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Title: BEANS, CABBAGE, AND SUGAR BEETS IN A CHEMICALLY SUPPRESSED SOD OF MANHATTAN II PERENNIAL RYEGRASS

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Crops were planted into tilled strips in an established perennial ryegrass (Lolium perenne L. 'Manhattan II'), sod covering various portions (55%, 66%, 77%) of the row width. Italian beans (Phaseolus vulgaris L. 'Romano II') biomass and yields showed a trend among sod strips with lower yields produced in plots with a greater proportion of the row width covered with sod. Sethoxydim and fluazifop did not suppress grass effectively when 1 cm tall grass was not growing vigorously. In a similar trial with green beans (Phaseolus vulgaris L. 'Oregon 43') there were no yield trends between sod strip width and crop yield. Biomass and pod yields in plots receiving sod suppression treatments were similar to the monoculture check. Sub-lethal rates of the two herbicides applied after grass had grown vigorously for one month suppressed grass effectively. Cabbage (Brassica oleracea L. 'Market Prize') head yields in sod culture plots were significantly lower than monoculture plots regardless of suppression rate and sod strip width. Mid-September chemical treatments did not suppress grass through the fall and dense sod growth over the winter interfered with sugar beet (Beta vulgaris L. 'Beta') grown as a seed crop.

BEANS, CABBAGE, AND SUGAR BEETS IN A CHEMICALLY SUPPRESSED SOD OF MANHATTAN II PERENNIAL RYEGRASS

by

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TABLE OF CONTENTS

LIST OF TABLES

BEANS, CABBAGE, AND SUGAR BEETS IN A CHEMICALLY SUPPRESSED SOD OF MANHATTAN II PERENNIAL RYEGRASS

Chapter 1

INTRODUCTION

The moldboard plow and disc are the nemeses of soil conservation. These and other implements produce smooth, clean seedbeds which enable the farmer to plant his crop and control the weeds, but they also leave the soil exposed to wind and rain.

Before the Corps of Engineers built the large reservoirs upstream, the Willamette Valley lowlands underwent periodic flooding. Even now the lowland adjacent to the river floods many years.

With the introduction of many herbicides, "no-till" crop production is becoming popular. In this cultural practice a crop is planted in a dead mulch or crop residue disturbing only enough soil to cover the seed. The main reason for using no-till is to reduce erosion.

Since a dead mulch controls erosion, a live mulch should do better. Living mulch, a cultural practice where the main crop shares the growing site with a living grass or legume (in most cases), may replace no-till. It has the more desirable features of dead mulch without the need for reestablishing the mulch each year.

Since this research project was done in Oregon, some information about the area could be helpful. Western Oregon is a diversified crop growing region. Green bush beans, cabbage, and sugar beets for seed are important crops. In 1986, 8,500 ha of green beans, 335 ha of cabbage, and 1,850 ha of sugar beets for seed were grown.

Many crops are rotated in the Willamette Valley. For example sugar beets for seed may be planted in September following a green bean crop. Because of the mild climate the sugar beets are grown over the winter and harvested the following summer. Fall cabbage, planted in June or July and harvested in October or November, may be followed by a green bean crop. Some field work is required during the winter months, but most soils will not support farm vehicles and equipment in the winter. Moving tractors and other equipment through a wet, muddy field compacts the soil and creates ruts. A dense resilient living mulch, however will spread the weight of equipment, prevent sinking and allow field work.

Manhattan II perennial ryegrass was chosen as a living mulch for cabbage, beans, or sugar beets for seed. Since a vigorous living mulch in a vegetable field would compete for resources, chemicals are used to suppress grass growth and reduce competition while the vegetable crop matures. Shortly before harvest the living mulch recovers, regains vigor and can provide an additional forage crop.

Living mulches provide soil conservation along with an additional crop and winter access to fields. Farmers know the value of soil conservation, but they are reluctant to use live mulching if the cost in chemicals and reduced crop results in a reduction of their net return.

The purpose of these trials was to find a cultural method whereby beans, sugar beets, and cabbage could be grown in a living mulch system.

Chapter 2

REVIEW OF LITERATURE

A. LIVING MULCH - BENEFICIAL EFFECTS

1. EROSION CONTROL

Erosion is a serious world-wide agricultural problem. Clean cultivation cropping practices allow wind and water erosion by removing the protective plant cover. Natural plant covers, dead mulches (no-till), and living mulches protect the soil from erosion in two general ways: they shelter the soil from raindrop impact, preventing soil loosening and soil particle movement, and the increased organic matter makes the soil more permeable so that water goes into the soil rather than running off (27).

Land in the Southern Piedmont, an area about 240 km wide and 640 km long extending from Virginia to Alabama, has been badly eroded over the past century because of steep slopes, heavy rains, and clean cultivation. Hendrickson et al. (31) who evaluated this cropping system's effect on erosion, showed that new methods were necessary to control the erosion and runoff on Piedmont soils under clean tillage.

The no-till method, in which the mulch is killed but not plowed under, reduces water and wind erosion (25, 26, 38, 53, 62). Adams and Barnett (1) showed that grass sod, in the Piedmont, reduced both runoff and soil loss to negligible amounts. Runoff from no-till corn (Zea mays L.) planted in a tall fescue (Festuca arundinacea Schreb.)/white clover (Trifolium repens L.) mulch or coastal bermudagrass (Cynodon dactylon (L.) Pers.)/crimson clover (Trifolium incarnatum L.) mulch was low even on steep slopes. McGregor et al. (41) found that soil in Mississippi was eroding at a rate of 17.5 metric tons per hectare per year. No-till reduced this to 1.8 tons per hectare.

Whereas no-till necessitates annual reseeding, and leaves the ground unprotected for a time, living mulches cover the soil continuously. When sod crops are grown in combination or in rotation with row crops, erosion is greatly reduced (6). Hendrickson et al. (31) interplanted corn with crotalaria (Crotalaria sp.) in the Piedmont, and reduced erosion. Interplanting corn with crimson clover, ryegrass or lespedeza (Lespedeza striata. 'Kobe') further reduced erosion. Smooth bromegrass (Bromus inermis Leyss.), Kentucky-31 tall fescue, and orchardgrass (Dactylis glomerata L.) living mulches significantly reduced runoff and erosion on mountain and hilly terrain (8).

Mulches improve soil water retention (35, 43). Bruce and Whisler (11) found that in comparison to a fescue mulch a clean cultivated surface had 50 to 60% less water infiltration. In no-till orchard grass, the two year average water runoff was 4.5% while runoff for clean cultivated was 27%. The mulched soil held more water in the top 30 cm (43).

2. SOIL IMPROVEMENT

Living mulches are superior to commercial fertilizers and no-till for soil improvement. The cost of commercial nitrogen fertilizer makes other nitrogen sources important (61). By having a living mulch system a plant can get nitrogen from three sources: the mulch, applied nitrogen, and the soil. The mulch and applied nitrogen largely determine the amount of nitrogen recovered by the main crop.

Legumes have long been used as a source for nitrogen in conventional farming (40, 44). Legumes are normally plowed under to release nitrogen before the new crop is planted. The amount of nitrogen supplied depends upon the type of legume, the condition of the stand, and the stage of growth when tilled. Mitchell and Teel (42) compared several grass/legumes mixtures for total nitrogen content. Winter rye (Secale cereale L.)/crimson clover, spring oats (Avena sativa L.)/hairy vetch (Vicia villosa Roth), spring oats/crimson clover, winter rye/hairy vetch, and annual ryegrass (Lolium multiflorum Lam.)/crimson clover provided 167, 173, 174, 175, and 210 kilograms per hectare (kg/ha) of nitrogen respectively. Pieters and McKee (52) found that hairy vetch supplied 153 to 227 kg/ha when plowed under.

The living mulch method, in which the mulch is neither killed nor plowed under, is a promising alternative to the widely used no-till method. With adequate moisture and fertility a crop grown with a suppressed mulch generally produces good yields. However, Adams et al. (2) found that corn grown in a tall fescue sward stunted by maleic hydrazide (1,2-dihydro-3,6pyridazinedione) produced low yields under normal Piedmont rainfall. By adding nitrogen Carreker and Cobb (15) on the other hand produced high yielding corn in a stunted tall fescue sod. In general, higher rates of added nitrogen increase crop yields. Also the density of a corn planting can be increased when nitrogen is applied. Harper et al. (24) planted corn in killed strips of tall fescue living mulch and found that fertilization increased the optimum corn density. Increasing chicken litter fertilization from 9 to 18 metric tons per hectare, increased optimum corn density from about 58,000 to 74,000 plants per hectare. Corn yields averaged about 10 metric tons per hectare at the higher rate of added nitrogen compared to about 8.5 at the lower rate.

Tropical soils under continuous cultivation lose fertility rapidly. Long fallow periods between cultivation replenish nutrients in the depleted soil. Akobundu (4) at the International Institute of Tropical Agriculture found that the fertility of the soil dropped after two years even when 60 to 120 kg/ha of nitrogen was added. Living mulches, however, improve fertility. A living mulch of psopho (Psophocarpus palustgris) increased soil organic matter, improved soil structure, and raised soil fertility. Typically west African tropical soils average about 2% organic matter after clearing for cultivation. In one study organic matter content dropped 20 to 32% in two years under conventional tillage, but less than 10% in the living mulch. Corn yielded consistently higher in living mulch culture than under conventional tillage, when two crops were grown in succession. Added nitrogen increased yields slightly.

B. INTERACTION OF LIVING MULCH WITH CROP PRODUCTION

1. COMPETITION FOR RESOURCES

The degree to which living mulches compete varies. Plants from different families, for example corn and legumes, or beans and grasses make suitable companions. When properly managed, legume mulches should compete minimally with non-legume crops for nitrogen, and even add nitrogen to the soil (27).

All mulches compete for soil nutrients and other resources. In general all nutrients, except nitrogen and water are immobile. Both the mulch and crop obtain soil-immobile nutrients from their immediate root zone, but not from outside the root zone. However, the mulch and crop compete for water and nitrogen (36). Assuming that nitrogen and water primarily determine the severity of competition, mulch and crop with adequate nitrogen and water should compete very little. When suppressed by herbicides, mulches use less resources leaving them available to the main crop. Two critical times for competition are at mulch establishment, if a crop is growing at that time, and during crop growth. If the main crop and mulch are established together, they must be sufficiently noncompetitive for each to survive.

Drought commonly limits crop production in the southern states. In periods of drought, crops growing at their peak rate exhaust the available soil moisture. Water stress limits nutrient availability; for example rate of mineralization of nitrogen is related to soil moisture supply. Water stress also has been shown to affect germination time. Mulches help relieve the effects of drought by improving water infiltration. Corn germinated in 46 hours when water potential was at a high value of 0.3 bars and 100 hours when at the low value of 15 bars (49, 51).

In contrast to these benefits a living mulch may compete rigorously with the main crop for water. An adequate water supply increases yields in a living mulch system (10, 14, 16). Worsham (68) showed that corn grown in killed strips of tall fescue could not obtain maximum yields under natural rainfall. Carreker et al. (14) found corn growing in an unstunted fescue living mulch developed a less extensive root structure than corn in a dead or stunted mulch. Early in the season corn and unstunted living mulch used more water and from a greater depth than did either the corn and stunted mulch or no-till corn. However, once the corn had developed a canopy, the corn and unstunted living mulch crop used less water than corn with stunted mulch or no-till corn. In general, corn yielded well in irrigated unstunted living mulch, but better in irrigated stunted mulch or no-till.

2. PEST MANAGEMENT

Weeds reduce yields. Living mulches enhance weed control by competing with them for space, nutrients, light, and water. Living mulches may also have possible allelopathic effects.

Early weed control is critical. Schepps and Ashley (58) found that green beans yields decreased 20 to 90% without at least five weeks of weed free soil. Plots that were weed free at the beginning of the season yielded 10% better than those that were not weed free until the end of the season.

Robinson and Dunham (56) found that a wheat (Triticum aestivum L.), rye, or field pea (Pisium sativum L.) mulch, planted immediately after soybeans

(Glycine max (L.) Merr.), controlled lambsquarter (Chenopodium album L.) and red root pigweed (Amaranthus retroflexus L.) well and Setaria viridis and yellow foxtail (Setaria lutescens) fairly well. Winter vetch (Vicia villosa Roth), alfalfa (Medicago sativa L.), red clover (Trifolium pratense L.), smooth bromegrass or timothy (Phleum pratense L.) didn't control weeds well in soybeans.

Vigorous mulches control weeds better than suppressed mulches. Winter wheat and spring rye controlled weeds better when these crops grown as living mulches were not suppressed (54).

Living mulches, unfortunately, supply nutrients to weeds as well as crops. However, Hartwig (29) found that moderately suppressed crown vetch (Coronilla varia L.) reduced yellow nutsedge (Cyperus esculentus L.) growth in corn planted in rows 76 cm apart. Nutsedge grew better in severely suppressed crown vetch than in clean cultivated plots. Hartwig suggested that the legume mulch assisted the nutsedge by releasing nutrients, whereas in the clean cultivated plot, such aid was not available. Therefore, the aid intended for the corn was confiscated by the nutsedge.

Weeds in another test reduced corn yields significantly in clean cultivation, but not in the presence of crown vetch (13).

Weeds may become established during mulch suppression and regrowth. In some tests glyphosate [N-(phosphonomethyl)glycine] suppressed the alfalfa mulch so much that weeds flourished, but when glyphosate was used to suppress white clover, the white clover out competed weeds during mulch regrowth (65).

In Nigeria three mulches, psopho, bahaigrass (Paspalum notatum Fluegge), and Centrosema pubescens Benth. were shown to control many weeds (4, 5).

Hartwig and Hoffman (30) found that even when suppressed, both smooth bromegrass and crown vetch living mulches control redroot pigweed and yellow foxtail. Suppressed birdsfoot trefoil (Lotus corniculatus L.), however, could not control these weeds.

Vrabel et al. (64) found that white and ladino clover (Trifolium repens L.) mulches controlled weeds more successfully than red clover or alfalfa.

Hughes and Sweet (34) found that perennial ryegrass, wheat, oats and rye controlled broadleaf weeds.

New weed species, predominently biennials or perennials, often come into an old mulch. Bahaigrass treated with glyphosate was used as a mulch in no-till corn. The bahaigrass, which was suppressed but never killed, competed effectively with crabgrass (Digitaria sanguinalis L.) and sandbur (Cenchrus pauciflorus Benth.). However blackberry (Rubus sp.), horsenettle (Solanum carolinense L.), maypop (Passiflora incarnata L.), and bermudagrass appeared after three years (55).

3. TEMPERATURE EFFECTS

Some mulches reduce temperatures more than others. Mitchell and Teel (42) found that dark crimson clover/hairy vetch mulch absorbed more light than did rye mulch so that temperatures beneath the vetch/clover mulch were warmer down to a depth of 10.2 cm. In July, soil temperatures under the legume mulch was 4 C warmer at 10.2 cm depth than the temperature under the rye mulch. The temperature under the mulch drops in the first few centimeters. In July temperatures under the mulches at 2.5 cm averaged 39 C and at 10.5 cm 30 C. This elevated temperature could increase mineralization of nitrogen and would account in part for greater root development near the surface of the soil. As the corn canopy shaded the mulches the differences became less pronounced.

Temperatures under bare soil are higher than under mulches. Bennett et al. (9) found during the growing season that soil temperatures under living mulch were from 2 to 10 C cooler than soils which were cleanly cultivated. He noted that higher rainfall moderated the temperature differences. The lower sod temperatures reduced water evaporation in the stunted living mulch plots, resulting in more water for plant growth. Of course, lower temperatures may slow germination and crop growth.

4. CULTURAL PRACTICE

Spacial Arrangement

A perennial forage crop nearly always has lower yields the first year, but a supplemental crop growing in conjunction with a forage mulch can compensate for this by increasing returns to the grower. In the establishment year, a mulch and a main crop can produce more total biomass collectively than either one separately (63). Spacial arrangement and row orientation may be important determinants in these yields.

Row spacing and seed density between the mulch and crop is a trade off affecting crop yield and sward stand. Wide row spacing (1.5 and 2.0 meters, as compared to 1.0 meter) reduced corn stand which in turn reduced corn yields, but insured alfalfa seedling establishment (40, 50, 57, 60). Tesar (60) found that corn yield dropped 17% in the 2.0 meter row where alfalfa stands were most vigorous. Alfalfa seeded within 20 cm of the corn did poorly. Pendleton et al. (50) found that corn yields dropped 20% in the 2.0 meter row, and vigor of the alfalfa stand increased with row spacing. Rows oriented north to south established better alfalfa stands than east to west because in the former the corn shaded half the alfalfa in the morning and the other half in the afternoon. In the rows oriented east to west, those seedlings on the south side of the corn dehydrated because they were exposed to sun all day.

Planting Dates

The time of the mulch planting, whether before, during, or after main crop planting, generally affects the crop yield, but not total mulch and crop biomass. Early planting of mulch reduces main crop yields, late plantings do not. Nordquist and Wicks (47), using irrigation, found that alfalfa seeded at corn planting reduced corn silage yields 33%. When alfalfa was planted at the last cultivation of the corn, silage yields were the same as those in plots where alfalfa was planted after corn harvest. Total alfalfa and corn biomass yields were about the same in all plots. Alfalfa regrowth in the fall was excellent in all plots. Vrabel et al. (63) seeded living mulches at three times: five weeks before corn planting; at corn planting; five weeks after corn planting. Red clover, ladino clover, white clover, alfalfa, and annual bluegrass (Poa annua L.) mulches planted five weeks prior to corn decreased corn yields significantly. When planted simultaneously, the legumes competed strongly with corn when corn was planted in rows and the legumes were broadcast over the entire plot. Corn and alfalfa competed less strongly when the legumes were planted in defined strips and not in the corn rows. Legumes planted five weeks after corn did not reduce corn yields, whether legumes were planted in bands or broadcast.

C. EVALUATION OF SPECIES/CULTIVARS FOR USE AS LIVING MULCH

What characteristics make a good mulch? An important consideration is ease of management. Is it easily suppressed and does it recover to form a vigorous mulch or does it suppress erratically or weaken and die after treatment? Many other inherent properties of a mulch add to its utility: pest resistance, weed control, dormancy, vigor, growth habit, tolerance to weather, and its ability to aid main crop growth.

Most mulches that have been evaluated are legumes or grasses. Legumes establish slower than many grasses but provide added nitrogen. Perennial ryegrass establishes quickly and provides significant early competition for many weeds (18).

Hartwig (29) found that crown vetch can ball up in front of the anhydrous nitrogen injection knives, lifting them from the soil. It also hindered a precision planter in planting corn seed, causing it to scatter seeds loosely on the soil, and decreasing the stand. Some grasses such as smooth bromegrass have root systems similar to legumes which creep into the crop row, while grasses such as perennial ryegrass, a bunch grass, do not encroach. Both types provide good annual weed control. Cool season grasses such as perennial ryegrass, Kentucky bluegrass (Poa pratensis L.) and tall fescue usually become dormant in the summer while the main crop is growing vigorously. However fertilization and irrigation may reduce or eliminate dormancy. Perennial ryegrass responds quickly when fertilized.

Mulches may directly retard or stimulate the main crop growth. Some researchers believe allelopathy affects some crop and mulch combinations (23, 54). Fales and Wakefield (23) found that leachates from perennial ryegrass, red fescue (Festuca rubra L.) , and Kentucky bluegrass inhibit growth of some woody perennials. On the other hand Bennett et al. (9) observed that corn grew at an accelerated rate in a smooth bromegrass mulch. He verified this in laboratory and greenhouse studies.

Some mulches are purported to have pest resistance (65). Rodents, however can become a serious problem in legumes. Legume living mulches unfortunately provide good habitat for pocket gophers and meadow mice (19).

Mulches must be judged on their reactions to chemical suppressants. Mulches must be able to recover after suppression (9, 20, 27, 30, 65). Atrazine

(6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine) mixed with simazine (6-chloro-N,N'-diethyl-1,3,5-triazine-2,4-diamine), cyanazine (2-((4-chloro-6-(ethylamino)-S-triazin-2-yl)amino)-2-methylpropionitrile), or penoxalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) suppressed crown vetch, but killed birdsfoot trefoil. Crown vetch regrowth following herbicide treatment averaged 53% of the untreated check. When diuron (N'-(3,4-dichlorophenyl)-N,N-dimethylurea) was added the crown vetch recovered poorly (28, 29). Smooth bromegrass, orchardgrass, and tall fescue recovered well from atrazine suppression, but not from paraquat (1,1'-dimethyl-4,4'-bipyridinium salts) or maleic hydrazide. Timothy and Kentucky bluegrass died even at the low atrazine rates (9, 20). White clover quickly recovered from atrazine, cyanazine, simazine, and paraquat, but not glyphosate (66). Alfalfa recovered poorly from glyphosate, and atrazine (20, 65). Grass/legume mixtures respond unequally. Various herbicides suppressed birdsfoot trefoil and crown vetch but not smooth bromegrass when in a grass legume mixture. Older mulches and vigorous mulches may require higher rates for suppression (12, 66).

D. EVALUATION OF LIVING MULCH MANAGEMENT TECHNIQUES

1. CHEMICAL SUPPRESSION

A living mulch growing with a main crop normally needs to be suppressed to minimize the competition between the mulch and the main crop. Hughes and Sweet (34) found that beets and cabbage interplanted with spring seeded perennial ryegrass or oats, or rye competed poorly when mulch was not suppressed. However, Stringfield and Thatcher (59) obtained good yields by double cropping of corn/wheat, corn/ryegrass, and corn/alfalfa. In general, however, it is found that the greater the suppression the greater the crop yield (9, 12, 20, 21, 22, 29).

a. Early Suppression

Timing of suppression is important. When herbicides suppress a living mulch one or two weeks before crop planting, the main crop usually yields well. When suppressed too early however, the mulches recover and compete with the main crop.

In 1976 and 1978 Cardina and Hartwig (12) planted corn in established crown vetch. Preemergence treatments of atrazine + simazine, atrazine + cyanazine, and atrazine + pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) applied three days after corn planting in 1976 and eight days after planting in 1978 suppressed crown vetch. In the 1976 test corn yields averaged 46.4 metric tons/ha (mt/ha) in clean cultivated land in comparison to 37.6 mt/ha in crown vetch mulch. In the 1978 test differences were slight, clean cultivated plots yielded 33.7 mt/ha and crown vetch plots yielded 32.7 mt/ha. Treatments that suppressed crown vetch well still yielded an average of 10% less corn than the monoculture check. A preplant treatment of atrazine + simazine + dicamba (3,6-dichloro--2-methoxybenzoic acid) applied six weeks before planting did not suppress mulch long enough and corn yielded poorly.

In 1974 Hartwig and Hoffman (30) applied several herbicide combinations to smooth bromegrass/crown vetch and smooth bromegrass/birdsfoot treefoil sod. Corn was planted eight days later in 97 cm rows at a density of 62,000 plants/ha. Corn yielded better and had better stands in the birdsfoot trefoil mulch. Chemicals which gave consistently higher yields were simazine + atrazine, cyanazine + atrazine and cyanazine.

Linscott and Hagin (39) found that atrazine and simazine applied six days before planting suppressed crown vetch, but the corn yielded only 25.5 and 21.9 mt/ha, well below the site average of 36.0 mt/ha.

Vrabel et al. (66) found that unsuppressed white clover mulch reduced corn yields as much as 75%. The white clover strongly competed for water and nutrients when grown with corn. Atrazine (0.84 kg/ha), cyanazine (0.9 kg/ha), or simazine (2.0 kg/ha) applied before crop emergence suppressed white clover and corn yielded similarly to clean cultivated plots.

b. Suppression at Planting

Crops yield well when the mulch is treated at the time of crop planting. Elkins et al. (20) planted corn and soybean crops in four established mulches: tall fescue, orchardgrass, smooth bromegrass, and alfalfa. Mulches were sprayed with various herbicide combinations at planting. Corn yielded well, ranging from 46.4 to 57.9 mt/ha in tall fescue, 49.7 to 58.5 mt/ha in orchardgrass, 45.1 to 56.6 mt/ha in smooth bromegrass, and 41.5 to 53.3 mt/ha in alfalfa. Soybeans also yielded well in tall fescue plots.

Although timing is important, an adequate level of herbicide is necessary. Bennett et al. (9) grew corn in five sod species: smooth bromegrass, orchardgrass, timothy, tall fescue, and Kentucky bluegrass. Herbicides were applied at planting. Corn yields dropped with low atrazine rates because the mulches recovered too quickly, but corn yielded consistently higher in mulch than in clean cultivated plots.

c. Late Suppression

Even mulches suppressed long after the main crop is planted may increase yields. Hartwig (28) planted corn in 97 cm rows into established plantings of a birdsfoot trefoil mulch and into a crown vetch mulch. Mulches were treated three weeks after planting. Atrazine + simazine, atrazine + cyanazine, and atrazine + penoxalin suppressed the mulches and corn yielded 31.4, 32.0, and 33.7 mt/ha in crown vetch plots and 25.8, 31.4, and 31.7 mt/ha in the birdsfoot trefoil plots. Untreated mulch out competed corn and reduced corn yields significantly. Without suppression, corn yielded only 14.7 mt/ha in the crown vetch and 13.4 mt/ha in the birdsfoot trefoil plots. Hartwig suggested that corn yields do not decrease when cover crops are removed within seven to ten days after corn emergence.

Vrabel et al. (65) planted corn in a rototilled strip 45 cm wide within the living mulches of white clover and alfalfa. Herbicides applied at the spike stage of corn suppressed mulches sufficiently to produce yields comparable to clean cultivation and no-till.

Chapter 3

ITALIAN AND GREEN BEAN PRODUCTION IN A LIVING MULCH CROPPING SYSTEM

ABSTRACT

Italian and green beans (Phaseolus vulgaris L.) were planted into tilled strips in an established perennial ryegrass (Lolium perenne L. 'Manhattan II') sod covering various portions of the row width. In one trial with inadequate suppression of the sod, 'Romano II' bean biomass and yield showed a trend for lower yields produced in plots with narrower tilled strips between the sod strips. In a second trial with greater sod suppression, green bean 'Oregon 43' yields appeared equal to the crop produced in monoculture.

INTRODUCTION

No-till or minimum-till procedures, in which all vegetation except the crop is killed with herbicides, have been a cultural practice in corn (Zea mays L.) and soybeans (Glycine max L. Merr.) since the 1960s (14, 21). Similar practices have been followed in orchards or other widely spaced perennial horticultural crops, using a mowed sod between the crop rows (3, 37, 48). Researchers have extended this concept to include the use of living plants grown as a ground cover between rows of vegetable or field crops grown at normal spacings (34, 40). The term "living mulch" has been applied to this concept. Reported benefits from use of a living mulch include erosion control (27, 38), soil water retention (35), improved soil structure and fertility (4) and weed control (34, 64). Concerns for competition between the main crop and the living mulch must be weighed against these benefits.

The mulch species can be planted at the same time as the vegetable crop and treated as an annual (34, 63) or the vegetable crop can be planted into prepared strips in an established planting of living mulch (28, 64). Crop rotations can be developed for this type of cropping system, with summer and winter grown crops planted in sequence in the same prepared strips.

The object of this study was to evaluate green bean production as a component of a cropping system using an established living mulch. This cropping system included spring planted beans followed by cabbage and, in the second year, beans followed by sugar beets grown for seed. Information on choice of living mulch type (5, 18, 46) and management of the mulch plants (7, 24, 36) was derived from other research.

METHODS AND MATERIALS

Manhattan II perennial ryegrass was seeded at 170 kg/ha in a level field near Corvallis, OR. in October 1984. Predominant weeds surviving in the sod were bristly hawksbeard (Crepis setosa Haller f.), pineappleweed (Matricaria matricarioides (Less.) C.L. Porter), Canada thistle (Cirsium arvense (L.) Scop.), bull thistle (Cirsium vulgare (Savi) Tenore), prickly lettuce (Lactuca serriola L. 'integrata' Gren. and Godr.), white clover (Trifolium repens L.), red clover (Trifolium pratense L.), and mustard (Brassica rapa L.).

In February 1985, strips of the grass were killed with paraquat (1,1'-dimethyl-4,4'-bipyridinium salts) applied at a rate of 0.8 kg/ha with a hand operated plot sprayer. Adjustable guards on each side of the nozzle kept the spray within the designated area. The two bean/mulch trials used a completely randomized design for each sod strip width, and each block contained seven treatments each replicated five times. Each block represented a different ratio between width of sod and vegetation free crop planting strip. These were 1.) 0.2 m wide killed strips leaving 0.7 m of grass between rows, 2.) 0.3 m killed strips with 0.6 m grass, and 3.) 0.4 m wide killed strips with 0.5 m grass. The three width blocks shared the same bean monoculture treatment replicated five times throughout the three blocks. Plots within each sod strip width block were suppression treatments of the sod. Sethoxydim {2[1(ethoxy-imino)butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one} and fluazifop {(+)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]-oxy]phenoxy]propanoic acid} were chosen for sod suppression since they have little effect on dicotyledonous species but at sub-lethal rates they will suppress grasses (17, 32, 67). These attributes made them ideal tools for managing the grass sod in these experiments.

In April 1985 the grass was mowed to a height of 1 cm. Before planting the crop, the soil in the killed strips was broken with a duck foot cultivator and tilled to a depth of 15 cm to make a seedbed. The herbicides EPTC (S-ethyl dipropyl-thiocarbamate) at 4.0 kg/ha and trifluralin, [2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl) benzenamine] at 0.56 kg/ha were incorporated to a depth of 15 cm in the bean rows and 670 kg/ha 8N-28P-6K fertilizer was applied at a depth of 10 to 15 cm. The herbicide sprays, other than paraquat, were applied with a CO_2 pressurized back pack sprayer. The beans were seeded with a Planet Jr. planter in the center of each prepared strip so that the rows were 0.9 meter apart. Each plot consisted of four rows 4.3 m long and treatments associated with these plots are shown in tables 1 and 4. Additionally a grass sod plot without chemical suppression and without a bean crop was included in each set of sub-plots. Bean monoculture checks were maintained free of vegetation other than beans by hand hoeing.

On 14 May 1985, 'Romano II' beans were planted at a seeding rate that resulted in an average of 24 plants/m. Immediately after planting, dinoseb [2-(methylpropyl)-4,6-dinitrophenol] amine was applied for weed control in the crop row at 5.0 kg/ha and the grass was mowed. Suppression treatments were applied 19 May. On 3, 10, 17, and 23 July four bean plants selected at random from each plot were cut at ground level and weighed. Bean pods were harvested from 1 meter of row from each plot on 23 July. Bean pods were hand graded. Grading was somewhat subjective, but pods which had seed that were obviously large and often loose were discarded. On 28 July, grass from the center strip of each plot was harvested by mowing to a height of 1 cm and weighed.

After no further treatment through the winter months of 1985-86 the grass was mowed 15 May, 1986. After preparing a seedbed, using the same rows and with procedures as described for 1985, 'Oregon 43' green beans were planted 30 May, 1986. The stand had an average of 39 plants/m. Sod suppression treatments were applied 15 June. All the bean plants in a 2.0 meter length of row of each plot were pulled and weighed on 14, 21, and 27 July and 6 August. Bean pods from the plants pulled on 6 August were harvested, and the beans were graded with a grading machine. On 11 August the grass was mowed to a height of 1 cm and the clippings weighed.

Suppression treatment means were compared by LSD, following an analysis of variance. Sod suppression treatments were compared to bean monoculture checks by using an unpaired t-test.

RESULTS AND DISCUSSION

At each sampling date in 1985, 'Romano II' plant fresh weight did not vary significantly with plot suppression treatments. Fresh plant weight trends did however vary among sod strip widths (Table 1). Incremental increases in sod strip width reduced bean plant weights at each harvest date except 10 July, at which time only a comparison of the widest and narrowest sod width showed trends in bean growth. Regardless of its proximity to the bean crop row, the grass sod competed with the beans and reduced bean plant size when compared to no sod.

The graded pods from the 1985 harvest had 42% oversized beans which were discarded and do not appear in the yield data of Table 2. Like plant fresh weights, bean pod yields did not differ significantly among sod suppression treatments while bean pods from the sod suppression treatments yielded significantly less than those from the monoculture check. The harvest of bean pods from plots with either 50 or 60 cm wide sod strips showed trends of being greater than the yield from the 70 cm wide sod strip.

Grass mean fresh weights were 16% lower in the chemically treated plots than in the grass checks 70 days after the suppression treatments were applied (Table 3). Sethoxydim at 0.005, 0.01, and 0.02 and fluazifop at 0.05, 0.1, and 0.2 kg/ha suppressed grass. Similarly, William and Brenner (67) found that sethoxydim applied at 0.01 kg/ha and fluazifop at 0.11 kg/ha suppressed grass for 56 days. Despite this grass yield decrease, bean growth was reduced by grass interference and it was apparent that an increased level of sod suppression would be required to prevent a reduction in yield of the bean crop. Sod strip widths did not appear to influence grass fresh weight production per unit area.

In 1986, chemical suppression treatments generally reduced interference from the grass sod to a level that bean plant growth was not significantly less than the monoculture check (Table 4). Bean plant fresh weight means continued to increase significantly through the sampling period. This agrees with Mosley (45) who showed that beans at a comparable density (38 plants/m^2) were still rapidly growing 50 days after emergence.

The small amount (1%) of the yield graded out as over sized bean pods (sieve size 6) is an indication that the harvest on 6 August was early. The greatest bean plant weight means and the smallest per unit area grass weights were from plots with 70 cm sod strips. The increased bean plant weight was unexpected and contrary to the result of the 1985 trial. The reduced grass growth may be explained by competitive effects, particularly shading by the larger bean plants.

Pod yields for all sod suppression treatments were not significantly different from the monoculture check except for the plots with fluazifop 0.4 kg/ha applied to the 60 cm sod strips (Table 5).

The 6 chemical treatment rates suppressed grass an average of 57% (Table 6). The mean grass weight from the 50 cm wide sod strips showed trends of being greater than the 70 cm sod strips, but not the 60 cm sod strips. This may in part be due to the edge effect. In 1985 all the grass in each strip was harvested, but in 1986 harvest only samples from the 50 cm strips were taken to the edge of the sod. Also, as noted above, the 70 cm sod strips were more heavily shaded by the bean plants. Grass growth did not vary significantly among suppression treatments but grass growth on check plots significantly exceeded that for all suppression treatments.

Fluazifop applied at 0.2 kg/ha adequately suppressed grass in the 1986 bean trial but not the 1985. Differences in the time of grass mowing and the time of application may explain this. In 1985 the grass was mowed the day of bean planting and suppressants were applied five days later. In 1986 the suppressants were applied 16 days after bean planting and 31 days after the grass was mowed. More grass leaf area was available for absorbtion of suppressants in 1986 since the grass grew for an additional month before treatment. The time between suppressant application and pod harvest was 65 days in 1985 and 50 days in 1986.

While the practical use of a living mulch has been demonstrated in certain cropping systems (1, 2) this cultural method needs to be tested for specific crops grown under specific environmental conditions. The results of this study show that an established perennial grass sod can interfere with bean crop production, but, if the grass growth is adequately suppressed with a sub-lethal dose of herbicide at the time the bean crop is growing, normal yields can be expected.

Table 1. The effect of chemical treatments on the bean plant fresh weights (metric tons/ha). 1985 Italian bean experiment.

Suppression chemicals and application rates	Sampling dates											
	July 3, 1985			July 10, 1985			July 17, 1985			July 23, 1985		
	Sod strip widths (cm)			Sod strip widths (cm)			Sod strip widths (cm)			Sod strip widths (cm)		
kg/ha	70	60	50	70	60	50	70	60	50	70	60	50
Sethoxydim 0.005	8.2**[z]	13.8	15.4	13.3**	16.3**	15.1**	20.1**	25.6*	28.6	21.7**	26.4**	25.8**
Sethoxydim 0.01	9.2**	11.2*	12.6	10.4**	16.0**	15.9**	17.1**	24.7*	22.0*	15.9**	21.4**	28.7**
Sethoxydim 0.02	9.1**	12.2	14.5	11.1**	13.5**	12.5**	19.7**	22.1*	25.8*	17.2**	24.5**	28.0**
Fluazifop 0.05	7.5*	12.8	13.3	11.2**	14.5**	15.6*	18.6**	23.6*	26.7	21.2**	23.3**	29.4**
Fluazifop 0.1	7.5*	12.5	13.7	12.8**	14.0**	18.5	19.7**	22.3*	28.7	17.3**	22.9**	28.3**
Fluazifop 0.2	9.7*	11.0	16.2	11.8**	11.4**	17.8	20.3**	18.0**	24.9*	19.4**	23.5**	28.2**
Means	8.5	12.3	14.3	11.8	14.3	15.9	19.3	22.7	26.1	18.8	23.7	28.1
LSD[y]	3.6	5.0	4.7	3.4	4.9	7.1	5.7	6.6	8.5	4.9	8.4	14.2
Monoculture check			16.3			24.2			40.2			59.2

[z]Significantly different unpaired t-test comparisons with monoculture check, * and ** at 5% and 1% level, respectively

[y]Suppression treatment means LSD at the 5% level.

Table 2. The effect of chemical treatments on graded bean pod yields (metric tons/ha). 1985 Italian bean experiment.

Suppression chemicals and application rates	kg/ha	Sod strip widths (cm) 70	60	50
Sethoxydim	0.005	3.4**z	4.1**	4.1**
Sethoxydim	0.01	2.6**	4.1**	3.9**
Sethoxydim	0.02	2.6**	3.7*	4.3*
Fluazifop	0.05	3.8**	4.8*	4.4**
Fluazifop	0.1	3.3**	3.6**	4.0**
Fluazifop	0.2	2.9**	3.3**	4.4**
Means		3.1	3.9	4.2
LSDy		1.4	1.8	1.9
Monoculture check		6.4		

zSignificantly different unpaired t-test comparisons with monoculture check at the 5% level and 1% level respectively.

ySuppression treatment LSD at the 5% level.

Table 3. The effect of chemical treatments on grass fresh weights (g/m^2). 1985 Italian bean experiment.

Suppression chemicals and application rates kg/ha	Sod strip widths (cm) 70	60	50
Sethoxydim 0.005	977	731	697
Sethoxydim 0.01	807	743	655
Sethoxydim 0.02	866	654	1031
Fluazifop 0.05	756	719	919
Fluazifop 0.1	940	677	744
Fluazifop 0.2	869	791	577
Grass Check	1021	861	919
Means	891	739	791
LSD[z]	261	196	263

[z]Suppression treatment LSD at the 5% level.

Table 4. The effect of chemical treatments on bean plant fresh weights (metric tons/ha). 1986 green bean experiment.

Suppression chemicals and application rates	Sampling dates											
	July 14, 1986			July 21, 1986			July 27, 1986			Aug 5, 1986		
	Sod strip widths (cm)			Sod strip widths (cm)			Sod strip widths (cm)			Sod strip widths (cm)		
kg/ha	70	60	50	70	60	50	70	60	50	70	60	50
Sethoxydim 0.08	6.9	5.9	5.6	8.4	7.4	9.1	10.0	11.0	9.8	13.8	14.2	14.2
Sethoxydim 0.1	7.3	5.6	5.4	8.7	6.9	7.1	11.5	10.8	10.1	17.2	14.4	13.1
Sethoxydim 0.12	7.0	5.9	5.6	8.8	7.2	8.1	12.6	10.6	10.6	17.7	14.0	14.0
Fluazifop 0.2	6.7	6.0	5.8	8.5	7.5	7.4	11.5	10.7	10.1	15.9	13.3	12.4
Fluazifop 0.4	6.2	5.4	5.8	7.8	6.4	7.6	10.7	9.9	8.1*z	15.3	12.8	12.2
Fluazifop 0.6	6.1	5.6	6.5	7.5	7.0	6.9	9.7	10.3	9.2	13.3	15.8	12.5
Means	6.7	5.8	5.8	8.3	7.1	7.7	11.0	10.6	9.7	15.6	14.1	13.1
LSD[y]	1.2	1.4	1.4	2.3	2.0	1.8	3.0	2.9	2.4	4.9	5.3	2.3
Monoculture check			6.2			8.4			10.7			14.1

[z]Signicantly different unpaired t-test comparison with monoculture check, * at 5% level.

[y]Suppression treatment means LSD at the 5% level.

Table 5. The effect of chemical treatments on graded bean pod yields (metric tons/ha). 1986 green bean experiment.

Suppression chemicals and application rates	kg/ha	Sod strip widths (cm) 70	60	50
Sethoxydim	0.08	4.7	4.9	5.0
Sethoxydim	0.1	6.3	4.9	5.2
Sethoxydim	0.12	6.5	4.5	5.4
Fluazifop	0.2	5.4	4.1	4.4
Fluazifop	0.4	5.7	3.7*[z]	4.6
Fluazifop	0.6	4.3	5.4	4.7
Mean		5.5	4.6	4.9
LSD[y]		1.8	2.2	1.3
Monoculture check		5.6		

[z]Significantly different unpaired t-test comparison with the monoculture check, at the 5% level.

[y]Suppression treatment LSD at the 5% level.

Table 6. The effect of chemical treatments on the grass fresh weights (g/m^2). 1986 green bean experiment.

Suppression chemicals and application rates kg/ha	Sod strip widths (cm) 70	60	50
Sethoxydim 0.08	327	459	440
Sethoxydim 0.1	266	311	460
Sethoxydim 0.12	256	273	504
Fluazifop 0.2	389	476	620
Fluazifop 0.4	292	373	519
Fluazifop 0.6	439	337	420
Grass Check	623	620	846
Means	370	407	544
LSD[z]	172	123	172

[z]Suppression treatment LSD at the 5% level.

Chapter 4

CABBAGE AND SUGAR BEET PRODUCTION IN A MANHATTAN II PERENNIAL RYEGRASS LIVING MULCH

METHODS AND MATERIALS

The same plot layout and a treatment system with different rates of sethoxydim and fluazifop were used on another site adjacent to the bean site. Grass was mowed to a height of 1 cm on 12 July, 1985. After preparing a seedbed, using the same row widths, sod strip widths, and with procedures as described for the 'Romano II' bean trial (dinoseb amine was not applied), cabbage 'Market Prize' seeds were planted on 13 July with a Planet Jr. planter. Plants were thinned to a 46 cm spacing three weeks after planting. Sod suppression treatments were applied 15 September (Table 7). Between 14 and 18 November ten cabbage heads were cut from each plot and weighed. The grass was harvested and weighed on 31 December.

On the 'Romano II' bean site, after preparing a seedbed, using the same rows and with procedures as described for the 'Romano II' bean trial, sugarbeet 'Beta' seeds were planted 8 September 1985 with a Planet Jr. planter. No herbicide was applied. Grass was cut to a height of 1 cm after the sugar beet seed was planted. The same block treatments (sod strip widths) as in the other trials were used. The sugar beet plants were thinned to 20 cm apart. The sod suppression treatments applied 15 September were the same as those applied to the cabbage plots (Table 7). The sugar beet plot was evaluated 5 April 1986, but the sugar beet plants were not harvested because of a poor surviving stand and heavy sod growth.

RESULTS AND DISCUSSION

None of the six suppression treatment means varied significantly among themselves. Cabbage head weight means in the monoculture check were significantly heavier than those in the chemically suppressed sod plots. Inadequate distribution of irrigation water and mechanical damage resulting from insecticide applications contributed to the high uncontrolled variances in the measured crop yields.

No chemical suppression treatments suppressed fall grass growth. Grass was growing vigorously at the time of application, but the chemical rates were too low and the fall temperatures too cool to sustain suppression through to harvest.

Grass weights varied greatly within treatments, again associated with irregular distribution of irrigation water in the experimental area. None of the six suppression treatment means were significantly different one from another (Table 8). Although application rates of chemical suppressants varied as attempts were made to find the best rate range of the next experiment in this series of trials, fluazifop at 0.2 kg/ha was used in all trials. Grass suppression in the 1986 'Oregon 43' bean trial was adequate at this rate, but not in the other three previous trials, possibly because of three conditions present in the 1986 bean trial. (1) the grass had been vigorously growing for one month making more leaf area available for uptake of the chemical suppressants, (2) there was adequate soil moisture, and (3) there were warmer temperatures. In the 1985 'Romano II' bean trial, even though temperatures were warm, the grass was not vigorously growing and was only 1 cm tall when the fluazifop was applied. Fluazifop at 0.2 kg/ha in both the cabbage and the sugar beet plots failed to suppress the grass. The mid-September application was followed by cooler fall temperatures which likely slowed chemical uptake and action. Without subsequent chemical applications grass recovered before harvest. Moreover, in the sugar beet trial, some annual ryegrass in the planted strip interferred with beet growth.

Table 7. The effect of chemical on cabbage head fresh weights (g/head). 1985 cabbage experiment.

Suppression chemicals and application rates	kg/ha	Sod strip widths (cm) 70	60	50
Sethoxydim	0.02	675*[z]	635*	701*
Sethoxydim	0.04	577*	470*	699*
Sethoxydim	0.06	460*	448*	804*
Fluazifop	0.1	417*	583*	657*
Fluazifop	0.2	531*	621*	761*
Fluazifop	0.4	645*	730*	625*
Mean		551	581	708
Monoculture check		1346		
LSD[y]		202	289	252

[z]Significantly different unpaired t-test comparison with the monoculture check, at the 5% level.

[y]Suppression treatment LSD at the 5% level.

Table 8. The effect of chemical treatments on the grass fresh weights (g/m^2). 1985 cabbage experiment.

Suppression chemicals and application rates	kg/ha	Sod strip widths (cm) 70	60	50
Sethoxydim	0.02	421	297	101
Sethoxydim	0.04	251	323	137
Sethoxydim	0.06	365	375	132
Fluazifop	0.1	266	231	60
Fluazifop	0.2	297	156	57
Fluazifop	0.4	245	127	51
Grass Check		320	450	74
Means		309	280	87
LSD[z]		168	69	16

[z]Suppression treatment LSD at the 5% level.

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