reduced nightshade by 48%, shepherdspurse by 95%, and common groundsel by 64%. The legume cover crops appeared to stimulate shepherdspurse emergence; Austrian peas and hairy vetch increased shepherdspurse emergence by 18% and 45% respectively compared to the fallow control.

Weed biomass following 'Monida' oats was significantly less than for all other treatments. Plots planted to legumes produced the greatest amount of weed biomass. The N coming from the legumes likely stimulated the weed growth. This legume N effect was apparent in the recovery of the weeds in the cover crop mixtures.

For the 1995 experiment, 'Monida' oats with no N fertilizer reduced total weeds by 54% and cereal rye by 44% compared with the fallow. The legumes stimulated the germination of hairy nightshade and Persian speedwell (*Veronica persica* Poir.). The influence of N fertilizer on weed germination varied among the different cover crop treatments. At each N rate (90, 180, and 270 kg N/ha) the fallow produced more weed biomass than did the cereals as a sole crop and 'Monida' oats in mixtures with both legumes. No weed suppressiveness was observed following the legume sole crops; however, only peas at 90 kg N/ha produced more weed dry biomass than did the fallow at the same N rate.

Introduction

Cover crops in crop production represent a potential for weed control in conservation tillage systems that include short-term crop rotation. Cover crops are commonly established in the fall to provide a dense cover by early spring that can suppress weed germination and establishment. Cover crops can restrict weeds by direct competition, allelopathy, and with physical effects through maintaining a surface residue cover (Smeda and Putnam, 1988; Lal et al., 1991).

Residue of rye and other small grain cover crops has been shown to limit weed emergence and growth in cropping systems (Barnes and Putnam, 1983; Teasdale et al., 1991). Cereal rye is an example of a plant that can provide weed suppression through both allelopathic and competitive mechanisms (Putnam et al., 1990). Vetch and rye cover crops have been used with ridge tillage management without herbicides to provide cover that helps in controlling weeds through competition and, in the case of rye, allelopathy (Doran and Smith, 1991).

Several crops with apparent allelopathic effects on common weeds include barley (*Hordeum vulgare* L.), oats, fescue (*Festuca* spp), sorghum (*Sorghum bicolor* (L.) Moench), and sunflower (*Helianthus annuus* L.) (Leather, 1983; Leather, 1987; Putnam and DeFrank, 1983; Eihelling and Leather, 1988; Putnam et al., 1983). Several researchers have found that use of the appropriate cover crop species suppresses weeds to the extent that herbicides are not needed (Worsham, 1991; Barnes and Putnam, 1983; Putnam and DeFranck, 1983; Putnam et al., 1983). Although allelopathy often is used to explain weed suppression by residue, physical alterations of the seed environment could be important as well (Teasdale and Mohler, 1993).

The objectives of this investigation were: (1) to evaluate the competitive effects of selected cereal and legume cover crops on weed biomass within the cover crop and (2) to evaluate the effects of cover crops on weed germination, density, and biomass in a succeeding broccoli crop.

Materials and Methods

Weeds within Cover Crop

Cover crop treatments were established as described in Chapter 2. Total weed above-ground dry matter biomass accumulation was estimated by clipping weeds at the soil surface in a 0.25 m^2 quadrat at two randomly selected locations within each cover crop plot on March 29 and April 26 for the 1994 study and March 28 and April 25 for the 1995 study. Samples were taken to the laboratory and oven-dried at 60°C for 48 to 60 hours and weighed.

Cover crops were flail-mowed and incorporated on May 2, 1994, for the 1994 study and on April 26 for the 1995 study. In the 1994 study, a cover crop disk was used to incorporate the cover crop above-ground biomass and the broccoli seedbed was prepared using a Lely Roterra® (power harrow). In the 1995 study, excessive soil moisture from abnormally rainy weather precluded the use of the disc to incorporate the cover crop. Instead, the cover crop treatments were flail-mowed, then incorporated into the soil using a tractor-mounted rotovator to approximately 12 cm depth, followed by two passes of the Lely Roterra® to prepare a seedbed for broccoli planting. Broccoli was planted as described in Chapter 2. At broccoli cultivation time, a 70 cm wide strip was left without cultivation at the middle of each cover crop plot for weed sampling. Broccoli was planted and managed as described in Chapter 2.

Weeds within Broccoli

1994 Study

Estimates of total weed species density were obtained by counting in a 0.25 m^2 quadrat at two randomly selected locations within each cover crop treatment between the sets of cultivated broccoli rows on July 5, 1994, in a center strip 16.6 m long by 0.6 m wide (Fig. 3.1a). Weeds were separated into predominant species: hairy nightshade (*Solanum sarrachoides* Sendtner), common groundsel (*Senecio vulgaris* L.), shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.). All other weeds were grouped into a miscellaneous category. Sample sites were flagged for later sampling. A second sampling was taken on July 11, 1994, in the same locations in each plot as sampled earlier. Estimates of weed dry matter biomass were obtained by clipping at the soil surface in the 0.25 m^2 quadrats. Weeds were sorted as described above, placed in paper bags, and taken to the laboratory where they were oven dried at 60°C for 48 to 60 hours and weighed. The remaining weeds were cultivated after samples had been taken.

1995 Study

The experimental design was changed in the 1995 study to evaluate the possible interaction between cover crop treatments and N fertilizer rates on the germination and growth of weeds. A split plot, randomized block design was established where each cover crop treatment was the main effect and four N fertilizer rates (0, 90, 180, and 270 kg/ha) the subplots. The weed experiment was established between the sets of broccoli rows, as described earlier. Four N fertilizer rate subplots 4.15 m long by 0.6 m wide were randomly established within these strips (Fig. 3.1b). On May 24, seven days after planting, 50 kg N/ha was broadcast as urea (46-0-0) to all treatments except for the 0 kg N/ha treatment. On June 20, the remaining N for the N-rate treatments was applied in a similar manner, 27 days after the first application. Irrigation was applied to assure optimum crop growth.

Estimates of total weed species density were obtained by counting in a 1 m long by 0.25 m wide (0.25 m^2) quadrat at one randomly selected location within each N fertilizer rate plot within cover crop treatments on June 22, 1995. Weeds were separated into predominant species: hairy nightshade, common purslane (*Portulaca oleracea* L.), and Persian speedwell (*Veronica persica* Poir). All other weeds were grouped into a miscellaneous category. A second sampling was taken at the same sites on July 3, 1995, to obtain estimates of total weed dry matter biomass accumulation using the same procedures described for the 1994 study.

Analyses of variance were conducted for total weed density and weed dry matter biomass (SAS, 1990). Data were square root-transformed to nornalize variances before analyses (Little and Hill, 1978; Ott, 1988). Mean separation was made using F-protected LSD with an F-distribution at a .05 probability level.

Results

Weeds within Cover Crops, 1994

The main weeds that appeared during the cover crop growing season were: Persian speedwell, redstem filaree (*Erodium cicutarium* (L.) L'Her. ex Ait.), shepherdspurse, and common groundsel.

On both March 29 and April 26 sample dates, all cover crop treatments contained significantly smaller weed biomass than did the fallow treatment (Figs. 3.2 and 3.3). Similar amounts of weed biomass were obtained following 'Monida' oats and cereal rye, grown as a sole crop, to that of the cereals grown in mixture with the legumes (Figs. 3.2 and 3.3).

On the March 29 sample date, a significantly greater biomass of weeds were found in the hairy vetch cover crop than in the cereal cover crops or the mixtures containing cereals (Fig. 3.2). By the April 26 sample date, however, weed biomass in the hairy vetch cover crop was similar to that in all other cover crops except Austrian peas (Fig. 3.3). Significantly greater weed biomass was found in the peas than in all cover crops except for the rye and peas mixture.

Weeds within Cover Crops, 1995

On the March 28 sample date, the fallow treatment accumulated the greatest weed dry matter biomass with an average of 1,399 kg/ha, but that did not differ significantly from the Austrian peas grown as a sole crop which accumulated an average of 1,021 kg/ha of weed dry matter biomass (Fig. 3.4). The least amount of weed dry matter biomass (438 kg/ha) was obtained following 'Monida' oats, grown as a sole crop, although that did not differ significantly from the cereal rye or the cereal plus legume mixtures (Fig. 3.4).

On the April 25 sample date, the fallow treatment again had the greatest weed biomass, significantly greater than for all other cover crop treatments (Fig. 3.5). There were no significant differences among the cover crop mixtures, the cereal rye, and the legumes in monoculture. The least amount of weed dry matter biomass (679 kg/ha) was obtained following 'Monida' oats treatment as a sole crop, significantly less than the weed biomass in the legumes. The great amount of weeds in the fallow treatment and the legumes in monoculture may be due to the lack of soil cover in the fallow and the slow growth from the legumes in the fall and winter, leaving empty niches that were used by the weeds to grow during the winter. The main weeds appearing during the cover crop growing season were the same as in the 1994 study, however, Persian speedwell was more dominant.

Cover Crop Effects on Weeds in Broccoli, 1994

Weed emergence. Both 'Monida' oats and rye cover crops significantly reduced weed emergence when compared to the fallow control (Table 3.1). 'Monida' oats reduced hairy nightshade emergence by 59%, shepherdspurse by 97%, and common groundsel by 82% compared to the fallow control (Table 3.2). Cereal rye reduced nightshade by 48%, shepherdspurse by 95%, and common groundsel by 64% (Table 3.2). Total weed emergence was greatest in the vetch plots with 900 weeds/m^2, but this did not differ significantly from Austrian peas as a sole crop, the fallow, and the mixtures of 'Monida' oats plus Austrian peas and cereal rye and peas (Table 3.1). The legume cover crops appeared to stimulate shepherdspurse emergence, with Austrian peas increasing shepherdspurse density by 18% and with hairy vetch by 45% compared to the fallow control (Table 3.2). In the cereal plus legume mixtures, however, both oats and rye in combination with peas reduced shepherdspurse germination.

Weed biomass. Weed biomass following 'Monida' oats was significantly less than for all other treatments (Fig. 3.6). The legumes produced the greatest weed biomass, significantly greater than the fallow (Fig. 3.6). The N coming from the legumes likely stimulated the weed growth. This legume N effect was also apparent in the cover crop mixtures, which contained intermediate levels of weed biomass between the cereals and the legumes. Even though the fallow had a high weed density, (Table 3.1) the apparent lack of N kept the dry biomass production at the same level, statistically, as cereal rye and the mixtures of 'Monida' oats with the two legumes, and the cereal rye plus Austrian peas (Table 3.3).

Cover Crop Effects on Weeds in Broccoli 1995

Weed emergence. The predominant weed species differed from 1994, with hairy nightshade, purslane, and Persian speedwell being most abundant. Because of a significant interaction between cover crop treatments and N-rates on weed emergence and weed biomass, the effects of these treatments will be discussed separately. As in 1994, 'Monida' oats as a sole crop significantly reduced total weed emergence when compared to the fallow control in the zero N fertilizer treatment (Table 3.3). None of the individual weed species counted differed significantly from the fallow. In the 0 N-rate treatment, both legumes produced significantly greater total weed biomass than the cereals as sole crops and the mixtures of 'Monida' oats plus legumes. At the higher N rates, however, none of the cover crop treatments significantly reduced weed emergence compared to the fallow (Table 3.5).

At the 90 and 270 kg N/ha rates, hairy vetch produced significantly greater weed emergence than following the 'Monida' oats and the cereal rye, however this difference was not significant at the 180 kg N/ha rate. The mixtures of 'Monida' oats plus legumes produced significantly fewer weeds than hairy vetch at all N fertilizer rates (Table 3.5).

When looking at the effects of N within individual cover crops on weed emergence (Table 3.4), no differences were detected for Austrian peas as a sole crop and the cover crop mixtures. Hairy vetch produced a greater weed density at 0 kg N/ha than at the other N rates. Nitrogen effects on weed emergence were mixed in the remaining cover crop treatments.

Weed biomass. When comparing impacts of cover crops on weed biomass with no N fertilizer (as in the 1994 experiment), results were rather similar to 1994. Both 'Monida' oats and cereal rye sole crops significantly reduced total weed biomass compared to the fallow and weed dry matter biomass was statistically greater following Austrian peas compared to that following fallow (Fig. 3.7). Weed suppression effects of 'Monida' oats in combination with the legumes was more pronounced than in 1994, with both mixtures producing significantly lower total weed biomass than the fallow (Fig. 3.7), as did the mixture of rye plus peas. Apparently the legume effect within the rye plus vetch overcame the weed suppressiveness of the rye as this mixture produced statistically similar weed biomass as the fallow.

Although N fertilizer increased weed growth in all cover crop treatments, the suppressive effects of 'Monida' oats and cereal rye were also exhibited at the greater N rates when compared to the fallow. At each N rate (90, 180, and 270 kg N/ha), significantly greater biomass of weeds was found in the fallow than in the cereal sole crops (except for cereal rye at the 270 kg N/ha rate) (Table 3.6). A similar effect was observed in the 'Monida' oats plus Austrian peas mixture across the 3 N rates. Only Austrian peas at 90 kg N/ha produced significantly greater weed biomass than the fallow at comparable N fertilizer rates (Table 3.6).

The addition of N fertilizer increased weed biomass in all cover crop treatments (Table 3.4). Five of the cover crop treatments, ('Monida' oats, Austrian peas, 'Monida' oats plus legumes, and cereal rye plus Austrian peas) showed no increase in weed biomass with increasing N fertilizer rate. Weed biomass response to increasing N fertilizer varied among the remaining cover crop and fallow treatments.

Discussion

Cereal cover crops used in this study reduced weed germination and growth, supporting the findings of Liebl and Worsham (1983), Einhelling and Leather (1980), Putnam et al. (1983), and Teasdale et al. (1991), while legumes increased germination and growth of weeds in most cases. Effects of legumes in the cover crop mixtures varied between years, overcoming the possible weed growth suppression effects from the cereals in 1994, but not in 1995.

Although most of the reported research on weed suppression by cover crops has been conducted in no-till situations with living or dead cover crop mulches, the results of this experiment show that the incorporation of the cereal cover crops into the soil can suppress weeds as well. Hairy vetch mulches have been reported to suppress weeds in several studies (Shilling et al., 1985; Shilling et al., 1986; Mohler, 1991; Moore et al., 1994; Janke and Peters, 1993; Barnes and Putnam, 1983; Putnam et al., 1983; Teasdale, 1993). In this study, however, when hairy vetch was incorporated in the soil, weed germination and dry matter biomass production was increased. Because of the rapid microbial decomposition of the hairy vetch in the soil, any allelopathic chemicals present in the vetch may have been degraded.

Among other cereals, oats has been identified as a weed suppresser when used as a mulch (Fortin and Pierce, 1991). In this experiment, the oats cultivar 'Monida' showed significant weed suppression after incorporation into the soil. This suggests that, as in the cereal rye, the possible allelochemical compounds released by this cereal are not affected after incorporation in the soil.

The depth and type of tillage may also affect the weed suppressiveness of cover crops. The moldboard plow typically buries surface residues well below the surface where weed seedlings germinate. This experiment used shallow tillage (disk and rototiller) that kept cover crop residues within the top 15-25 cm, possibly influencing the weed suppression obtained by the cereals.

Weed suppression from cover crops can be an important component in integrated weed management strategies, perhaps enabling farmers to reduce the use of herbicides. However, selection of the right cover crop will play an important role in the weed suppression process (Worsham, 1991). More research is needed to determine whether there are allelopathic chemicals associated with 'Monida' oats and what chemicals are responsible for this activity. Also, more research is needed to evaluate whether the reported allelopathic effect from hairy vetch is degraded when hairy vetch is incorporated in the soil.

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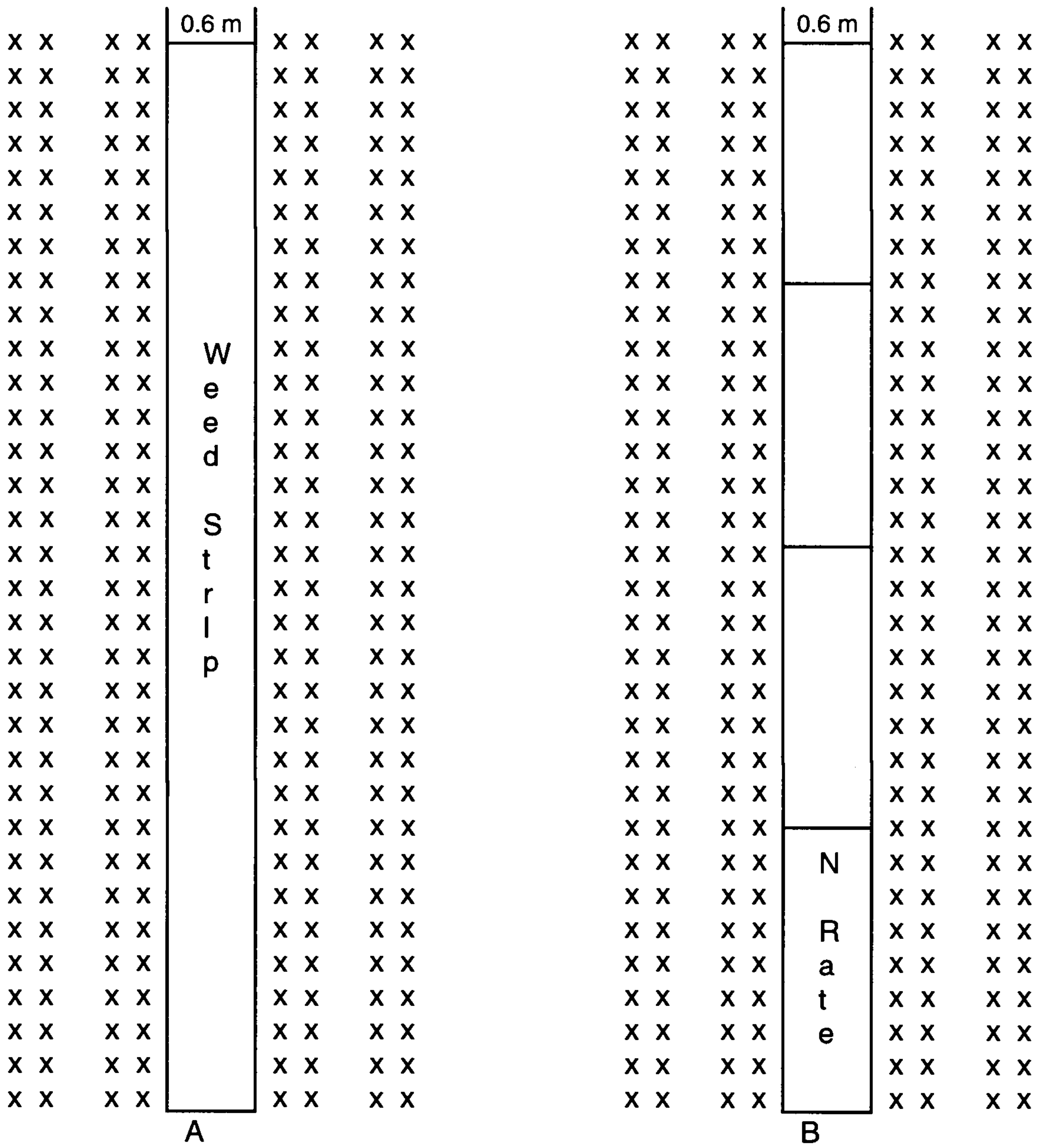
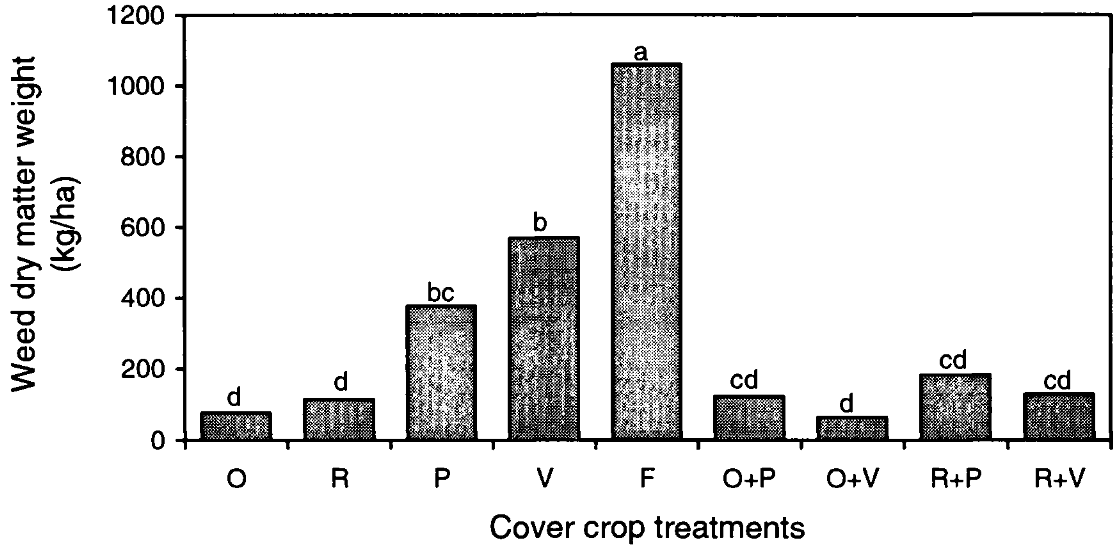
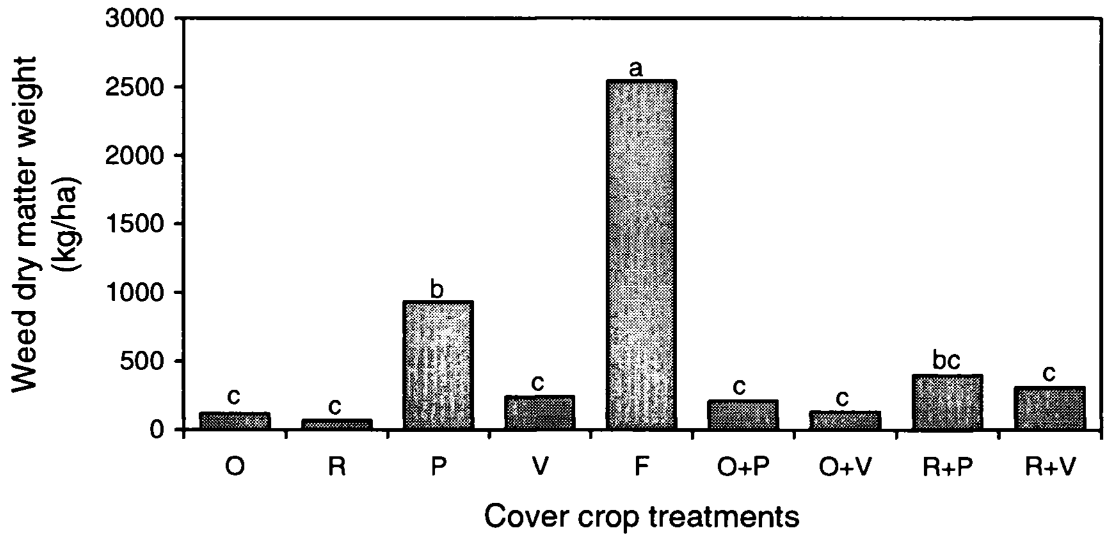


Figure 3.1. Weed experimental design between sets of broccoli rows, 1994 and 1995. Note: Letter A = 1994 Experiment and letter B = 1995 Experiment.



O = 'Monida' oats	V = Hairy vetch	O + V = Oats + Vetch
R = Cereal rye	F = Fallow	R + P = Rye + Peas
P = Austrian peas	O + P = Oats + Peas	R + V = Rye + Vetch

Figure 3.2. Effects of cover crops on weed dry matter biomass accumulation, March 29, 1994. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, $\alpha = .05$).



O = 'Monida' oats	V = Hairy vetch	O + V = Oats + Vetch
R = Cereal rye	F = Fallow	R + P = Rye + Peas
P = Austrian peas	O + P = Oats + Peas	R + V = Rye + Vetch

Figure 3.3. Effects of cover crops on weed dry matter biomass accumulation, April 26, 1994. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, $\alpha = .05$).

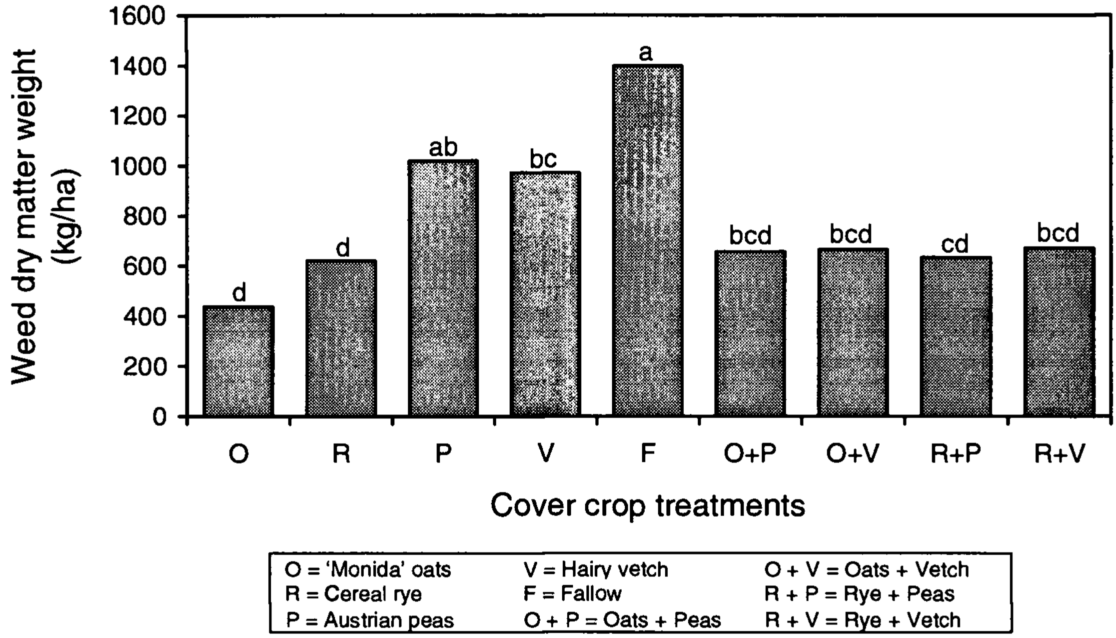


Figure 3.4 Effects of cover crops on weed dry matter biomass accumulation, March 28, 1995. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, α = .05).

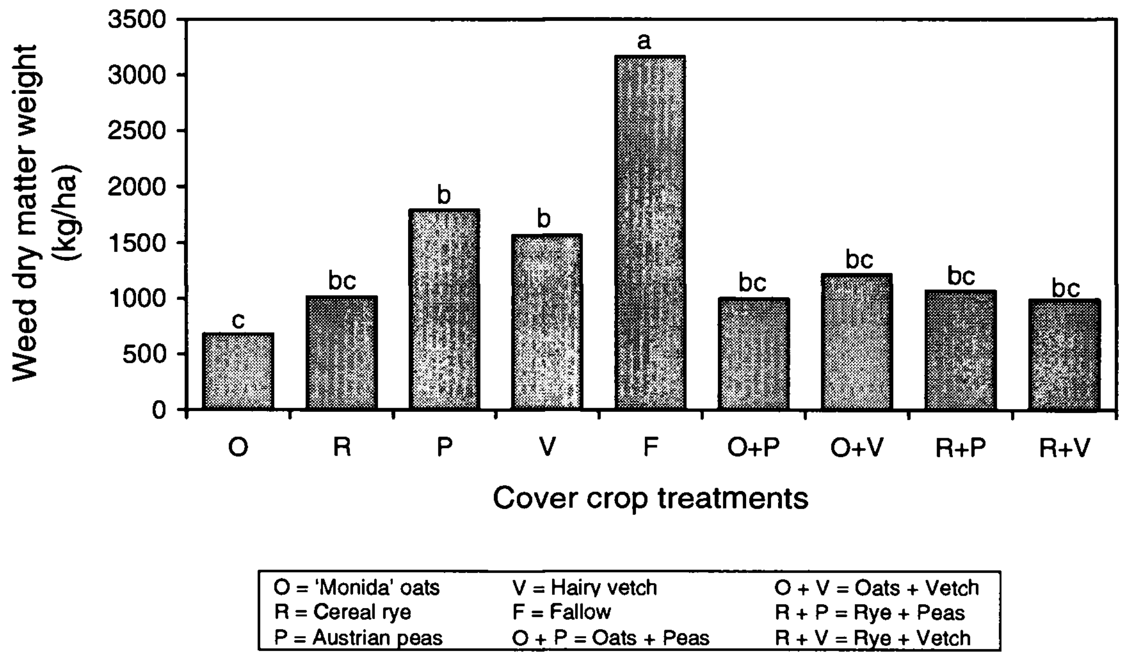


Figure 3.5. Effects of cover crops on weed dry matter biomass accumulation, April 25, 1995. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, α = .05).

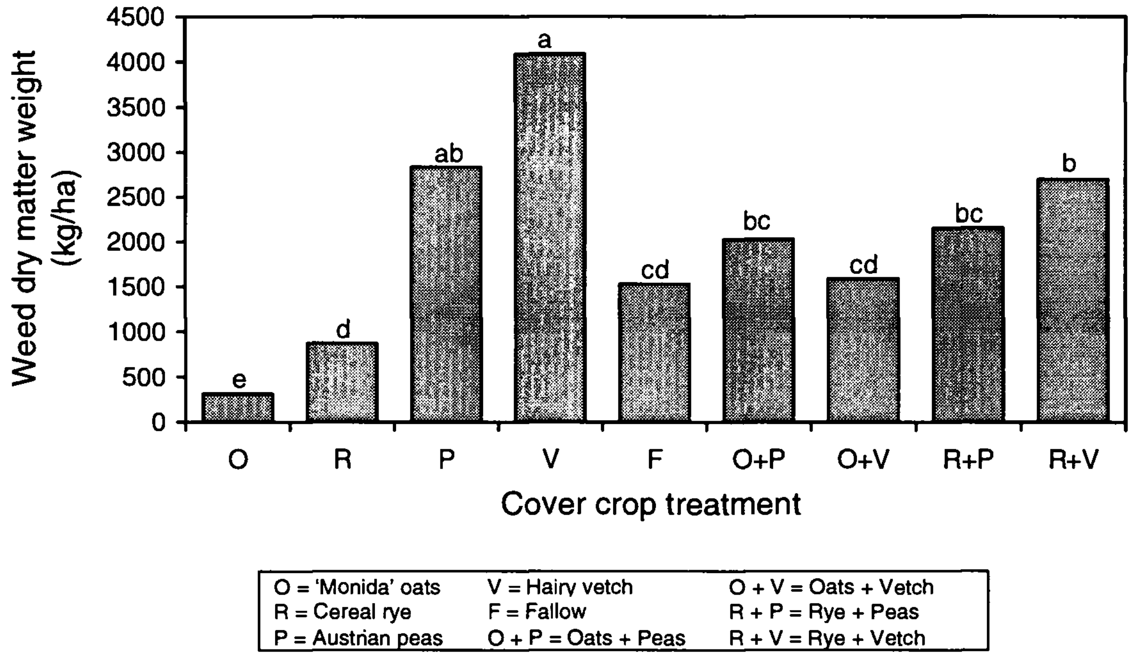


Figure 3.6. Effect of cover crops on weed dry matter biomass accumulation, July 11, 1994. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, $\alpha = .05$).

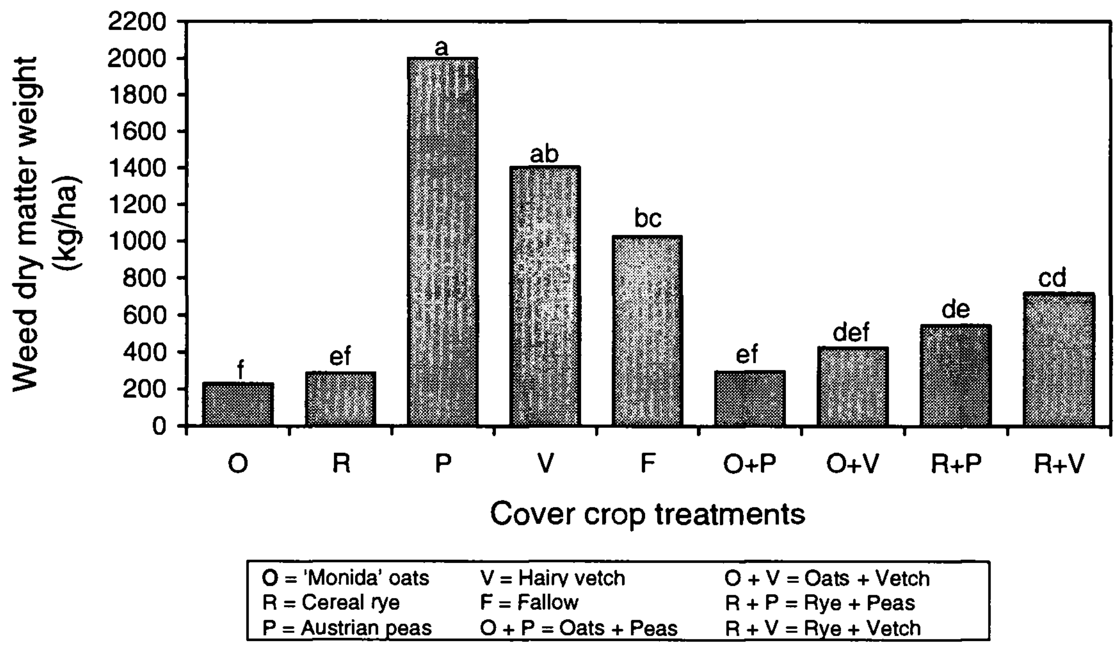


Figure 3.7. Effect of cover crops with no N fertilizer on weed dry matter biomass accumulation, July 3, 1995. Note: Bars with the same letters above indicate no significant differences (F-protected LSD, $\alpha = .05$).

Table 3.1. Cover crop effects on total weed density in broccoli, July 5, 1994.

	Weed species (No./m^2)				
Cover crop treatments	Nightshade	Groundsel	Shepherdspurse	Miscellaneous	Total
'Monida' oats	108 cd*	37 c*	6 e	59 b	210 d
Cereal Rye	136 bcd	74 bc	9 e	184 a	403 c
Austrian peas	176 abc	195 a	228 ab	166 ab	765 a
Hairy vetch	229 ab	199 a	279 a	193 a	900 a
Fallow	262 a	206 a	193 abc	159 ab	820 a
'Monida' oats + Austrian peas	184 abc	170 a	62 d	263 a	679 ab
'Monida' oats + hairy vetch	127 bcd	70 bc	124 cd	139 ab	460 bc
Cereal rye + Austrian peas	201 abc	131 ab	61 d	256 a	649 abc
Cereal rye + hairy vetch	60 d	106 ab	137 bc	172 ab	475 bc

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$. Mean separation is based on square root-transformed data.

Table 3.2. Cover crop effects on percentage reduction in weed density, July 5, 1994.

Cover crop treatments	Weed species				
	Nightshade	Groundsel	Shepherdspurse	Miscellaneous	Total
'Monida' oats	59	82	97	63	74
Cereal rye	48	64	95	-16	51
Austrian peas	33	5	-18*	-4	7
Hairy vetch	13	4	-45	-21	-10
Fallow	0	0	0	0	0
'Monida' oats + Austrian peas	30	18	68	-65	17
'Monida' oats + hairy vetch	52	66	36	13	44
Cereal rye + Austrian peas	23	37	68	-60	21
Cereal rye + hairy vetch	77	49	29	-8	42

*Negative values indicate that cover crops stimulated weed emergence by that percentage.

Table 3.3. Cover crop effects on total weed density in broccoli, June 22, 1995, with no applied N fertilizer.

	Weed species (No./m^2)				
Cover crop treatments	Nightshade	Persian speedwell	Purslane	Miscellaneous	Total
'Monida' oats	79 bcd*	7 c	12 a	15 c	113 d
Cereal rye	46 d	21 bc	17 a	56 ab	140 cd
Austrian peas	185 a	69 ab	12 a	60 a	326 ab
Hairy vetch	160 ab	168 a	11 a	54 a	393 a
Fallow	116 abcd	41 abc	40 a	51 ab	248 abc
'Monida' oats + Austrian peas	79 bcd	27 abc	0 a	36 abc	142 cd
'Monida' oats + hairy vetch	75 cd	52 abc	8 a	17 bc	152 cd
Cereal rye + Austrian peas	97 abcd	30 abc	11 a	63 a	201 bcd
Cereal rye + hairy vetch	124 abc	39 abc	31 a	46 abc	240 abc

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$. Mean separation is based on square root-transformed data.

Table 3.4. Effects of N rates within cover crops on weed dry matter biomass accumulation and weed density, 1995.

Cover crop treatments	N rates (kg/ha)	Weed biomass (kg/ha)	Weed density/m^2
'Monida' oats	0	230 b*	113 b
	90	1,476 a	186 a
	180	2,119 a	200 a
	270	1,898 a	139 ab
Cereal rye	0	286 c	140 b
	90	1,534 b	207 ab
	180	2,298 ab	237 a
	270	2,618 a	196 ab
Austrian peas	0	2,000 b	326 a
	90	4,033 a	298 a
	180	3,685 a	289 a
	270	3,545 a	299 a
Hairy vetch	0	1,403 c	393 a
	90	2,546 b	326 b
	180	3,718 a	311 b
	270	3,113 ab	311 b
Fallow	0	1,024 c	248 ab
	90	2,687 b	265 a
	180	3,511 ab	262 a
	270	3,653 a	205 b
'Monida' oats + Austrian peas	0	294 b	142 a
	90	1,670 a	179 a
	180	1,998 a	175 a
	270	2,029 a	158 a
'Monida' oats + hairy vetch	0	426 b	152 a
	90	2,047 a	188 a
	180	2,085 a	186 a
	270	2,039 a	146 a
Cereal rye + Austrian peas	0	547 b	201 a
	90	2,648 a	267 a
	180	2,836 a	238 a
	270	2,843 a	247 a
Cereal rye + hairy vetch	0	722 c	240 a
	90	1,545 b	257 a
	180	2,230 ab	220 a
	270	2,804 a	227 a

*Means within a column within a cover crop treatment followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 3.5. Effects of cover crops within N rates on weed density, June 22, 1995.

	Nitrogen rates (kg/ha)			
Cover crop treatments	0	90	180	270
'Monida' oats	113 d*	186 c	200 ab	139 d
Cereal rye	140 cd	207 bc	237 ab	196 bcd
Austrian peas	326 ab	298 ab	289 ab	299 ab
Hairy vetch	393 a	326 a	311 a	311 a
Fallow	248 abc	265 abc	262 ab	205 abcd
'Monida' oats + Austrian peas	142 cd	179 c	175 b	158 cd
'Monida' oats + hairy vetch	152 cd	188 c	186 b	146 d
Cereal rye + Austrian peas	201 bcd	267 abc	238 ab	247 abc
Cereal rye + hairy vetch	240 abc	257 abc	220 ab	227 abcd

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Table 3.6. Effects of cover crops within on weed dry matter biomass accumulation, July 3, 1995.

	Nitrogen rates (kg/ha)			
Cover crop treatments	0	90	180	270
'Monida' oats	230 f*	1,476 d	2,119 b	1,898 c
Cereal rye	286 ef	1,534 d	2,298 b	2,618 abc
Austrian peas	2,000 a	4,033 a	3,685 a	3,545 a
Hairy vetch	1,403 ab	2,546 bc	3,718 a	3,113 ab
Fallow	1,024 bc	2,687 b	3,511 a	3,653 a
'Monida' oats + Austrian peas	294 ef	1,670 cd	1,998 b	2,029 bc
'Monida' oats + hairy vetch	426 def	2,047 bcd	2,085 b	2,039 bc
Cereal rye + Austrian peas	547 de	2,648 b	2,836 ab	2,843 ab
Cereal rye + hairy vetch	722 cd	1,545 d	2,230 b	2,804 abc

*Means within a column followed by the same letter do not differ significantly using F-protected LSD, $\alpha = .05$.

Chapter 4

Conclusions

There was a yearly variation for the cover crop and total N yields, with a significant increase in the production of cover crop dry matter biomass for both cereals in 1995 compared to 1994. On the other hand, the legumes yielded less in 1995 than in the previous year. Pure stands of cereal rye and 'Monida' oats increased the total above-ground N accumulation from 1994 to 1995, while hairy vetch as a pure stand decreased the above-ground N accumulation from 1994 to 1995.

In this study, hairy vetch showed the potential to contribute up to 90 kg/ha N fertilizer equivalent in broccoli yield. Austrian peas and the mixtures of 'Monida oats plus Austrian peas and cereal rye plus hairy vetch contributed with up to 90 kg/ha of N equivalent to broccoli yield in 1994, but not in 1995 when legume stands were reduced by weed competition.

During the late winter and early spring of 1994, while the cover crops were growing in the field, all cover crop treatments significantly reduced weed biomass compared to the fallow. In 1995, this suppression was repeated for all cover crops except Austrian peas, which had had poor stand establishment and winter growth.

Cereal rye and 'Monida' oats appear to have some weed suppression and the legumes appear to increase weed growth. Also, broccoli following 'Monida' oats and cereal rye as sole crop with no N fertilizer added experienced some delay in growth, maturity, and yielded the least amount of broccoli. However, in both cases, the weeds and the broccoli, when the cereals were mixed with the legumes or N fertilizer was added the suppression level was overcome.

Although there was some weed and crop suppressiveness from the 'Monida' oats, it is not clear whether this was due to allelopathic chemicals or if the N in the system is been immobilized by the decomposing cereal cover crop. Therefore, further studies are needed to explore the mechanisms for the suppressiveness.

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Appendices

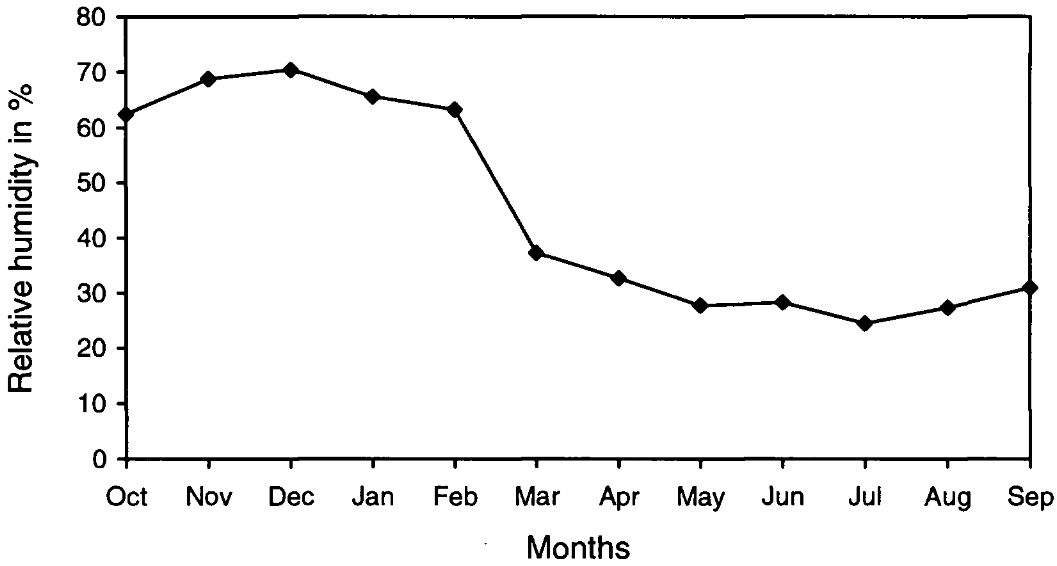

Figure A-1. Relative humidity during the 1993-1994 cover crops and broccoli growing season.

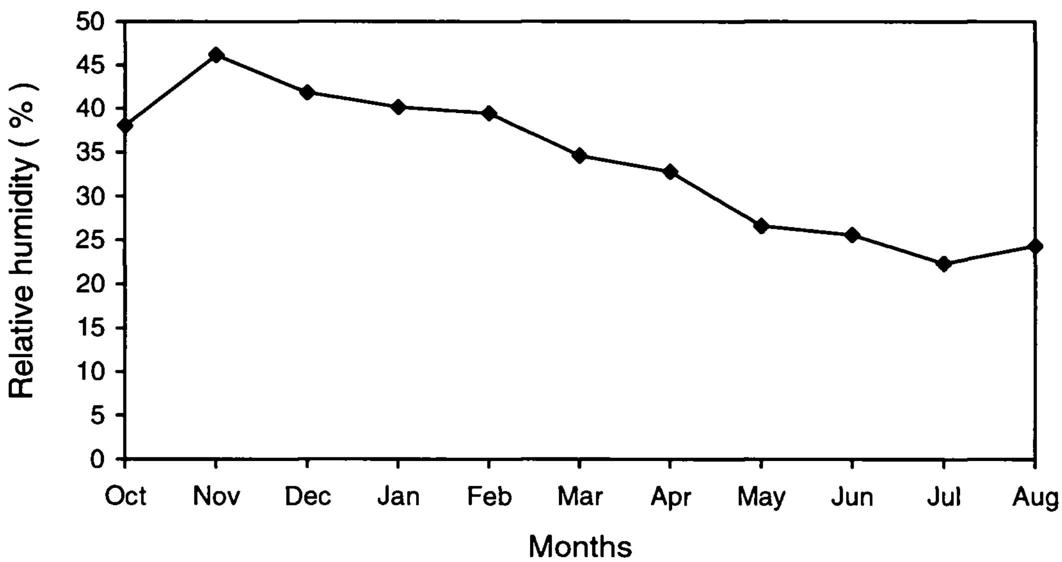

Figure A-2. Relative humidity during the 1994-1995 cover crops and broccoli growing season.

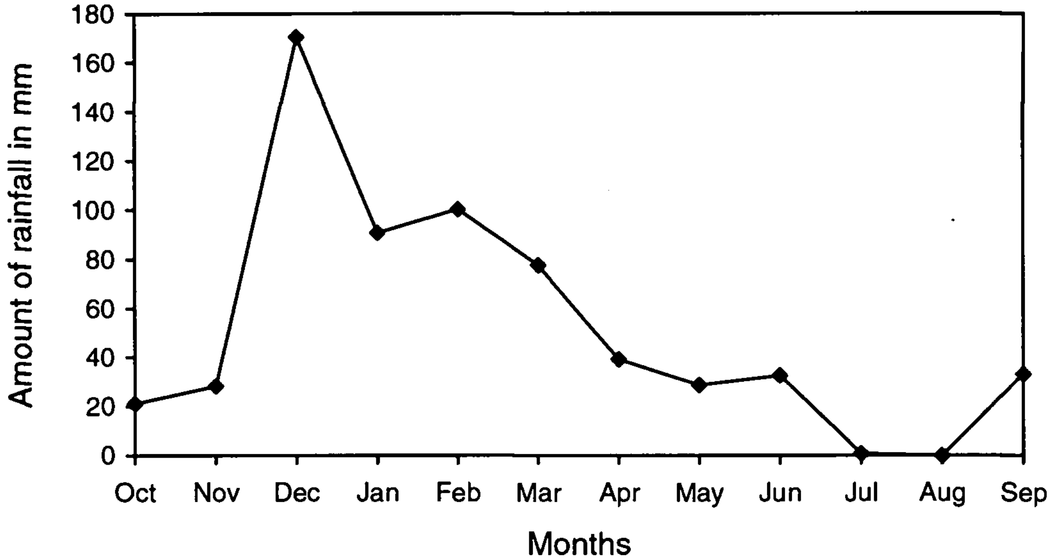

Figure A-3. Rainfall during the 1993-1994 cover crops and broccoli growing season.

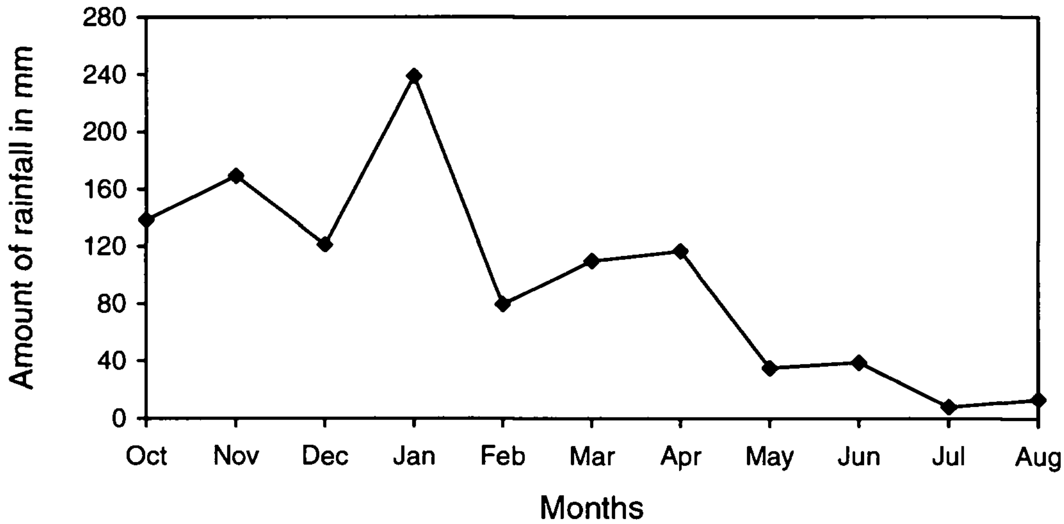

Figure A-4. Rainfall during the 1994-1995 cover crops and broccoli growing season.

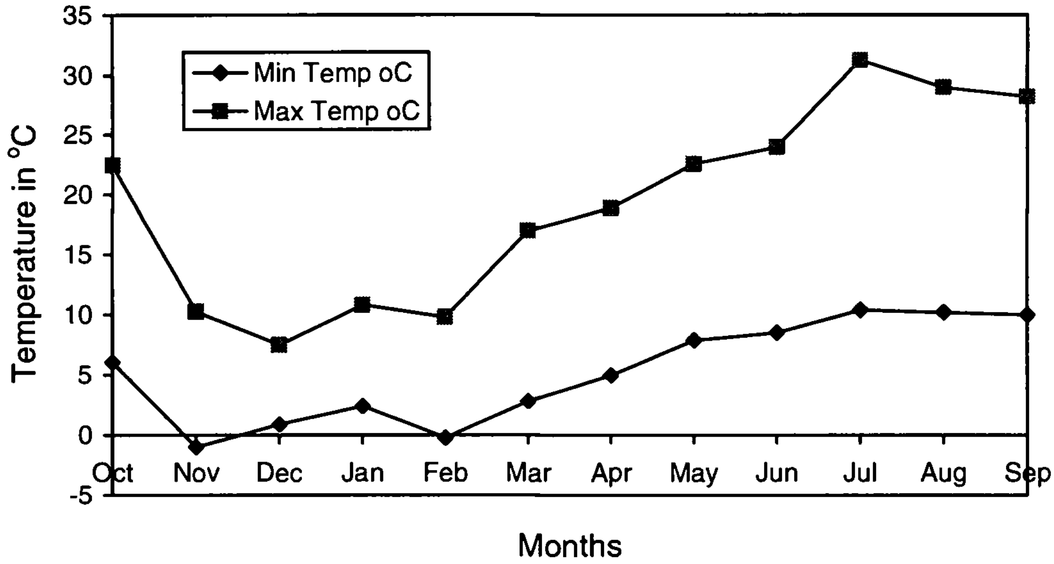

Figure A-5. Maximum and minimum temperature during 1993-1994 cover crops and broccoli growing season.

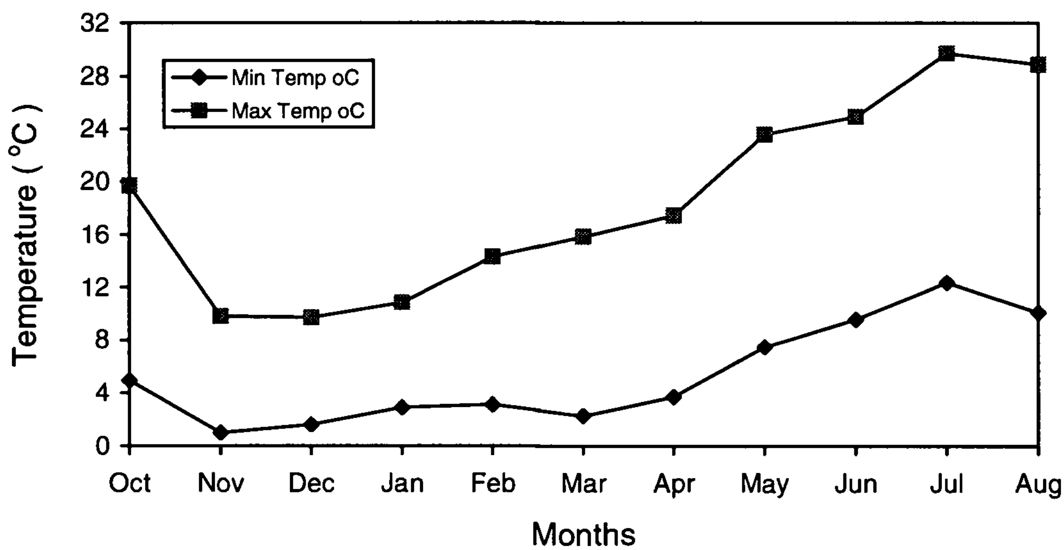

Figure A-6. Maximum and minimum temperature during 1994-1995 cover crops and broccoli growing season.