Influence of Cover Crop and Herbicide Treatment on Weed Control and Yield in No-Till Sweet Corn (*Zea mays* L.) and Pumpkin (*Cucurbita maxima* Duch.)[1]

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Abstract. Sweet corn and pumpkin were planted no-tillage (NT) into cover crop residue treatments of vetch, rye, crimson clover, and ladino clover controlled with glyphosate, and a bare ground conventional tillage (CT) control. Objectives included evaluation of crop growth, yield, and weed suppression in NT versus CT treatments. Herbicide application was also investigated, with a plus and minus herbicide treatment (alachlor plus cyanazine for sweet corn, or ethalfluralin for pumpkin) as the main factor in the factorial experiment, and cover crops the subfactors. Weed control 4 wk after planting was dependent upon cover crop. The fewest weed numbers and least biomass were found in the ladino clover plots, but clover regrowth and subsequent competition with the cash crop were severe. Herbicides also affected weed biomass at 4 wk after vegetable planting, with least biomass in herbicide-treated plots. Neither cover crop nor herbicide treatment significantly affected weed weight by 8 wk after planting or pumpkin fruit weight at harvest. Pumpkin yield was not influenced by herbicide application. The vetch cover, although harboring greatest weed biomass, produced the greatest total yield (ear weight) in sweet corn. When averaged over cover crop, sweet corn yields were higher in herbicide-treated plots than in untreated ones. Both sweet corn and pumpkin maturity were generally delayed in the absence of herbicide treatments or in the presence of cover crop residues, especially clover and rye residues. **Nomenclature:** Alachlor, 2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide; cyanazine, 2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile; ethalfluralin, *N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine; glyphosate, *N*-(phosphonomethyl)glycine; crimson clover, *Trifolium incarnatum* L.; ladino clover, *Trifolium repens* L.; pumpkin, *Cucurbita maxima* Duch. Ex Lam.; rye, *Secale cereale* L.; sweet corn, *Zea mays* L.; bigflower vetch, *Vicia grandiflora* Scop.; hairy vetch, *Vicia villosa* Roth.

Additional index words: Alternative weed control, cover crops, no-till vegetables.

INTRODUCTION

Minimum or no-tillage (NT)[3] is not a new concept in the production of agricultural crops. The benefits of tillage systems and cover crop residues are well documented. Some of the benefits associated with minimum tillage include decreased soil erosion and compaction, and increased soil moisture and N availability if legumes are used as the preceding cover crop (2, 17). In addition, short-term weed suppression may be provided due to the physical and/or allelopathic effects of the cover crop or its decomposing residues (13, 14, 15).

Alternative, nonchemical methods of weed control involving minimum tillage production systems have been investigated for agronomic crops such as soybean (*Glycine max* L.) and grain corn, but relatively little work with minimum tillage has been done in horticultural crops. Earlier studies have generally focused on the cover crop-yield relationship (6, 10, 12, 17), often without considering the effect of cover crop residues on weed suppression. It is important to evaluate the use of cover crops as a weed control tool for horticultural cropping systems because of recent losses of labeled herbicides for horticultural food crops. NT and organic production systems are also increasing in acreage in the U.S. due to consumer preference for reduced pesticide usage in food crops and environmental concerns of consumers as well as producers.

Studies have shown mixed results when cover crops are used in NT production of horticultural crops. Certain trans-

[1]Received for publication June 26, 1995 and in revised form Jan. 14, 1996. Journal series paper no. 96-11-073 of the Kentucky Agric. Exp. Stn.

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[3]Abbreviations: NT, no-tillage; CT, conventional tillage; WAP, weeks after planting.

planted crops such as tomato (*Lycopersicon lycopersicon* L.) and cole crops have performed well when planted into killed residues (1, 6). Processing tomatoes and broccoli (*Brassica oleracea* L.) were successfully produced using NT in rye mulches in the central and southern U.S. (1, 7, 9). Further, larger seeded, quickly germinating species perform better in NT when direct-seeded than do small-seeded, slowly germinating species (18). Sweet corn has been successfully produced in both rye and white clover (*Trifolium repens* L.) mulches without adversely affecting yields (8). Snapbean (*Phaseolus vulgaris* L.) and cucumber (*Cucumis sativus* L.) were easily established in NT residues (18). Pumpkin was also direct-seeded into rye residues successfully (16). Rapid germination of larger seeded crops may allow seedlings to establish more quickly in adverse growing conditions.

Planting no-till vegetables in early spring may cause poor seedling establishment since soils are often cold and wet. Under these conditions, decomposing mulch may also release greater levels of phytotoxins over longer periods of time which are injurious to slowly emerging seedlings (15, 19).

Several cover crop species are suitable for Kentucky's growing conditions and provide an adequate mulch once killed or suppressed. Winter rye, wheat (*Triticum aestivum* L.), and hairy vetch overwinter and establish in Kentucky. Less information is available on the efficacy of clover cover crops in Kentucky production systems.

This study evaluated the growth of early summer plantings of larger seeded, rapidly germinating vegetable crops in cover crop residues. Warmer soil conditions and adequate soil moisture normally prevail in Kentucky at this time. However, pest pressures including insects, pathogens, and weeds may also be significant at this later planting date. Sweet corn and pumpkin were selected for evaluation in NT systems since both direct-seeded crops establish quickly and our preliminary studies indicate both perform well in minimum tillage production. Sweet corn is currently the number one vegetable crop (by acreage) in Kentucky while pumpkin is increasing in acreage because of potential high profits in the lucrative Halloween market.

Therefore, the objectives of our research were to evaluate 1) selected cover crops for their ability to overwinter, 2) the weed suppressive potential of these covers and 3) sweet corn and pumpkin crop growth and yield. Cover crop treatments included a mixture of vetches, winter rye, ladino clover, and crimson clover.

MATERIALS AND METHODS

Overall experimental design. Research was conducted at the University of Kentucky South Farm in Lexington, KY. The soil type was a Maury silt loam (fine, mixed, mesic, typic Paleudaelfs) with an organic matter content of 3.0% and a pH of 6.2. The experiment was a two-factor split block design with three replications. The main factor was herbicide versus no herbicide treatment while subfactors were cover crop treatments (rye, vetch mix, ladino clover, crimson clover, and bare ground conventionally tilled control). Each subplot measured 6.4 m by 15.2 m (0.0097 ha).

Cover crop establishment. 'Wheeler' rye was successfully established on Nov. 12, 1993 at a seeding rate of 103 kg/ha. Clovers were also seeded at this time and became established, but due to a harsh winter (with temperatures as low as –29 C) and late seeding date they did not survive in adequate numbers. Ladino and crimson clovers were therefore reseeded on Mar. 6, 1994 at 7.73 kg/ha and 17.5 kg/ha, respectively. The stand of clover was still sparse on Apr. 28, so plots were overseeded at the same rates. Vetch was established adjacent to this site previously (2 yr before) and plots contained a dense mixture of self-seeded hairy and bigflower vetch, with hairy vetch tending to predominate in plot locations. Little winter kill was observed in the vetch plots. Bare ground treatments had no cover crop established and were conventionally tilled by plowing in October, followed by cultivation to a depth of 10 cm before planting.

Cover crop control and seeding of crop. All cover crops were killed or suppressed with glyphosate at 1.8 kg/ha on June 13, 1994, approximately two weeks before planting. Rye was mowed with a sickle bar side arm mower in order to distribute residue uniformly over the surface of the plot. Sweet corn (cv. 'Bodacious') and pumpkin (cv. 'Howden') were planted on June 30 at conventional seeding rates (15 and 4 kg/ha, respectively) with a no-till planter. Stands were thinned in early July to 1 plant per 25 cm row for sweet corn and 1 plant per 60 cm row for pumpkin. Ammonium nitrate was then immediately broadcast at 112 kg/ha N over all plots according to soil test recommendations. Ethalfluralin (1.2 kg/ha) and alachlor plus cyanazine (2.2 kg/ha plus 2.2 kg/ha) were also applied over one-half of the cover crop residues in main plots for weed control in pumpkin and corn, respectively. Herbicides were applied using a tractor-mounted sprayer with 8004 nozzles delivering 243 L/ha. Untreated plots received no herbicide application.

Data collection and evaluation. Weed data was collected at 4 and 8 weeks after vegetable planting (WAP)[4] from each plot. Within a randomly chosen 0.5-m^2 area per plot, weeds were cut off at the soil surface and placed in separate bags for broadleaf weeds, grass weeds, and nutsedge. If regrowth of clover occurred within this area, it was separated from weeds and collected. The bags were then dried for 2 d in a drying oven and dry weights were determined. Crop height (sweet corn) or vine length (pumpkin) measurements were also taken at 4 and 8 WAP. Three measurements per subplot were randomly collected and averaged.

Harvest sampling. Crops were subjected to a once-over harvest. Sweet corn was harvested on Sept. 12 and pumpkin on Oct. 7, 1994. Sweet corn was harvested in 6.4 m of middle rows in each treated area. Sporadic raccoon damage was noted at harvest time and damaged areas were not harvested for yield determinations. Data collected included total number of ears and total ear weight. Ear length and maturity (ear diameter, tip fill, marketability) were estimated from a random subsample of 20 ears per subplot. All pumpkins were harvested from each subplot. Pumpkin data included fruit number, weight, and maturity (a visual estimation of percent orange coloration).

Data were subjected to analysis of variance for a two factor split block design with three replications using SAS. Main effects are presented where possible, when interactions were not significant. Data were also subjected to Bartlett's test for homogeneity of variance. Data were transformed only if variances were not homogeneous.

RESULTS AND DISCUSSION

Cover crops. Clover cover crops were difficult to establish from late fall seeding as previously reported by Fischer and Burrill (4) in Oregon and Nelson et al. (11) in Oklahoma. The unusually harsh Kentucky winter accompanied by a sustained period of temperatures below –29 C, as well as the relatively late planting date in November, may have contributed to the inability of clover to overwinter. In comparison, rye was easily established and overwintered well as did the previously established mixture of vetch (data not shown). Reseeding of clover cover crops in the spring resulted in good clover stands.

Rye and vetch mixtures were controlled by one application of glyphosate at 1.8 kg/ha, whereas clover cover crops were only initially suppressed. Vetch and rye were approximately 60 and 90 cm in height, while clovers were 15 to 20 cm in height at the time of glyphosate application. By 4 to 6 wk after application, significant regrowth of clovers was observed. Poor suppression of clovers was likely due to a differential response of legume species to glyphosate (18). Others have noted that complete suppression of cover crops is critical for early crop establishment and uniform weed control (4, 11). Future treatment of clovers with a postemergence broadleaf herbicide may be desirable to provide complete kill. Residue biomass varied among cover crops, judging by visual evaluation. Rye and hairy vetch had greater initial biomass than clover covers, Vetch residue decomposed readily, and by 4 WAP residue was well decomposed. In contrast, significant levels of clover and rye residues were retained on the soil surface throughout the experiment.

Weed control. Heavy weed pressures are often encountered in Kentucky in NT production systems. In NT production of field corn and soybean in Kentucky, applications of both pre- and postemergence herbicides are used to achieve high yields. In this experiment, the main weeds encountered were redroot pigweed (*Amaranthus retroflexus* L. #[4] AMARE), giant foxtail (*Setaria faberi* Herrm. # SETFA), and large crabgrass (*Digitaria sanguinalis* L. # DIGSA).

At 4 WAP, both herbicide application and cover crop treatment affected the total weed biomass in the sweet corn plots and the interaction between these factors was significant (Figure 1). The greatest weed pressure was in vetch

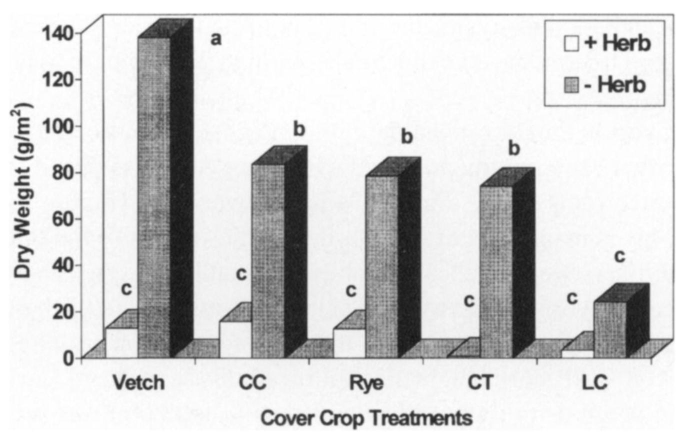

Figure 1. Influence of cover crop treatment and herbicide application on total weed weight (g/m^2)in sweet corn at 4 wk after planting. Means presented with the same letter are not statistically different at the 0.05 level according to Fisher's protected LSD test. Alachlor plus cyanazine were applied for weed control in sweet corn, while ethalfluralin was applied for weed control in pumpkin. CC = crimson clover, CT = bare ground-conventional tillage, LC = ladino clover.

[4]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

plots without herbicide where total weed biomass was two-fold greater than in the bare ground control. The least weed biomass was in the ladino clover plots which is likely attributed to the extensive regrowth of the clover that interfered with competing weeds. Other cover crop treatments had intermediate numbers (data not presented) and weights of weeds. These trends were also observed in pumpkin plots at 4 WAP, with vetch plots containing the greatest weed biomass (data not presented). This was also observed in past studies conducted in Kentucky with vetch residues (data not presented). Vetch residues may provide additional moisture and nitrogen to developing weeds, such that weed biomass may be increased in the presence of vetch residue when compared to the conventionally tilled control or other cover crop residues. In contrast, Johnson et al. (5) found that hairy vetch and mowed rye provided good control of giant foxtail (60 to 65%). In this experiment, grasses dominated the weed populations in the vetch plots.

Herbicide application had a significant effect on weed weight at 4 WAP (Figure 1), with biomass approximately eight to nine times greater in untreated sweet corn plots as compared to treated plots. Similar trends were observed in pumpkin plots, with three times greater weed biomass at 4 WAP in untreated plots (data not presented). By 8 WAP, neither herbicide nor cover crop significantly affected total weed weight in pumpkin plots. Weed density was generally heavy across all pumpkin treatments by 8 WAP. However, averaged over cover crop treatment, fewer weeds at 8 WAP were in sweet corn plots treated with alachlor plus cyanazine than all other treatments (data not presented). Alachlor plus cyanazine likely persisted longer in sweet corn treatments than did ethalfluralin in the pumpkin treatments.

Crop height. Corn and pumpkin heights were affected by cover crop treatment at 4 WAP. Sweet corn was tallest in vetch plots and shortest in ladino clover plots (Figure 2). This is in agreement with earlier studies which found that living clover mulches can inhibit vegetable crop growth by being overly competitive (4, 11, 17). Compared to the bare ground control, corn plants in vetch plots were 23% taller. At 8 WAP, corn height also followed this same trend, corn in vetch or rye was tallest and corn in ladino clover was most stunted. Sweet corn height was significantly affected by herbicide treatment only at 8 WAP, with herbicide-treated corn 15% taller than nonherbicide-treated corn (data not presented).

Pumpkin height in cover crop residues was somewhat variable (Figure 3). At 4 WAP, pumpkin responded much like sweet corn with vetch plots producing the tallest pumpkin plants. Pumpkins produced in ladino clover plots exhibited reduced height at 8 WAP when compared to other treatments. In contrast to sweet corn, pumpkin produced in plots with no herbicide were taller (data not presented). This may be due to the shading effect of weeds present in the plots without herbicide, resulting in some etiolation of developing pumpkin plants (5). Sweet corn seedlings,

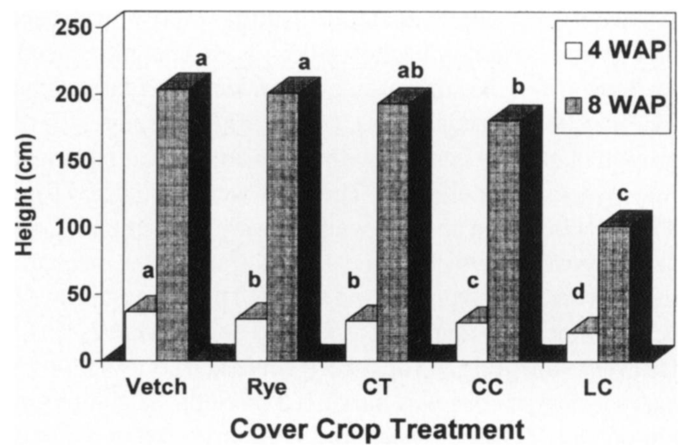

Figure 2. Influence of cover crop treatment averaged over herbicide treatment on corn height (cm) at 4 and 8 wk after planting. Means presented with the same letter are not statistically different at the 0.05 level according to Fisher's protected LSD test. CC = crimson clover, CT = bare ground-conventional tillage, LC = ladino clover.

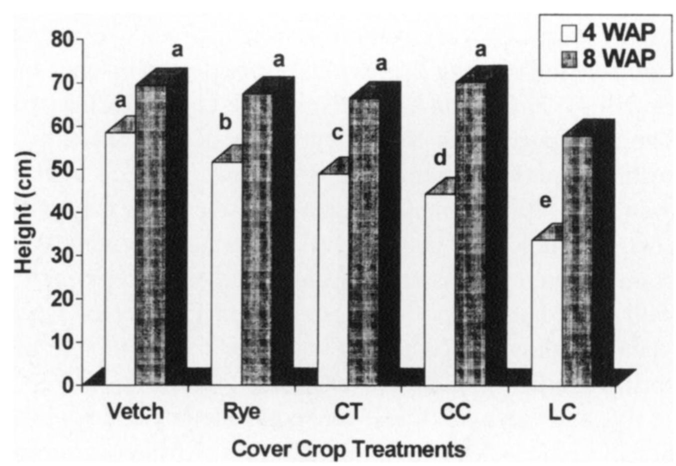

Figure 3. Influence of cover crop treatment averaged over herbicide treatment on pumpkin height (cm) at 4 and 8 wk after planting. Means presented with the same letter are not statistically different at the 0.05 level according to Fisher's protected LSD test. CC = crimson clover, CT = bare ground-conventional tillage, LC = ladino clover.

Table 1. Influence of herbicide application averaged over cover crop treatment on corn yield.[a]

Herbicide[b] application	Total weight	Total ear number	Ear weight
	kg/ha	No. ear/ha	g/ear
Yes	12103	70427	175
No	4821	58462	78
Significance	**	NS	*
LSD (0.05)	5722	—	31.59

[a]Means were statistically different at * (0.05) or ** (0.01) level using Fisher's protected LSD test.

[b]Herbicides applied were alachlor plus cyanazine.

which gain height more rapidly than pumpkin, may have been less affected by interspecific weed competition.

Yields. Application of herbicide had greater effects on final corn yields (as measured as weight per ear and total ear weight) than did cover crop treatments (Table 1 and Figure 4). There were no significant herbicide by cover crop interactions for corn yields. When averaged across cover crop treatments, the average total ear weight of corn harvested from plots treated with alachlor plus cyanazine was more than double those collected from plots where no herbicide was applied. Interestingly, sweet corn grown in vetch yielded 24% more ear weight than the bare ground control, even though weed numbers were also highest in vetch plots initially. This is in contrast to an earlier study by Mohler which reported that corn yields produced by NT seeding into a white clover residue were dependent mainly on good weed control and mulch suppression (8). Results

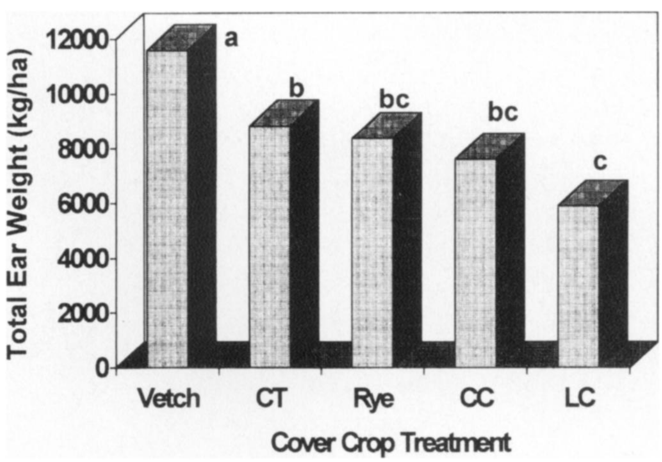

Figure 4. Influence of cover crop treatment averaged over herbicide treatment on final corn yield in kg/ha. Means presented with the same letter are not statistically different at the 0.05 level according to Fisher's protected LSD test. CC = crimson clover, CT = bare ground-conventional tillage, LC = ladino clover.

from our studies may be attributed to the inherent ability of vetch to add significant levels of N to the soil (1, 2, 6, 17) and the well-documented yield response of corn to additional nitrogen fertilizers (3). Sweet corn ear diameters were also highest in vetch treatments (data not shown). In contrast, sweet corn grown in ladino clover covers exhibited stunting and greatly reduced yields. Ladino clover proved to be an aggressive mulch, with considerable regrowth which competed with the sweet corn crop. Previous research has also shown that living mulch competition resulted in reduced sweet corn yields and ear size (4, 11, 17).

Pumpkin yields were not affected by either cover crop treatment or herbicide application and there were no significant interactions between these factors. However, when averaged over herbicide treatment, the bare ground control produced the highest total fruit weight (Table 2). An earlier study by Knavel (6) found that yields of summer squash (*Cucurbita pepo* L.), another cucurbit crop, were higher in NT rye residues than in conventional tillage. However, we saw no differences in pumpkin yields associated with tillage. Pumpkin is generally not as responsive to fertilizer N applications as is sweet corn (3). Interestingly, yields were also not increased in the vetch treatments in comparison to the control. Herbicide also had no effect on total pumpkin weight harvested. Ethalfluralin treatment provided only short term weed suppression with control observed for 4 to 5 wk after application.

Although fruit weight was not affected by herbicide treatment, fruit maturity was affected. Pumpkin fruit harvested from ethalfluralin-treated plots exhibited greater orange coloration than fruit from untreated plots (data not presented). In addition, sweet corn and pumpkins produced in rye and clover residues generally exhibited somewhat delayed maturity (i.e., smaller ear diameter in sweet corn and reduced orange coloration in pumpkin rind) in com-

Table 2. Influence of cover crop treatment averaged over herbicide treatment on pumpkin yield.

Cover crop treatment	Total number harvested	Total weight
	No. fruit/ha	kg/ha
Bare ground/tillage	1392	3142
Rye	1340	2608
Crimson clover	1426	2467
Vetch mix[a]	1152	1599
Ladino clover	585	1513
Significance	NS	NS

[a]Vetch mix refers to a mixture of *Vicia villosa* and *Vicia grandiflora.*

parison to the vetch or bare ground conventionally tilled treatments.

This preliminary work has shown promising results for the production of direct-seeded summer vegetables in cover crops in conjunction with herbicide application and indicated a need for further studies. Sweet corn yields and quality were increased in the vetch treatment in comparison to CT, while pumpkin yields were not statistically affected by cover crop treatment, with the exception of the ladino clover treatment. Vetch, although not weed suppressive, may be a potentially useful cover, especially for crops like sweet corn with high N requirements.

In the absence of herbicide, clover mulches proved to be most weed suppressive over time. In the presence of herbicide, cover crops did not generally differ in their ability to suppress weeds. Different management of the cover crop may result in enhanced weed suppression and reduced cash crop interference (1). For example, suppression by repeated mowing or natural senescence may prove useful. Altering management of the vegetable crop itself, perhaps by varying row width or crop spacing, may also lead to higher yields and improved ability of the cash crop to compete with weeds (4).

ACKNOWLEDGMENTS

The authors thank the Weed Science Society of America for supporting this undergraduate research project. We also express our thanks to Ann Clements, Dr. Paul Cornelius, Roselee Harmon, Darrell Slone, and Dr. John Snyder for their assistance in field preparation, data collection, and analysis.

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