NO-HERBICIDE, NO-TILL SUMMER BROCCOLI— QUANTITY OF RYE AND HAIRY VETCH MULCH ON WEED SUPPRESSION AND CROP YIELD

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ABSTRACT

In no-till systems, high-residue cover crop mulch can suppress weed growth and reduce or even eliminate the need for applied herbicides. The extent of weed suppression by cover crop residues is determined by many interacting factors, including seasonal weed pressure and quantity, type (legume vs. grass) and maturity of the residues. This study was conducted to evaluate the effectiveness of high-residue *in-situ* mulch on suppression of summer weeds and yield of broccoli (*Brassica oleracea* L. Gp. Italica). Experimental design was a split-plot with four replications. Main plot treatments were cover crops: hairy vetch, HV (*Vicia villosa* Roth); grain rye, R (*Secale cereale* L.); and a mixture of rye and hairy vetch, R/HV. Subplot treatments were residue management methods: rolled, flail-mowed and no-residues. Growth of all cover crops was excellent, achieving dry weight biomass levels of 2.8, 4.7 and 4.5 ton/acre of HV, R and R/HV, respectively. Persistence of cover crop residues and yield of broccoli were highest in rolled treatments. Broccoli yield was reduced by 23% in flail-mowed and by 71% in no-residues, compared to rolled treatments; these yield reductions were more severe in HV and R/HV than in R plots. Weed biomass was negatively correlated with broccoli yield. Based on these data, when high-residue levels of R or R/HV mulch (4.5-4.7 ton/acre) were left intact (rolled) and undisturbed over the soil surface, excellent yields of summer broccoli were grown without application of herbicides. The R/HV biculture mixture and rolling were the best combination for production of no-herbicide, no-till summer broccoli.

INTRODUCTION

High-residue (3-6 ton/acre), no-till (NT) systems have been successfully used in Virginia and other states for production of brassicas such as cabbage and broccoli (Hoyt et al, 1994; Morse 1999b). Organic growers have expressed interest in using high-residue cover crops as an *in-situ* NT mulch instead of as green manure (Morse, 2000). In the traditional organic system, cover crop residues are incorporated before planting vegetable crops, leaving the soil uncovered and prone to germination and proliferation of weeds. Under this traditional system, weed control has become the greatest production problem facing organic growers (Walz, 1999). Without access to modern herbicides, organic growers resort to integrated weed management strategies (Regnier and Janke, 1990). While mechanical cultivation can effectively control weeds, soil organic matter declines in cultivated fields. Organic mulches suppress weeds;

however, growing, harvesting and spreading cover crop mulch are both costly and labor intensive. Using legume cover crops as green manure will provide organic nitrogen; however, weeds flourish after leaving the soil surface bare when legume cover crops are incorporated.

Weed management with reduced or even total elimination of chemical herbicides is appealing to all crop producers, especially those who are concerned about reducing environmental pollution and improving soil quality (Gallandt et al., 2000; Regnier and Janke, 1990; Wicks et al., 1994). Soil organic matter and soil quality are increased more rapidly when high-residue cover crops are produced and remain intact as surface mulch than when incorporated as green manure (Schomberg et al., 1994).

In previous research, no-herbicide NT fall broccoli has been successfully produced using a monoculture of foxtail millet (*Setaria italica* L. P. Beauv.) or a biculture of millet and soybean (*Glycine max* L.) (Infante and Morse, 1996; Morse, 1999a). In recent years, several researchers have shown that mature annual cover crops can be effectively killed using mechanical methods (Ashford et al., 2000; Creamer et al., 1995; Dabney et al., 1991; Morse, 1999a). Since weed populations are more severe in summer than in the fall, a factorial experiment was conducted to evaluate the effectiveness of (1) high-residue mulch from three overwintering cover crops and (2) four mechanical residue management methods on suppression of summer weeds and yield of transplanted broccoli.

MATERIALS AND METHODS

An experiment was conducted in the summer of 1995 at the Virginia Polytechnic Institute and State University Kentland Agriculture Research Farm, Blacksburg. The soil was a Hayter loam (fine-loamy, mixed, mesic, Ultic Hapludalf), with a pH of 6.5. The experimental design was a split plot with four replications. Main plots (36 x 24 ft) were cover crops. On 6 October 1994, hairy vetch (HV), grain rye (R) and a mixture of rye and hairy vetch (R/HV) were drilled in rows 7 in. apart at a rate of 45, 168 and 90/40 lb/acre, respectively. The entire field had been planted with grain rye in the fall of 1993; straw was removed in early June and the plots left fallow and sprayed with N-(phosphonomethyl) glycine (glyphosate) at 2 qt/acre 3 wk before seeding the crops on 6 October 1995.

Subplot treatments (36 x 6 ft) were residue management methods. On 30 May 1995, designated plots were either rolled followed by application of 1,1'-dimethyl-4-4'-bipyridinium ion (paraquat), rolled(+H); rolled without paraquat, rolled(-H); flail mowed without paraquat, flail-mowed(-H); or flail mowed, residues removed, without paraquat, no-residues(-H). All plots were left untouched for 5 wk until broccoli transplants were set on 6 July 1995. Flail mowing was done with a reverse-rotor Alamo-Mott (Alamo Group Co., Sequin, TX), equipped with a rear-mounted, heavy-duty (6 in. wide) roller. Rolling was accomplished by pulling the disengaged Alamo-Mott flail mower across the plot. Flail mowing killed all cover crops; however, only rye was completely killed by rolling. The hairy vetch in the rolled(-H) HV and R/HV treatments was only partially killed. In the paraquat-untreated subplots, stems of hairy vetch grew erect after rolling, eventually leaving two residue layers--at the bottom a mat of dead material and above a layer of living stems. The double layer became pronounced in approximately 2 wk after rolling and the top living layer was mowed with the flail mower raised so as to kill the living stems without disturbing the dead layer.

Above ground cover crop dry weight was determined by taking residue samples from 20 x 20 in. sections of each subplot and drying them at 70ºC for 2 wk. Sampling was taken at initial residue management treatment (30 May), at transplanting (6 July, 5 wk after killing, WAK), and again on 10 August (10 WAK). Cover crop persistence was determined by calculating the percentage of cover crop biomass remaining at 5 WAK and 10 WAK [(DW remaining x 100)/(DW at initial residue management treatment)]. Weed growth in all subplots was determined by harvesting the above-ground portions of weed plants from 20 x 20 in. between-row sections at transplanting (5 WAK) and again at 5 wk after transplanting (10 WAK). The weed material was dried for biomass determination following procedures described earlier for determining biomass of cover crops.

On 6 July 1995, bareroot 'Arcadia' broccoli transplants were set with the Subsurface Tiller-Transplanter (SST-T) (Morse et al., 1993). Granular fertilizer was surface banded at planting 3 in. from both sides of each row at (in lb/acre) 45N-19P-75K-2B, using the SST-T. All plots were sidedressed by hand with calcium nitrate at 50 lb N/acre 2 wk and again 6 wk after transplanting. To ensure a complete stand, transplants that did not survive were replaced by hand. One twin row was planted in each subplot. Rows were spaced 18 in. apart and 54 in. between adjacent twin rows (72 in. center to center); in-row spacing was 12 in. between plants (14,520 plants/acre). Sprinkler irrigation was used throughout the growing season to minimize soil water stress. Pesticides were applied at planting and at regular intervals thereafter, according to the Virginia Commercial Vegetable Production Recommendations (Virginia, 1995).

Marketable broccoli yield was determined from plants in an interior section (6 ft long, 12 plants/plot) of each twin row. United States Department of Agriculture (UDA) grading standards were followed for head broccoli (USDA, 1943). The length of the flowers and stem from the uppermost tip of the dome to the cut stem was 8 in. Heads that were deformed or weighed less than 3 oz. were not considered marketable. Four harvests were made from 27August through 22 September.

Statistical Analysis System (SAS) was used to perform all statistical analysis procedures (Scholtzhauer and Littell, 1987). Percentage data for cover crop persistence were analyzed after arcsine transformation.

RESULTS AND DISCUSSION

Cover Crop Growth and Persistence

Growth of all cover crops was excellent, averaging 5,500, 9,100 and 8,700 lb/acre for hairy vetch (HV), rye (R) and rye/hairy vetch (R/HV), respectively (Table 1). The quantity of cover crop residues remaining (persistence) 10 wk after killing (WAK) varied considerably among cover crops, averaging 31, 66 and 59% for HV, R and R/HV, respectively (Table 1). These residue persistence data are similar to other studies, showing that rate of breakdown is relatively rapid with legumes and slow with mature grain residues (Abdul-Baki et al., 1997;

Morse, 1999a). Rolling delayed breakdown of cover crop residues (improved persistence), compared to flail mowing. Rolling tends to layer and thus expose less residue surface area in contact with the soil, compared to flail mowing, which shreds residues into small pieces (Dabney et., 1991; Morse, 1999a).

Weed Biomass

Weed biomass at 10 WAK (5 wk after transplanting broccoli) was affected by both the type of cover crop and method of residue management (Fig. 1). Except for rolled(+H) treatments, growth of weeds was highest in HV plots for all residue management methods, especially with treatments in which cover crops had been chopped (flail mowed) or removed (no residues). Weed growth in HV plots was inversely related to cover crop persistence at 10 WAK; level of weed biomass was highest in flail-mowed and lowest in rolled subplots (Fig. 1). More weed biomass in unmulched HV than unmulched R or R/HV treatments is attributed to high levels of plant-available N mineralized from the extensive N-rich root system of hairy vetch. These data illustrate why using NT systems and precision placement (band application near the row) of N fertilizer are highly recommended as a weed-control strategy (Morse, 1999b). Broadcasting and incorporating N fertilizer at planting or postplanting are both inefficient and promotes weed growth. In like manner, production and incorporation of HV residues simulates broadcast incorporation of N fertilizer. Thus, incorporation of HV residues before planting broccoli should be avoided, unless appropriate preemergence herbicides or mulch (organic or plastic) are applied to suppress weed growth (Infante and Morse, 1996).

In this experiment, broccoli transplants were set (6 July) 5 wk after killing the cover crops. If broccoli transplants had been set immediately after killing (30 May) the cover crops, probably weed growth would not have reduced broccoli yield (Morse, 1999a). Likewise, if contact herbicides such as paraquat had been applied just before planting broccoli to kill emerged weeds and achieve a stale seedbed, possibly weed growth (even in flail-mowed and no-residues treatments) would have been minimized before canopy closure of the broccoli plants, thus avoiding deleterious effects on broccoli yield (Infante and Morse, 1996; Morse, 1999a). Although weed biomass was low at transplanting (data not shown), emerged weed numbers were high in many plots, particularly in all HV and unmulched R and R/HV plots. When not removed before planting, these small weeds grew rapidly (especially in HV plots) and competed with the young broccoli transplants for light, water and nutrients.

Broccoli Yield

Cover crop effects. Overall across all residue management treatments, broccoli yield was higher in R and R/HV than in HV plots (Fig. 2). Lower broccoli yield in HV plots is attributed to (1) low residue persistence (Table 1), resulting from rapid breakdown of above-ground HV residues; and (2) early weed emergence and rapid weed growth, resulting from above- and below-ground mineralization of HV residues. Delayed weed emergence and relatively slow weed growth occurred in R and R/HV plots, presumably because allelochemicals leached from the thick rye mulch, resulting in no apparent broccoli yield-limiting effects. In the R/HV plots, 85% of the initial residues was rye and only 15% was hairy vetch (data not shown). Therefore, weed growth in R/HV plots was similar to that found with monocrop rye (Fig. 1).

Residue management effects. Although weed biomass tended to be lowest in rolled paraquat-treated subplots, broccoli yield and weed biomass differences between untreated and paraquat-treated were not significant (Fig. 1 and 2). Averaged across cover crops, broccoli yield was reduced by 23% in flail-mowed(-H) and by 71% in no-residues(-H), compared to rolled treatments. However, in R plots, flail mowing did not reduce broccoli yield, and yield in unmulched (no residues) was relatively high. These yield differences among cover crops in flail-mowed treatments probably occurred because weed growth in R plots was held in check because low levels of plant-available N and relatively high levels of allelopathic chemicals were released from the rye residues.

Selecting the best cover crop x residue management combination. Based on these data, a biculture mixture of R/HV and rolling to flatten and retain the cover crop is the best combination for production of no-herbicide, NT broccoli. In rolled treatments, broccoli yield was significantly higher in R/HV than in a monoculture of HV, probably because persistence of HV residues was low and consequently weeds were relatively high in HV plots. In monoculture R plots, low plant-available N probably limited broccoli yield. Applying higher N rates possibly would have increased broccoli yield in R plots (Abdul-Baki et al., 1997).

Determining which combination of cover crop x residue management is best is basically a compromise between the growers need for organic N or weed suppression. Selecting the best combination may depend on whether the grower uses organic or conventional production practices. For example, organic growers might favor a monoculture of hairy vetch because this legume supplies abundant organic N and weed growth could be managed using mechanical cultivation. Conventional growers, who can easily meet the high N demand for broccoli plants by using chemical fertilizer, may opt for a monocrop of rye to achieve excellent weed control and moisture conservation throughout the growing season. However, a mixture of R/HV may be readily suitable for both organic and conventional growers, providing excellent weed suppression and some organic N. In addition to weed suppression and high yields, cover crop mixtures often promote improvements in soil microbial biodiversity and soil quality (Creamer and Bennett, 1997; Magdoff and van Es, 2000).

CONCLUSIONS

High-residue, no-till systems are a viable option for production of transplanted broccoli. Effort and expense to produce and appropriately manage high-residue levels of *in-situ* mulch will be greatly rewarded later in terms of improved weed suppression, increased broccoli yield, and reduced production inputs such as water and nitrogen. In addition, using high-residue systems over time can result in improved soil quality and crop productivity.

The decision as to which cover crop x residue management combination is best often depends on whether the producer is an organic grower who needs the cover crop to supply organic N or a conventional grower who is looking for improved weed suppression and conservation of soil and water. In the former case, the organic grower may opt for a monocrop of HV, either rolled or flail mowed, and would rely on mechanical cultivation for weed suppression. In the latter case, the conventional grower may prefer a combination of monocrop rye and rolling to achieve conservation of soil and water and weed suppression without requiring herbicides. Regardless of the grower's production preference, the combination of R/HV biculture and rolling offers many advantages, including high residue persistence, no-herbicide weed suppression, high yields, and production of some organic N. Transplanting soon after killing the cover crop is recommended to optimize both weed suppression and N-use efficiency of the high-residue NT mulch.

With regard to the quantity of cover crop residues needed to suppress weed growth below yield-limiting levels for NT transplanted broccoli, two conclusion can be drawn, based on data from this experiment and other related studies. First, if three or more ton/acre of mulch are produced, distributed and retained evenly over the soil before transplanting, weed growth can be effectively suppressed below yield-limiting levels without application of herbicides. Second, and most important, when residues are left undisturbed and persist at two or more ton/acre throughout early canopy development (3-4 wk after transplanting), weed suppression lasts several weeks after transplanting and broccoli yield is not reduced.

Literature Cited

Abdul-Baki, A.A., R.D. Morse, T.E. Devine, and J.R. Teasdale. 1977. Broccoli production in forage soybean and foxtail millet cover crop mulches. HortScience 32:836-839.

Ashford, D.L., D.W. Reeves, M.G. Patterson, G.R. Wehtje, and M.S. Miller-Goodman. 2000. Roller vs. herbicides: An alternative kill method for cover crops. p. 64-69. *In* P. K. Bollich (ed.) Proc. Southern Conservation Tillage Conference for Sustainable Agriculture, Monroe, LA.

Creamer, N.G. and M.A. Bennett. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. HortScience 32:866-870.

Creamer, N.G., B. Plassman, M.A. Bennett, R.K. Wood, B.R. Stinner, and J. Cardina. 1995. A method for mechanically killing cover crops to optimize weed suppression. Am. J. Alt. Agri. 10:156-161.

Dabney, S.M., N.W. Buehring, and D.B. Reginelli. 1991. Mechanical control of legume cover crops. p. 146-147. *In* W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Cons. Soc., Ankeny, IA.

Gallandt, E.R., M. Liebman, and D.R. Huggins. 2000. Improving soil quality: Implications for weed management. p. 95-121. *In* D.D. Buhler (ed.) Expanding the context of weed management. Food Products Press (Haworth Press), NY.

Hoyt, G.D., D.W. Monks, and T.J. Monaco. 1994. Conservation tillage for vegetable production. HortTechnology 4(2):129-135.

Infante, M.L. and R.D. Morse. 1996. Integration of no-tillage and overseeding legume living mulches for transplanted broccoli production. HortScience 31:376-379.

Magdoff, F. and H. van Es. 2000. Building soils for better crops, second ed. p. 87-98. Sustainable Agriculture Network, Burlington, VT.

Morse, R.D. 1999a. Cultural weed management methods for high-residue/no-till production of transplanted broccoli (*Brassica oleracea* L. Gp. Italica). *In* Liptay et al. (ed.) Proc. Sixth Symposium on Stand Establishment. Acta Horticulturae 504:121-128.

Morse, R.D. 1999b. No-till vegetable production--its time is now. HortTechnology 9:373-379.

Morse, R.D. 2000. High-residue, no-till systems for production of organic broccoli. p. 48-51. *In* P.A. Bollich (ed.). Proc. Southern Conservation Conference for Sustainable Agriculture, Monroe, LA.

Morse, R.D., D.H. Vaughan, and L.W. Belcher. 1993. Evolution of conservation tillage systems for transplanted crops: Potential role of the Subsurface Tiller-Transplanter (SST-T). p. 145-151. *In* P.A. Bollich (ed.) Proc. Southern Conservation Tillage Conference for Sustainable Agriculture, Monroe, LA.

Schlotzhauer, S.D. and R.C. Littell. 1987. SAS system for elementary statistical analysis. SAS Institute, Inc. Cary, NC.

Schomberg, H.H., P.B. Wood, and W.L. Hargrove. 1994. Influence of crop residues on nutrient cycling and soil chemical properties. p. 99-121. *In* P.A. Unger (ed.) Managing agricultural residues. Lewis Publ. Boca Raton, FL.

U. S. Department of Agriculture, Agricultural Marketing Service. 1943. United States standards for grading bunched Itialian sprouting broccoli. U. S. Govt. Printing Office, Washington, DC.

Virginia commercial vegetable production recommendations. 1995. VA Coop. Ext. Serv. Publ. 420-456.

Walz, E. 1999. Third biennial national organic farmers' survey. p. 19-47. Organic Farming Research Foundation, Santa Cruz, CA.

Wicks, G.A., O.C. Burnside, and W.L. Felton. 1994. Weed control in conservation systems. P. 211-244. *In* R.W. Unger (ed.) Managing agricultural residues. Lewis Publ., Boca Raton, FL.

Table 1. Initial quantity and persistence (10 wk after killing, WAK) of cover crop biomass as influenced by cover crop species and residue management method.

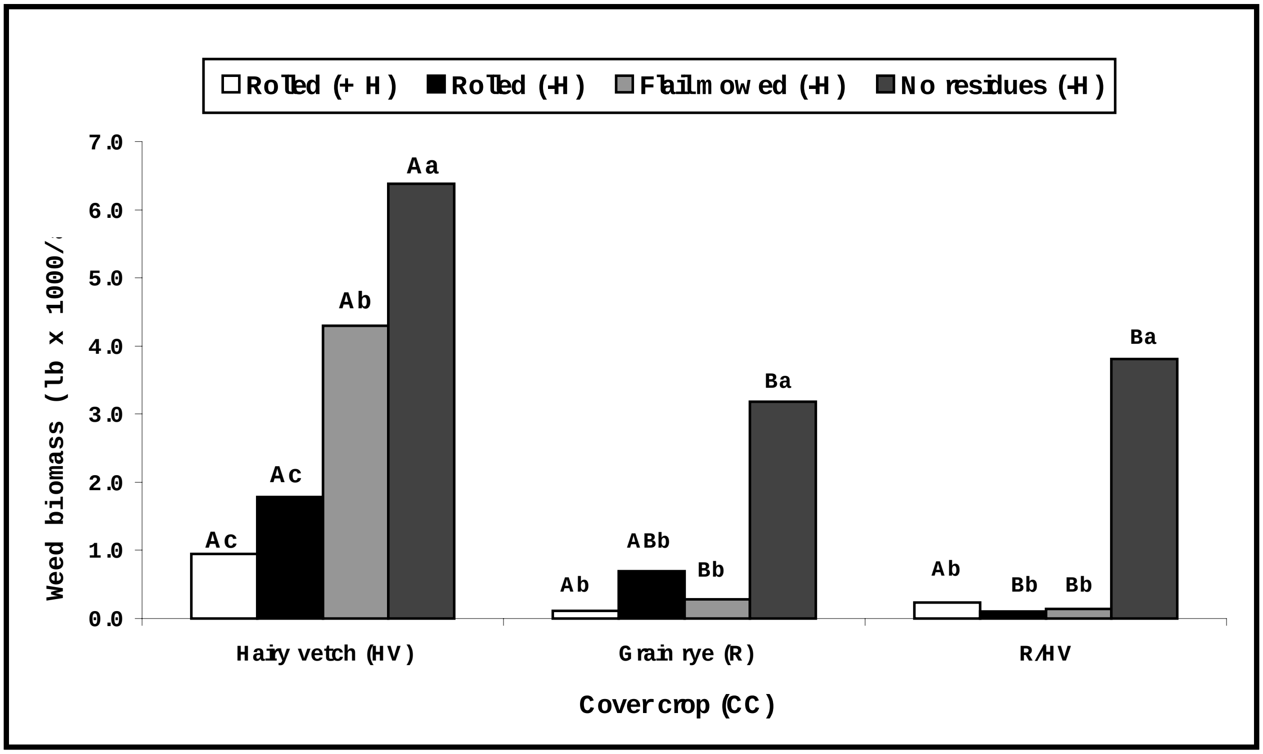
Residue management[z] (RM)	Time (WAK)	Cover crops (CC)							
		Hairy vetch (HV)		Grain rye (R)		R/HV		Mean (RM)	
		lb/a	RQ[y](%)	lb/a	RQ (%)	lb/a	RQ (%)	lb/a	RQ (%)
Rolled (+H)	0	5,610	---	9,500	---	9.200	---	8.200	---
	10	2,000	36	6,600	67	6.000	65	4.500	59a[x]
Rolled (-H)	0	5,800	---	9,010	---	8.800	---	7.800	---
	10	2,000	35	6,400	71	5.600	63	4.600	59a
Flail mowed (-H)	0	5,100	---	8,600	---	8.200	---	7.400	---
	10	1,200	24	5,000	58	3.800	46	3.400	46b
Mean (CC)	0	5,510	---	9,100	---	8.700	---		
	10	1,700	31b	6,000	66a	5,100	59a[x]		

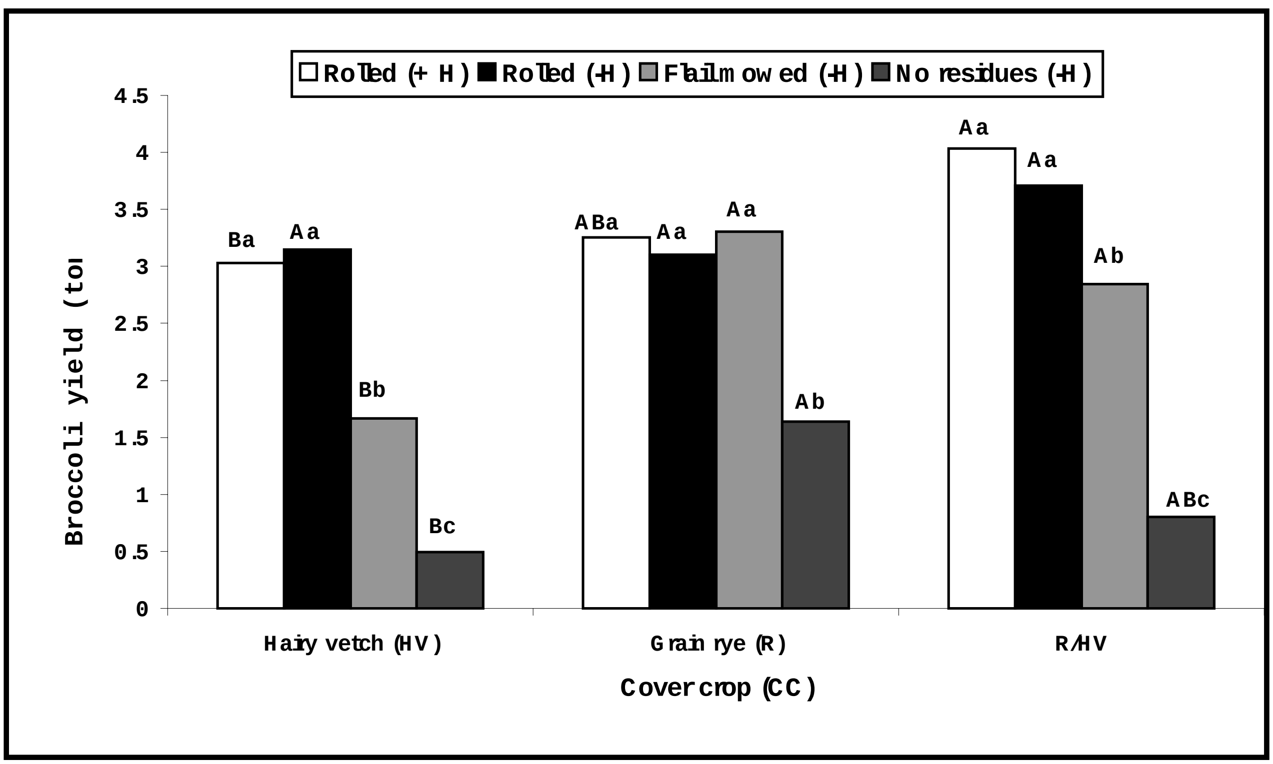
[z]Residue management – After flattening the cover crops by rolling or flail mowing, paraquat was applied [rolled (+H)] or not applied [rolled(-H) or flail mowed(-H)].
[y]RQ = Relative quantity (persistence) in percentage of residues remaining 10 wk after killing (WAK) cover crops by rolling or flail mowing (100%).
[x]Mean separation of RM and CC by LSD ($P = 0.05$). There were no interactions among treatments at $P = 0.05$.

Figure Legends

Fig. 1. Weed biomass at 10 wk after killing (WAK), as influenced by cover crop (CC) and method of residue management (RM). The interaction (CC x RM) was significant ($P>F$ = 0.0076). Mean separation by Tukey's hsd at P = 0.05; lowercase letters indicate RM comparisons within a given CC and uppercase letters indicate CC comparisons within a given RM.

Fig. 2. Broccoli yield as influenced by cover crop (CC) and method of residue management (RM). The interaction (CC x RM) was significant ($P>F$ = 0.0414). Mean separation by Tukey's hsd at P = 0.05; lowercase letters letters indicate RM comparisons within a given CC and uppercase letters indicate CC comparisons within a given RM.


□ Rolled (+ H) ■ Rolled (-H) ■ Flail mowed (-H) ■ No residues (-H)
Weed biomass (lb x 1000/
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Aa
Ab
Ac
Ac
Ab
ABb
Bb
Ba
Ab
Bb
Bb
Ba
Hairy vetch (HV)
Grain rye (R)
R/HV
Cover crop (CC)


□ Rolled (+ H) ■ Rolled (-H) ■ Flail mowed (-H) ■ No residues (-H)
Broccoli yield (to
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Ba
Aa
Bb
Bc
ABa
Aa
Aa
Ab
Aa
Aa
Ab
ABc
Hairy vetch (HV)
Grain rye (R)
R/HV
Cover crop (CC)