The Use of Legume Cover Crops in No-tillage Broccoli and Cabbage Production

by

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DEDICATION

To my wife

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INTRODUCTION

Interest in using conservation tillage practices for crop production has escalated in recent years due to an increased need to control wind and water erosion of soils. However, tillage practices can affect the relative concentration and location of nutrients in the soil profile. Nitrate levels have been shown to be lower under no-tillage (NT) soils when compared to conventionally tilled (CT) soils (25, 26). This is attributed to the higher moisture under NT soils leading to increased leaching and possibly denitrification (25). In addition, availibility of soil nitrates may be decreased with NT because 1) the soil is cooler and more compacted with NT resulting in decreased mineralization of organic matter in the total root zone, and 2) there are higher levels of microbial populations in the upper 7-15 cm of NT soils resulting in increased immobilization of surface applied N in this region, especially for non-legume residues with high C/N ratios (8).

Using legumes in a conservation tillage operation seems a logical step for adding N to the soil system. Several studies have been done to determine how much nitrogen is supplied by different legume crops (11, 26). Hairy vetch is among the most efficient legume studied, supplying an estimated 90-100 kg/ha N annually (11).

Cabbage and broccoli production in Virginia are located in areas of the state that are highly subject to soil erosion and moisture deficits. Because of these inherent problems, vegetable growers are interested in practices that improve soil and water conservation. This study was conducted to compare the effects of two legumes, Austrian winter pea and hairy vetch, versus cereal rye on yields of cabbage and broccoli under CT and NT conditions. Nitrogen rates were varied to assess the potential N contribution of the legume cover crops on subsequent growth and yield of cabbage and broccoli. Hairy vetch was selected in this study because it is well adapted in Virginia and is known to produce heavy yields of both dry matter and fixed nitrogen (15). Austrian winter pea was studied because it is sufficiently hardy to survive most Virginia winters and produces heavy forage yields by mid-June. If winter injury occurs, Austrian winter pea can be reseeded in March or early April and still obtain good growth by mid-June (27). Austrian winter pea has an added advantage over hairy vetch because it germinates more rapidly and more uniformily than hairy vetch. Austrian winter pea has relatively few hard seeds compared to hairy vetch which is known to have from 5 to 25% hard seeds that could pose a potential weed problem during the growing season (15).

LITERATURE REVIEW

There is relatively little data available on no-tillage vegetable production. Most of the literature is limited to field crops, such as corn and soybeans. Therefore, in this review most of the information on no-till crop production will be derived from research of field crops.

Tillage Effect on Plant Nutrition

No-till crop production precludes broadcast fertilizer incorporation. Surface-applied fertilizers have been used successfully in many instances. Surface-applied lime has also proven to be effective in controlling low soil pH. The following is a brief discussion of several elements and the effect of tillage practices on their uptake.

Nitrogen. Thomas *et al*. showed that soil nitrate levels are lower under NT fields when compared to CT fields (31). It was concluded that leaching was responsible for the lower soil nitrate levels. Evaporation is very low with NT soils, greatly reducing salt and water movement upward in the soil profile. With rain, the saturated NT soil aggregates will not absorb additional moisture, resulting in penetration of water and nitrates through the soil profile. With CT soils, the soil aggregate will absorb some of the water and nitrates, decreasing the depth of penetration in the soil profile. In another study Doran (9) concluded that decreased total mineralization of organic matter and higher microbial populations also contributed to the lower nitrate levels found with NT soils.

Triplett et al. (33) investigated the ability of legumes to supply nitrogen for NT corn. They found little or no crop response to applied N fertilizers when corn was planted into a vigorous legume meadow. Ebelhar et al. (11) using hairy vetch, (*Vicia villosa* Roth), big flower vetch (*Vicia grandiflora* W. Koch var. *Kitailbeliana*), and crimson clover (*Trifolium incarnatum* L.) as covers, found similar results. Hairy vetch supplied the highest amount of N, estimated at 90-100 kg/ha fertilizer N annually. Using a legume as the cover is one way to lower production costs because it can provide a considerable portion of the N needed as fertilizer.

Phosphorous. Knavel et al. (19), working with four different vegetable crops, and Mullins et al. (24), using snap beans, found that P absorption was equal to or higher for NT plots when compared to CT plots. Other researchers have found similar results working with corn (23, 30, 35).

Looking at P availibility through the soil profile Mullins et al. (24) found that the top 5 cm in CT and NT soils contained the same amount of P, but from 5 to 10 cm P content was lower for NT soils. This indicates a better nutrient efficiency under NT for P fertilizers. This is attributed to 1) the higher moisture levels found under NT soils, 2) less fixation of P by soil colloids in NT due to reduced contact between soil and fertilizer, and 3) better root development in the upper portion of the soil because of the higher moisture under NT.

Potassium. K uptake has also been shown to be unaffected by tillage method (19, 24, 29). K in the soil profile was found to decrease with depth in NT plots, but remained uniform in CT plots (24, 35). This gradient in NT soils does not affect K availibility to plants, and often allows for higher K content in plants grown on NT soils.

Tillage Effect on Soil Moisture

Most researchers agree that moisture levels are higher under NT soils when compared to CT soils (3, 6, 7, 17, 18). The reasons for higher moisture levels under NT are attributed to reduced water evaporation from the soil surface and a decrease in water runoff.

The difference in moisture levels is more obvious during the early part of the growing season (3, 17). Later, if an adequate stand is achieved, a canopy is formed which reduces the amount of water lost to evaporation.

As much as 30% of the total rainfall can be lost to runoff (18). This can be reduced to less than 5% by using NT practices. Similar results were found by McDowell and McGregor (21). This is of considerable importance when considering the damage that can be caused by a torrential rain early in the growing season.

Tillage Effect on Soil Temperature

NT soils consistently have lower temperatures than do CT soils. For spring planted crops this could be detrimental, decreasing germination or leading to decreased yields (20). For fall crops, this can be beneficial by cooling soil temperatures during the hottest part of the summer.

The lower soil temperatures in NT contribute to reduced evaporation (1). This, in combination with the reduced runoff with NT, leads to more water being available to the plant.

Tillage Effect on Soil Properties

Organic Matter. Comparing the organic matter content of soils (NT and CT) after five years of continuous corn, Blevins *et al*. (5) found that the organic carbon content was higher under NT in the top 0 to 5 cm. In the 5 to 10-cm region CT had a higher organic carbon content. Once past the 10-cm mark, the tillage system had no effect on the organic carbon content.

Bulk Density. Looking at bulk density in a clay loam soil, Gantzer and Blake (14) found that soil under NT had significantly higher bulk density values in the top 30 cm of the soil profile, when compared to CT. Below 30 cm, significant differences for tillage treatments were not found. In another study Blevins et al. (5) found no differences in bulk densities when comparing the two tillage systems.

Soil pH. In a three year study, Mullins et al. (24) observed that tillage practices did not affect soil pH in the 0 to 10-cm depth, but the soil pH was higher with NT in the 10 to 15-cm region. On the other hand, Blevins et al. (5) found that the pH was lower under NT plots in the top 0 to 5-cm region after five years of continuous corn. They also found that the pH decreases further with increased N fertilizer rates. In a later study Blevins et al. (4) concluded that surface liming is an effective method in overcoming soil acidity caused by N fertilizers in NT corn.

Tillage Effect on Weed Control

It has been reported (25, 34, 36) that a gradual shift in predominant weed species occurs under continual NT crop production. In NT, perennial weeds become an increased problem, while in CT annuals are predominant. This change in weed species populations can be attributed to tillage practice. With NT the soil is not disturbed, so fewer annual weed seeds are brought to the surface for germination, and no perennial weed root systems are uprooted and brought to the surface for dessication (13).

Chemical control of weeds is often hindered when large amounts of organic matter are present on the soil surface. Much of the chemical is intercepted by the plant residue, rendering it ineffective in controlling weeds (27). This is not always the case; with atrazine and alachlor researchers found no significant differences in effectiveness under varying residue quantities if sufficient rates were used (12, 28).

Tillage Effect on Yield of Vegetable Crops

The studies available comparing yields of vegetables in NT and CT fields are often contradictory, making it difficult to draw any definite conclusions. Table 1 is a summary of the available reports. Eight of these reports show significant differences in favor of CT, six reports show significant differences in favor of NT, and eleven reports show no significant differences between NT and CT yields. This suggests that more research is needed to fully understand the many interacting effects NT has on plant growth.

Table 1. Effect of the tillage system on vegetable crop yield, research data available up to 1984.

Crop	Yield[z] CT	NT	Authors
Cabbage	*	--	Knavel et al. (20)
	--	*	Morse et al. (22)
Cucumber	--	*	Morse et al. (22)
	*	--	Beste et al. (2)
	NS	NS	Knavel et al. (19)
Squash	--	*	Morse et al. (22)
Muskmelon	NS	NS	Grenoble et al. (16)
Watermelon	--	*	Beste et al. (2)
Lima beans	*	--	Mullins et al. (24)
Snap beans	NS	NS	Mullins et al. (24)
	NS	NS	Beste et al. (2)
Carrot	NS	NS	Orzolek et al. (26)
Tomato	NS	NS	Beste et al. (2)
	--	*	Morse et al. (22)
	*	--	Doss et al. (10)
	*	--	Grenoble et al. (16)
	*	--	Knavel et al. (19)
Pepper	*	--	Knavel et al. (19)
Potato	NS	NS	Thorton (32)
	NS	NS	Grant et al. (15)
	NS	NS	Dallyn et al. (8)
Sweet corn	--	*	Beste et al. (2)
	NS	NS	Knavel et al. (19)
	*	--	Grenoble et al. (16)

[z]* - significantly higher at the 5% level; NS - no significance at the 5% level.

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MATERIALS AND METHODS

Field experiments were conducted in 1983 and 1984 at the Virginia Polytechnic Institute and State University Horticulture Research Farm in Blacksburg, Virginia. The sod, a lodi loam, is characterized by high clay and low organic matter below the A horizon. Hairy vetch, Austrian winter pea, and rye were sown in early October in 1983 and 1984. Legume seeds were innoculated with the appropriate species of Rhizobium prior to planting. In the spring of 1984 hairy vetch and Austrian winter pea were reseeded due to a very severe frost on December 24, 1983. In the second week of July each year an amine formulation of 2,4-D [(2,4-dichlorophenoxy)acetic acid] was applied at a rate of 1.68 kg active ingredient (ai)/ha over the whole field. On July 19, 1984 glyphosate [N-(phosphonomethyl)glycine] was used at a rate of 3.38 kg ai/ha to control yellow nutsedge. On July 25 of 1983 and July 30 of 1984 paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was sprayed at a rate of 0.55 kg ai/ha to insure total vegetation control. In 1983 trifluralin (α,α,α-trifluoro-2,6-dinitro-N-N-dipropyl-p-toluidine) and oxyfluorfen [2-chloro-1-(3-ethoxy-4- nitrophenoxy)-4-(trifluoromethyl)benzene] were tank-mixed and applied just prior to planting at rates of 1.10 kg ai/ha and

0.40 kg ai/ha respectively and incorporated with 0.5 inches of irrigation water. In 1984 oxyfluorfen and metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] were tank-mixed and applied prior to planting at rates of .40 kg ai/ha and 1.68 kg ai/ha respectively. In 1983 paraquat was applied as a directed spray for control of emerged weeds at a rate of 0.55 kg ai/ha. In 1984 the butyl ester of fluazifop (±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propionic acid) was used in 1984 for grass weed control at a rate of .25 kg ai/ha.

Estimates of cover crop biomass were determined by sampling 2 representative quadrants measuring 61 cm X 61 cm per replication. These samples were dried at 70 °C and N content was determined using the Kjeldahl method (23).

Just before planting one half of each cover crop in each replication was disked twice (CT), and the other half was not (NT). On August 1 two rows of broccoli and cabbage were planted using a locally built no-tillage transplanter. In 1983 spacing was 61 cm between rows and 30.5 cm within rows; in 1984 it was 61 cm between rows and 45.7 cm within rows.

The experimental design was a randomized split-split plot, with cover crops as main plots (1983, 15.8 X 13.4 m; 1984, 6.4 X 28 m), tillage systems as the split plots (1983, 7.9 X 13.4 m; 1984, 3.2 X 28 m) and N rates as the split-split plots (1983, 7.9 X 3.4 m; 1984, 3.2 X 7 m). A 0-10-10 fertilizer was applied prior to planting at a rate of 1100 kg/ha.

Because several vegetable crops had shown relatively little response to N fertilizer at the Horticulture Research Farm, (20) low N rates of 0, 30, 60 and 90 kg/ha were used in 1983. However, N rates were doubled in 1984 because head size had not leveled off at the highest N rate in 1983. Calcium nitrate was used as the N source and was applied just after planting. The additional N in 1984 was applied as a sidedressing one month after planting. In 1983 there were 4 replications, and in 1984 3 replications were used.

Soil samples were taken in mid-September in order to monitor soil nitrate levels. Samples were taken randomly from 5 different points in each plot and mixed to form a composite sample. Samples were taken at 2 depths: 0-7.5 cm and 7.5-15 cm. Soil nitrate levels were determined using the copper sulfate extractable method and a nitrate electrode (5).

Just prior to heading in both crops, tissue samples were taken by removing two recently matured leaves from every other harvested plant in each plot. These samples were dried at 70 °C and ground using a cyclone mill. A sub-sample from each dried and ground sample was then tested for nitrogen content using the Kjeldahl method (23).

Soil temperature and moisture readings were taken at three separate times during the growing season. Soil moisture of the top 10 cm was determined gravimetrically (12). Soil temperature at a depth of 10 cm was determined with a two point thermograph.

Broccoli was harvested weekly, and cabbage was harvested every 2 weeks. Heads were allowed to attain maximum marketable size before harvesting. Since multiple harvests were used eventually all plants were harvested, with the exception of an occasional damaged plant. Broccoli heads measured 23 to 30 cm in length at harvest. All leaves were removed for broccoli and outer leaves were removed for cabbage.

RESULTS AND DISCUSSION

Since there were no interactions among treatments, only main effects will be discussed.

YIELDS. Austrian winter pea produced the largest amount of above ground dry matter but was not significantly different from hairy vetch (Table 1). Austrian winter pea had the highest tissue N levels in both years, although in 1983 it was not significantly different from hairy vetch. Rye was consistently lower in tissue N than either of the legumes. Austrian winter pea produced larger amounts of organic N per ha than did hairy vetch or rye. Hairy vetch was next, and rye was last with 64-79% less organic N produced than either of the legume covers.

Head number and yield per ha were not affected by tillage system in any year with either crop (Tables 2-5). However, larger head size was recorded in the 1983 broccoli and 1984 cabbage crops grown under NT. Similar increases in head size occured for the 1983 cabbage and 1984 broccoli but they were not significant. These results are consistent with some previous reports (1, 13, 18, 22), but other researchers have found decreased yields using NT, particularly with early plantings (14, 19).

Table 1. Dry matter yield and N content of cover crops.

Year	Cover crop[z]	Yield of cover crop (MT/ha)	% N	N content (kg/ha)
1983	Rye	2.9b[y]	1.62b	47c
	AWP	4.8a	3.41a	163a
	HV	3.8ab	3.36a	129b
1984	Rye	2.3b	1.13c	26c
	AWP	3.8a	3.29a	125a
	HV	3.4a	2.94b	100b

[z]AWP = Austrian winter pea; HV = hairy vetch.

[y]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 2. Influence of tillage systems, cover crops, and N rates on head number, yield, and head size of cabbage, 1983.[z]

Treatment	Head no. (1000/ha)	Yield (MT/ha)	Head size (kg/head)
Tillage system			
No-tillage	32.2a[y]	28.0a	.87a
Conv.-tillage	34.6a	28.6a	.78a
Cover crops[x]			
Rye	31.6a	24.4a	.77a
AWP	35.2a	31.0a	.88a
HV	34.0a	27.4a	.80a
N rate (kg/ha)			
0	32.8	26.2	.80
30	34.6	28.6	.83
60	33.4	29.2	.88
90	33.4	34.0	1.02
Significance[w]			
Linear	NS	NS	*
Quadratic	NS	NS	NS
Cubic	NS	NS	NS

[z]There were no interactions among treatments.

[y]Mean separation within columns for each main effect by Duncan's multiple range test, 5% level.

[x]AWP = Austrian winter pea; HV = hairy vetch.

[w]Significant at 5% (*), 1% (**), or non-significant (NS).

Table 3. Influence of tillage systems, cover crops, and N rates on head number, yield, and head size of broccoli, 1983.[z]

Treatment	Head no. (1000/ha)	Yield (MT/ha)	Head size (kg/head)
Tillage system			
No-tillage	39.3a[y]	14.9a	.37a
Conv.-tillage	41.1a	13.1a	.32b
Cover crops[x]			
Rye	40.5a	13.7a	.34a
AWP	38.1a	13.7a	.36a
HV	42.3a	14.9a	.36a
N rate (kg/ha)			
0	39.3	14.9	.36
30	39.9	13.7	.35
60	41.1	16.1	.39
90	40.5	15.5	.38
Significance[w]			
Linear	NS	NS	NS
Quadratic	NS	NS	NS
Cubic	NS	NS	*

[z]There were no interactions among treatments.

[y]Mean separation within columns for each main effect by Duncan's multiple range test, 5% level.

[x]AWP = Austrian winter pea; HV = hairy vetch.

[w]Significant at 5% (*), 1% (**), or non-significant (NS).

Table 4. Influence of tillage systems, cover crops, and N rates on head number, yield, and head size of cabbage, 1984.[z]

Treatment	Head no. (1000/ha)	Yield (MT/ha)	Head size (kg/head)
<u>Tillage system</u>			
No-tillage	36.2a[y]	45.2a	1.25a
Conv.-tillage	35.6a	41.6a	1.17b
<u>Cover crops</u>[x]			
Rye	35.6a	39.2b	1.10b
AWP	32.0a	43.4ab	1.30a
HV	38.6a	47.6a	1.22ab
<u>N rate (kg/ha)</u>			
0	34.4	36.8	1.07
60	35.6	42.2	1.19
120	35.6	45.2	1.27
180	38.0	50.1	1.32
<u>Significance</u>[w]			
Linear	NS	NS	**
Quadratic	NS	NS	NS
Cubic	NS	NS	NS

[z]There were no interactions among treatments.

[y]Mean separation within columns for each main effect by Duncan's multiple range test, 5% level.

[x]AWP = Austrian winter pea; HV = hairy vetch.

[w]Significant at 5% (*), 1% (**), or non-significant (NS).

Table 5 . Influence of tillage systems, cover crops, and N rates on head number, yield, and head size of broccoli, 1984.[z]

Treatment	Head no. (1000/ha)	Yield (MT/ha)	Head size (kg/head)
Tillage system			
No-tillage	31.4a[y]	10.9a	.35a
Conv.-tillage	32.6a	10.9a	.30a
Cover crops[x]			
Rye	30.8a	9.1b	.30b
AWP	32.0a	11.5a	.36a
HV	32.6a	12.1a	.37a
N rate (kg/ha)			
0	31.4	8.4	.27
60	32.0	10.3	.32
120	31.4	11.5	.36
180	32.6	13.9	.43
Significance[w]			
Linear	NS	**	**
Quadratic	NS	NS	NS
Cubic	NS	NS	*

[z]There were no interactions among treatments.

[y]Mean separation within columns for each main effect by Duncan's multiple range test, 5% level.

[x]AWP = Austrian winter pea; HV = hairy vetch.

[w]Significant at 5% (*), 1% (**), or non-significant (NS).

Hairy vetch and Austrian winter pea, when compared to rye, were effective in increasing yields and head size (Tables 2-5). Differences were significant only in 1984. Increased yield and head size in legume plots possibly can be explained in part by the higher N content of the legumes becoming available to the plants after mineralization of the cover crops. It appears that other growth factors could be responsible for some of the improved head sizes because the values did not level off even at the highest N rate (Fig. 1).

Head number was not affected by N treatment, but yield was highest with the highest rate of applied N. Head size also increased as the applied N was increased. This was significant in all cases except for the 1983 broccoli. The differences in yields and head size due to legume covers and applied N could be expected to increase with sandier soils (10). Even with 180 kg/ha of applied N the yield increase over the control treatment was not more than 56%.

TISSUE N and SOIL NITRATES. Tillage system had no effect on broccoli or cabbage tissue N levels. (Table 6). However, cover crops did have an effect with higher values found for hairy vetch and Austrian winter pea. It appears that N in the legumes was made available through mineralization and taken up by the crop plants, allowing for increased

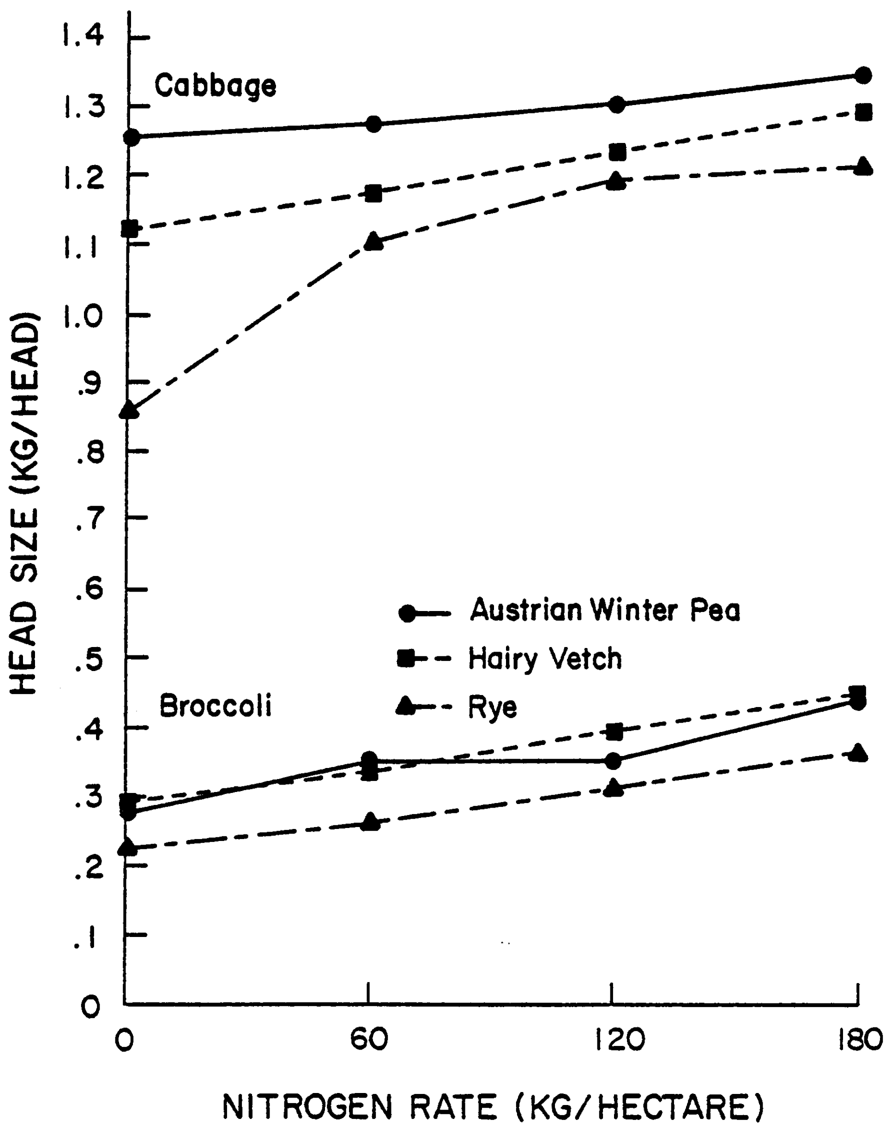

Figure 1. Head size of cabbage and broccoli as influenced by N rate and cover crop, 1984.

Table 6 . Effect of tillage systems, cover crops, and N rates on broccoli and cabbage leaf N content, 1983 and 1984.[z]

Treatment		Tissue N (%)			
		Cabbage		Broccoli	
		1983	1984	1983	1984
Tillage system					
No-tillage		3.01a[y]	2.96a	3.47a	3.30a
Conv.-tillage		3.08a	2.88a	3.43a	3.48a
Cover crops[x]					
Rye		2.94b	2.67b	3.36b	3.04b
AWP		3.06a	3.09a	3.46ab	3.63a
HV		3.13a	3.00a	3.54a	3.51a
N rate (kg/ha)					
1983	1984				
0	0	2.89	2.40	3.28	2.75
30	60	2.95	2.82	3.36	3.05
60	120	3.07	3.09	3.51	3.74
90	180	3.25	3.37	3.64	4.02
Significance[w]					
Linear		**	**	**	**
Quadratic		NS	NS	NS	NS
Cubic		NS	NS	NS	NS

[z]There were no interactions among treatments.

[y]Mean separation within columns for each main effect by Duncan's multiple range test, 5% level.

[x]AWP = Austrian winter pea; HV = hairy vetch.

[w]Significant at 5% (*), 1% (**), or non-significant (NS).

tissue N when compared to rye. Similar results were obtained in a study by Ebelhar et al. for field corn (11).

Tillage system had a pronounced effect on soil nitrate levels (Table 7). Possibly decreased total mineralization of organic matter, higher surface microbial activity and increased leaching in NT soils allowed for the lower nitrate levels under NT plots (8). The tendency for NT soils to be lower in nitrates corresponds with previous observations (25, 26). In 1983 soil nitrates in CT plots were more than double those found in NT plots. In 1984 the same trend was observed, but it was not significant.

Soil nitrate levels and applied N rates were poorly correlated for both sampling depths and years (R^2 value of .025 in 1983 and .16 in 1984), indicating that either the applied N had been utilized by the crop and/or lost from the soil sampling zone by harvest time. Much higher soil nitrates were found for the highest N rate in 1984 than for any other treatment. This is probably due to the calcium nitrate sidedressing applied 6 weeks prior to soil sampling.

There were no significant differences in soil nitrate levels among cover crop plots. In 1983 hairy vetch tended to give the highest values for soil nitrate content in the 0-7.5 cm depth and in 1984 hairy vetch and Austrian winter pea tended to produce higher soil nitrate levels at both

Table 7. Effect of tillage systems, cover crops, and N rate on soil nitrate content, 1983 and 1984.[z]

Treatment		Soil nitrate			
		0 - 7.5 cm		7.5 - 15 cm	
		1983	1984	1983	1984
		(ppm)			
Tillage system					
No-tillage		9.7b[y]	17.5a	8.2b	13.2a
Conv.-tillage		24.9a	19.5a	18.9a	22.5a
Cover crops[x]					
Rye		17.0a	15.5a	15.1a	16.1a
AWP		14.6a	21.2a	10.9a	18.9a
HV		20.5a	18.9a	14.6a	18.6a
N rate (kg/ha)					
1983	1984				
0	0	17.2	9.0	12.1	10.9
30	60	18.6	13.1	14.7	11.3
60	120	13.5	15.1	11.1	14.3
90	180	20.0	36.8	16.2	35.0
Significance[w]					
Linear		NS	**	NS	**
Quadratic		NS	NS	NS	NS
Cubic		NS	NS	NS	NS

[z]There were no interactions among treatments.

[y]Mean separation within columns for each main effect by Duncan's multiple range test, 5% level.

[x]AWP = Austrian winter pea; HV = hairy vetch.

[w]Significant at 5% (*), 1% (**), or non-significant (NS).

depths. Although there was no interaction between cover crops and applied N, the data indicate that some nitrogen was supplied to the soil system. Because of the higher N content of hairy vetch and Austrian winter pea, greater soil nitrate levels could be expected in the legume plots through mineralization. Two main reasons probably account for the non-significant differences in soil nitrates among cover crops. First, there was more N taken up by the crop plants grown in the legumes, as indicated by the higher tissue N levels found in these plants (Table 6). Second, because of the higher amounts of organic matter found in the legumes (Table 1), there was probably more immobilization of N by the soil microbes (8).

When the nutrient supplying capacity of a soil is below the critical nutrient concentration range, a high correlation would be expected between tissue nutrient concentration and the applied nutrient (9, 24). Since in our case the R^2 values only ranged between .23 and .59, apparently the soils used in these experiments have a relatively high capacity to supply plant available N. Associated data further indicate that the soils used had a high N supplying power. First, there were no yield interactions between cover crops and applied N for broccoli and cabbage either year. Second, the yield responses to applied N were relatively low (Tables

2-5). Third, the leaf tissue N content of the control plants receiving no applied N were 2.40 to 3.38% (Table 6), which is considered to be in the lower level of the sufficiency range (7). Kovach (20) found similar tissue N responses to applied N for tomatoes grown at the same research farm. Prior to fertilizing, the soil nitrate levels ranged from 8 to 16 ppm, which is considered to be relatively low for these soils (6). The soil nitrate levels for the control plots at sampling time (10 weeks after planting) were equal to or greater than those at planting (data not shown). It appears, therefore, that these soils had a high capacity to replenish the plant available nitrate pool during the growing season.

SOIL MOISTURE. Soil moisture was greater for NT than for CT in both years (Table 8). Moisture content was increased from 14.5% for CT soils to 17.9% for NT soils. Considering that this increase in soil moisture was within the available range, this difference in soil moisture content would represent a relatively large improvement in available soil moisture in NT plots (20). Researchers have consistently found greater moisture conservation with NT, and it is now commonly accepted that NT soils generally have greater moisture levels (2, 3, 4, 16, 17). This can prove to be very important, particularly to growers with limited irrigation potential.

Table 8 . Effect of tillage systems on soil moisture and soil temperature averaged over 3 sampling dates.

Year	Tillage system	Soil moisture (%)	Soil temperature (°C)
1983	No-tillage	16.8a	17.1b
	Conv.-tillage	13.9b	17.5a
1984	No-tillage	19.0a	16.8b
	Conv.-tillage	15.0b	17.3a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

SOIL TEMPERATURE. Although NT plots had significantly lower temperatures than CT plots, the difference was only 0.45 °C averaged over both years and sampling dates (Table 8). This small temperature difference probably had little or no effect on plant growth because the soil temperature in these experiments were all considered to be in the optimum range (21).

One of the drawbacks to NT crop production is the decreased germination and/or plant growth observed when early spring plantings are used. In this study of fall production of broccoli and cabbage, NT would be economically beneficial for growers because of the higher soil moisture and reduced erosion. If a legume is used as the cover crop, the added benefit of some nitrogen being added to the soil system with possible yield increases above those using a cereal cover could be expected.

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APPENDIX

Table 9 . Influence of cover crops, tillage systems, and N rates on head number, yield, and head size of cabbage, 1983.

Cover crops[z]	Tillage systems	N rate (kg/ha) 0	30	60	90	Avg
		Head no. (1000/ha)				
Rye	No-tillage	30.4	26.2	33.4	29.8	29.8
	Conv.-tillage	34.0	32.8	32.2	35.2	33.4
AWP	No-tillage	33.4	37.0	30.4	34.0	34.0
	Conv.-tillage	32.8	34.6	33.4	39.9	35.2
HV	No-tillage	28.0	39.9	35.2	29.8	33.4
	Conv.-tillage	37.0	35.2	37.6	33.4	35.8
	Avg	32.8	34.6	33.4	34.0	
		Yield (MT/ha)				
Rye	No-tillage	22.7	22.1	31.6	26.2	25.6
	Conv.-tillage	26.2	28.0	26.9	28.0	27.4
AWP	No-tillage	32.2	34.0	31.6	38.1	34.0
	Conv.-tillage	22.1	26.2	31.6	48.3	32.2
HV	No-tillage	24.4	31.6	25.6	39.3	30.4
	Conv.-tillage	31.0	28.6	28.6	25.0	28.6
	Avg	26.2	28.6	29.2	34.0	
		Head size (kg/head)				
Rye	No-tillage	.68	.86	.87	.85	.82
	Conv.-tillage	.69	.77	.80	.74	.75
AWP	No-tillage	.88	.84	.85	1.06	.91
	Conv.-tillage	.65	.69	.84	1.07	.81
HV	No-tillage	.79	.74	.80	1.19	.88
	Conv.-tillage	.80	.76	.69	.71	.83
	Avg	.75	.78	.81	.94	

[z]AWP = Austrian winter pea; HV = hairy vetch.

Table 10. Influence of cover crops, tillage systems, and N rates on head number, yield, and head size of broccoli, 1983.

Cover crops[z]	Tillage systems	N rate (kg/ha) 0	30	60	90	Avg
		Head no. (1000/ha)				
Rye	No-tillage	37.5	38.7	41.1	44.1	40.5
	Conv.-tillage	41.1	39.9	39.3	43.5	41.1
AWP	No-tillage	39.3	32.8	43.5	34.6	37.5
	Conv.-tillage	35.8	42.3	35.2	39.9	38.1
HV	No-tillage	37.0	44.1	43.5	38.1	40.5
	Conv.-tillage	44.1	43.5	44.1	43.5	44.1
	Avg	39.3	39.9	41.1	40.5	
		Yield (MT/ha)				
Rye	No-tillage	16.7	14.3	16.1	17.3	16.1
	Conv.-tillage	11.9	13.7	13.7	15.5	13.7
AWP	No-tillage	15.5	12.5	19.7	15.5	16.1
	Conv.-tillage	14.3	13.7	13.1	12.5	13.7
HV	No-tillage	14.9	13.7	17.3	16.7	15.5
	Conv.-tillage	15.5	14.9	17.3	15.5	16.1
	Avg	14.9	13.7	16.1	15.5	
		Head size (kg/head)				
Rye	No-tillage	.42	.35	.36	.36	.37
	Conv.-tillage	.26	.32	.33	.33	.31
AWP	No-tillage	.36	.36	.41	.41	.39
	Conv.-tillage	.35	.31	.35	.29	.32
HV	No-tillage	.37	.30	.38	.41	.36
	Conv.-tillage	.32	.32	.36	.33	.33
	Avg	.35	.32	.37	.36	

[z]AWP = Austrian winter pea; HV = hairy vetch.

Table 11. Influence of cover crops, tillage systems, and N rates on head number, yield, and head size of cabbage, 1984.

Cover crops[z]	Tillage systems	N rate (kg/ha) 0	60	120	180	Avg
		Head no. (1000/ha)				
Rye	No-tillage	34.4	34.4	39.2	37.4	36.2
	Conv.-tillage	34.4	33.2	35.6	35.6	35.0
AWP	No-tillage	31.4	38.6	37.4	35.0	35.6
	Conv.-tillage	37.4	29.6	24.1	33.2	31.4
HV	No-tillage	34.4	35.6	35.6	41.0	36.8
	Conv.-tillage	35.0	42.2	40.4	44.6	40.4
	Avg	34.4	35.6	35.6	38.0	
		Yield (MT/ha)				
Rye	No-tillage	33.8	41.0	52.5	51.9	44.6
	Conv.-tillage	29.5	38.6	45.2	46.4	39.8
AWP	No-tillage	42.2	53.7	59.7	53.7	52.5
	Conv.-tillage	48.2	41.0	29.6	47.0	41.6
HV	No-tillage	44.0	46.4	49.5	59.7	50.0
	Conv.-tillage	40.4	51.3	54.3	63.3	52.5
	Avg	39.8	45.2	48.2	53.7	
		Head size (kg/head)				
Rye	No-tillage	.91	1.14	1.23	1.27	1.14
	Conv.-tillage	.82	1.09	1.18	1.18	1.09
AWP	No-tillage	1.27	1.32	1.46	1.41	1.36
	Conv.-tillage	1.27	1.27	1.18	1.32	1.23
HV	No-tillage	1.18	1.23	1.27	1.32	1.27
	Conv.-tillage	1.09	1.14	1.23	1.32	1.18
	Avg	1.07	1.19	1.26	1.31	

[z]AWP - Austrian winter pea; HV = hairy vetch.

Table 12. Influence of cover crops, tillage systems, and N rates on head number, yield, and head size of broccoli, 1984.

Cover crops[z]	Tillage systems	N rate (kg/ha) 0	60	120	180	Avg
		Head no. (1000/ha)				
Rye	No-tillage	31.4	27.7	34.4	27.1	30.2
	Conv.-tillage	27.1	32.6	32.6	35.0	32.0
AWP	No-tillage	29.6	32.6	29.6	35.0	32.0
	Conv.-tillage	34.4	33.2	27.7	33.2	32.0
HV	No-tillage	32.6	31.4	31.4	31.4	32.0
	Conv.-tillage	32.6	35.0	34.4	35.0	34.4
	Avg	31.4	32.0	32.0	32.6	
		Yield (MT/ha)				
Rye	No-tillage	7.2	7.8	12.1	10.9	9.7
	Conv.-tillage	6.6	9.7	10.3	13.9	10.3
AWP	No-tillage	9.7	12.7	11.5	16.9	12.7
	Conv.-tillage	9.1	12.7	10.9	15.7	12.1
HV	No-tillage	10.3	11.5	13.9	16.3	13.3
	Conv.-tillage	10.3	12.7	15.1	16.3	13.9
	Avg	9.1	10.9	12.1	15.1	
		Head size (kg/head)				
Rye	No-tillage	.22	.25	.34	.37	.30
	Conv.-tillage	.23	.28	.30	.36	.30
AWP	No-tillage	.30	.37	.36	.46	.37
	Conv.-tillage	.26	.35	.36	.44	.35
HV	No-tillage	.30	.34	.40	.48	.38
	Conv.-tillage	.29	.34	.41	.44	.37
	Avg	.27	.32	.36	.42	

[z]AWP = Austrian winter pea; HV = hairy vetch.

Table 13. Influence of cover crops, tillage systems, and N rates on soil nitrate levels, 1983.

Cover crops[z]	Tillage systems	N rate 0	30	60	90	Avg
		0-7.5 cm (ppm)				
Rye	No-tillage	10.0	7.1	6.0	8.1	7.8
	Conv.-tillage	32.1	25.8	21.0	25.5	26.1
AWP	No-tillage	10.1	5.2	4.4	4.4	6.0
	Conv.-tillage	29.5	10.9	14.5	37.3	23.1
HV	No-tillage	6.2	18.5	21.8	15.0	15.4
	Conv.-tillage	15.1	44.0	13.2	30.1	23.3
	Avg	17.2	18.6	13.5	20.0	
		7.5-15 cm (ppm)				
Rye	No-tillage	7.0	7.3	6.9	7.5	7.2
	Conv.-tillage	20.2	23.7	14.4	33.8	23.0
AWP	No-tillage	10.2	7.4	2.9	6.7	6.8
	Conv.-tillage	16.8	9.9	11.5	21.7	15.0
HV	No-tillage	9.1	9.4	10.0	13.4	10.5
	Conv.-tillage	9.5	30.5	20.8	14.0	18.7
	Avg	12.1	14.7	11.1	16.2	

[z]AWP = Austrian winter pea; HV = hairy vetch.

Table 14. Influence of cover crops, tillage systems, and N rates on soil nitrate levels, 1984.

Cover crops[z]	Tillage systems	N rate 0	60	120	180	Avg
		0-7 cm (ppm)				
Rye	No-tillage	6.2	9.9	9.4	56.6	20.5
	Conv.-tillage	5.7	18.3	16.2	47.1	21.8
AWP	No-tillage	5.6	8.3	14.2	15.4	10.8
	Conv.-tillage	9.0	10.1	11.9	49.1	20.0
HV	No-tillage	10.4	21.7	26.7	25.5	21.0
	Conv.-tillage	17.0	10.8	12.1	26.9	16.7
	Avg	9.0	13.1	15.1	36.8	
		7.5-15 cm (ppm)				
Rye	No-tillage	4.8	6.2	6.3	28.4	11.4
	Conv.-tillage	6.8	11.2	23.6	41.4	20.7
AWP	No-tillage	4.4	4.2	11.0	9.0	7.2
	Conv.-tillage	20.8	14.4	18.8	68.6	30.6
HV	No-tillage	10.8	17.2	17.9	38.9	21.2
	Conv.-tillage	20.3	12.0	8.4	23.5	16.1
	Avg	10.9	11.3	14.3	35.0	

[z]AWP = Austrian winter pea; HV = hairy vetch.

Table 15. Monthly and annual precipitation, Blacksburg (inches).

	1983	1984	Normal
Jan.	2.09	2.64	2.95
Feb.	2.53	4.79	2.94
Mar.	6.77	4.37	3.91
Apr.	5.26	4.96	3.55
May	3.96	5.98	3.62
June	14.81	1.45	3.61
July	2.07	4.82	3.65
Aug.	1.84	4.42	3.53
Sept.	2.12	1.04	3.48
Oct.	6.03	3.69	3.14
Nov.	3.12	2.00	2.68
Dec.	4.80	1.78	2.92
Total	55.40	41.95	39.98

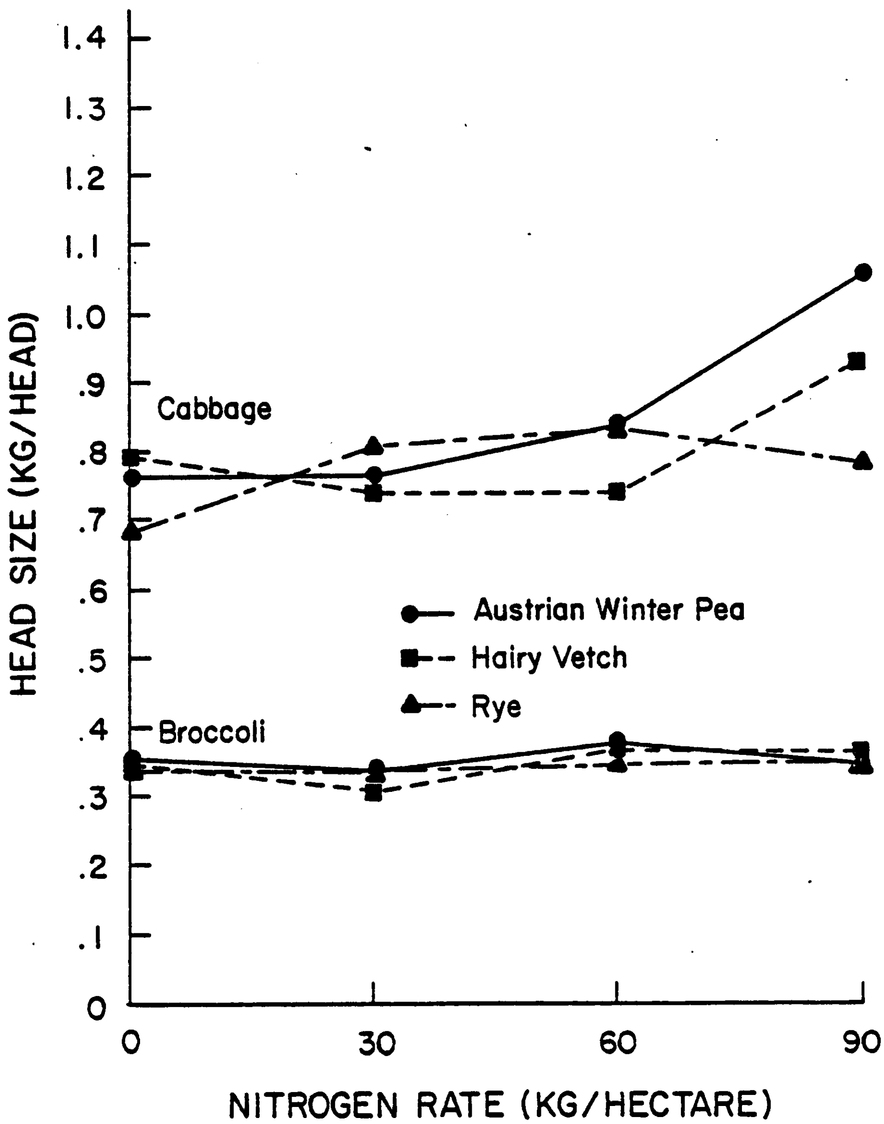

Figure 2. Head size of cabbage and broccoli as influenced by N rate and cover crop, 1983.

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The Use of Legume Cover Crops in No-tillage Broccoli and Cabbage Production

by

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(ABSTRACT)

Field experiments were conducted in 1983 and 1984 to compare conventional tillage (CT) versus no-tillage (NT) production of broccoli and cabbage. The tillage treatments were applied in combination with four rates of applied nitrogen fertilizer and three cover crops: hairy vetch (*Vicia villosa* Roth), Austrian winter pea (*Pisum arvenu* L.), and cereal rye (*Secale cereale* L.). Transplants of 'Premium Crop' broccoli (*Brassica oleracea* var. *italica* Plenck) and 'Market Prize' cabbage (*Brassica oleracea* var. *capitata* L.) were set with a locally adapted NT vegetable planter. None of the variables studied affected the final plant stand. Yield and head size with NT were equal to or greater than CT. Soil moisture was higher under NT plots throughout the growing season. Yield and head size with the two legume covers were equal to or greater than those with the rye cover. Yield and head size tended to increase as applied N was increased, although differences were not always significant. The data, although not conclusive, indicate that the legume cover crops provided additional nitrogen for the cole crops.