Final Report

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Final

Project Report

Weed Control in Reduced Tillage Cropping Systems: Use of Overseeded Cover Crops in Maine
1989 - 1991

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INTRODUCTION

Maine agriculture currently faces important challenges to its long-term viability, including excessive rates of soil erosion, environmental contamination by synthetic fertilizers and pesticides, and increases in production costs that have outpaced increases in commodity prices. Increasing numbers of farmers and researchers are now working to develop crop production practices that conserve natural resources, protect environmental quality, and improve farm profitability. Alternative crop production practices being examined generally involve less tillage, lower inputs of fertilizers and pesticides, and increased use of cover crops. Despite farmer and researcher interest in these approaches, at present there is inadequate information concerning the agronomic and economic performance of alternative cropping systems, particularly for crops other than corn, soybean, and wheat. Available data suggest that weed control and maintenance of adequate nitrogen fertility are two of the most important problems confronting farmers seeking to reduce their use of pesticides and fertilizers.

This report describes the results of two experiments and one on-farm demonstration conducted to compare the agronomic and economic performance of conventional vs. reduced tillage/cover crop systems for producing dry beans (Phaseolus vulgaris). Approximately 700,000 ha of dry beans are grown nationally. Although less than 1500 ha of dry beans are grown in Maine, the crop can be a useful source of cash for its producers because of high prices received for specialized local varieties (e.g., Maine Yelloweye, Jacob's Cattle, and Soldier). Profitability of producing the crop might be increased if production expenses were reduced while yield levels were maintained. Primary tillage operations (plowing and disking), herbicides and their application, and fertilizers (N, P, and K) currently comprise an estimated 15.1%, 12.9%, and 19.8%, respectively, of the variable costs of producing beans in Maine.

More than a third of Maine cropland requires conservation treatment to reduce soil erosion below tolerable levels (i.e., when the rate of soil formation exceeds that of soil loss). Fields planted to beans in Maine are particularly susceptible to erosion because the crop leaves only a small amount of residue, and its late harvest date limits opportunities to establish fall cover crops. Planting beans without tillage into a mulch crop could increase soil cover and decrease erosion potential. Rye, the most winter hardy of the annual cover crops used in Maine, has been used as a mulch crop for no-till production of soybeans and snap beans in midwestern and mid-Atlantic states. Rye has also been reported to be chemically toxic (i.e., allelopathic) to many weed species. Before the experiments and demonstration reported here, use of rye as a mulch crop for no-till production of dry beans had not been examined in Maine.

Dry beans rank ninth out of crops grown in the U.S. for total herbicide use, with an estimated 94% of bean fields receiving an average application rate of 3 kg of active ingredients per hectare. Despite their widespread use, herbicides are not always highly effective in Maine. Bean producers have reported particular problems in some years with control of lambsquarters (Chenopodium album), redroot pigweed (Amaranthus retroflexus), wild mustard (Brassica kaber), and wild radish (Raphanus raphanistrum).

Several herbicides (e.g., dinoseb, chloramben) that were widely used for bean production have recently been withdrawn from the marketplace as the result of regulatory actions.

Although dry beans are legumes, the short-season bush varieties commonly grown in north temperate areas are generally regarded as poor fixers of atmospheric nitrogen. Forty-five kg N/ha is routinely recommended for dry bean production in New England, but the nitrogen requirement of the crop grown with reduced tillage/cover crop practices has not been established. As compared to conventional tillage systems, reduced tillage systems for corn in north temperate areas have often been found to have increased requirements for nitrogen because of increased leaching and denitrification losses, and microbial immobilization.

It has been suggested that long-term application of high levels of fertilizers to soils managed with conventional tillage may create sufficient reserves of phosphorus and potassium to permit production of adequate crop yields for several years without new applications of P and K. However, the influence of reduced tillage/cover crop practices on dry bean P and K nutrition and fertilization requirements is not adequately understood.

Given the shortage of information concerning low-input production methods for dry beans, two experiments and an on-farm demonstration were conducted with the following objectives:

1. Compare crop nutrition, growth, and yield in conventional vs. rye mulch production systems, when the conventional system is managed with moldboard plowing, pesticides and fertilizers, and the rye mulch system is managed without plowing, pesticides, and fertilizers.

2. Compare the effects of weeds on crop yield in the conventional/(+) agrichemical vs. rye mulch/(-) agrichemical production systems.

3. Compare the effects of nitrogen fertilizer on crop growth and yield in a conventional bean production system managed with clean tillage and multiple herbicides vs. a rye mulch system managed without plowing and with only one herbicide.

4. Compare the economic performance of the conventional, rye mulch/(-) agrichemical, and rye mulch/limited agrichemical systems.

The experiments reported here were conducted at the University of Maine's Sustainable Agriculture Research Farm in Stillwater during the 1989 and 1990 growing seasons. The on-farm demonstration was conducted during the 1989 and 1990 growing seasons on a commercial farm operated by Mr. Anthony Neves in Freedom, Maine.

PLANTING AND CULTIVATING EQUIPMENT

Prior to the 1989 growing season a three point hitch mounted two row no-till planter was constructed. To form the basic machine structure, commercially available no-till openers (Acra-Plant Sales, Inc., Garden City, KS)[a] were mounted on a tool bar along with depth wheel assemblies between the rows adjacent to each opener. The openers have two disks angled so they contact at the front and leave room for a seed tube and row forming device at the rear. The sharp disks cut through surface mulch and open a row with very little soil disturbance. Seed was metered to each row from a conventional corn planter unit taken from a used machine. A plate drive and seed box was mounted directly above each opener. The units were powered by a chain drive from the left side depth wheel. Depth of seed placement was adjusted by setting the depth wheels and the top link of the three point hitch. A single narrow press wheel was used to firm soil around and cover the seed. The planter, used in this form in 1989, did a good job of seed placement in the rye cover crop. However, in heavier soils the seed was not always covered completely.

Between the 1989 and 1990 seasons the original press wheels were replaced with angled closing wheels (Yetter Manufacturing Co., Colchester, IL)[a]. These wheels are spring loaded and adjustable in angle and pitch to place and firm soil around the seed by pushing from the sides of the row. After this modification seed was properly covered. In addition, fertilizer hoppers and disk openers (Yetter Manufacturing Co.)[a] were added to permit placement of starter fertilizer. The openers were positioned so that fertilizer is placed about four inches from the seed. The planter is illustrated in Figure 1.

A major consideration in weed control for the minimum tillage/cover crop system is to cultivate between the rows with a minimum amount of disturbance of the mulch. To this end a rear mounted toolbar cultivator was assembled with a rolling coulter (Yetter Manufacturing Co.)[a] directly in front of each tool mounting standard. The coulter cuts through the mulch permitting the tool to move through the soil without clogging. Low crown sweeps were used to undercut weeds on either side of the slot with minimum disturbance of the mulch. To improve weed control while protecting young stages of the crop, disk hillers and cultivation shields were added in 1991. The cultivator is illustrated in Figure 2.

The no-till planter and heavy residue cultivator were used in the two experiments conducted at the University of Maine's Sustainable Agriculture Research Farm in Stillwater. A conventional, unmodified bean planter and Lilliston rolling cultivator[a] were used for the on-farm comparison of conventional vs. rye mulch production practices conducted in Freedom, Maine.

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[a] Mention of any specific product does not imply endorsement by the Maine Agricultural Experimental Station.

Figure 1. Schematic diagram of the planter used in Experiments 1 and 2.

Figure 2. Schematic diagram of the cultivator used in Experiments 1 and 2.

FIGURE 1

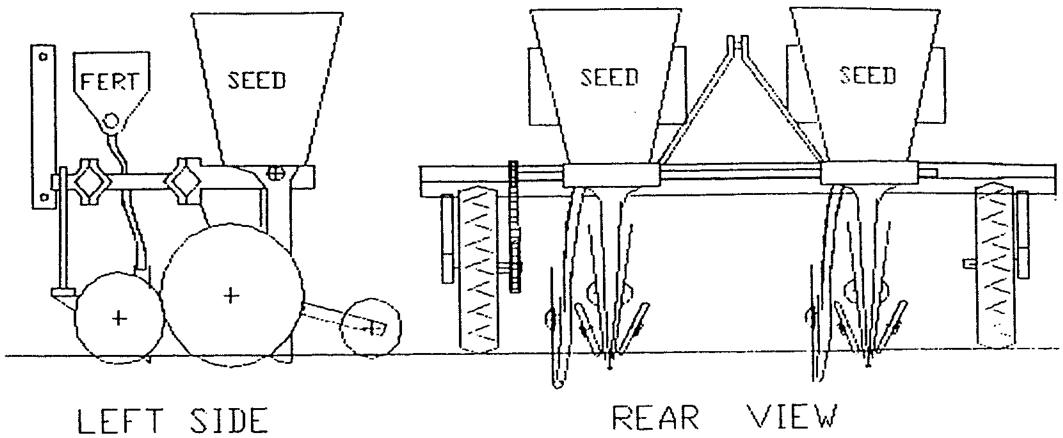
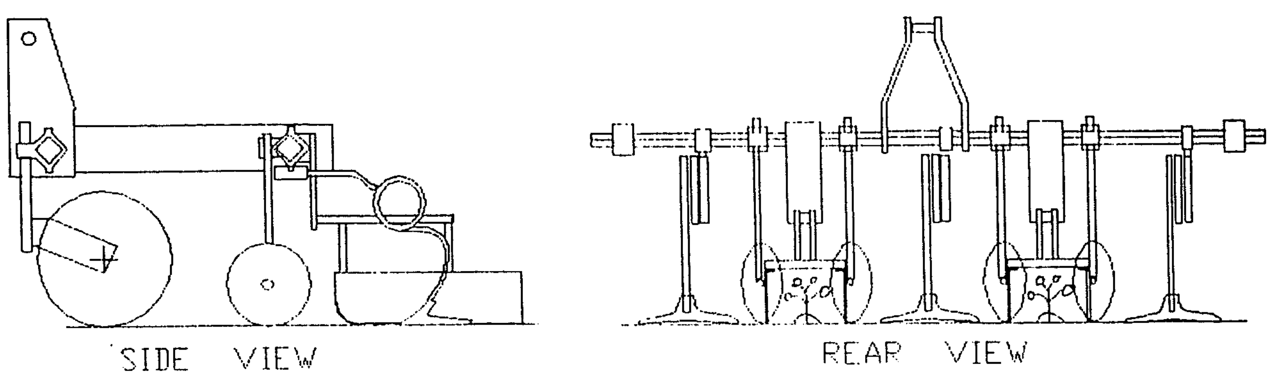


FIGURE 2



Experiment 1. Agronomic and economic performance of conventional vs. rye mulch/reduced tillage bean production systems.

Experiment 1 was conducted to compare the agronomic and economic performance of conventional vs. rye mulch/reduced tillage bean production systems. Synthetic fertilizers and pesticides were not used in the rye mulch management system of this experiment. Specific objectives of the experiment included i) estimation of the competitive effects of weeds on crop yields in each management system, and ii) measurement of crop nutrient status in each management system.

The experiment was conducted during 1988-1990 on a Buxton silt loam (fine, illitic, frigid Aquic Dystric Eutrochrept) at the University of Maine's Sustainable Agriculture Research Farm in Stillwater. Plots were 10 rows (0.82 m spacing) x 12.3 m.

Field operations and materials used for the conventional and rye mulch management treatments are shown in Table 1. Rye (Secale cereale cv. Aroostook) was drilled in appropriate plots on September 10, 1988 and September 8, 1989. Following tillage and herbicide applications for the conventional management treatment, beans (Phaseolus vulgaris cv. Maine Yelloweye) were planted in both treatments on June 3, 1989 and June 7, 1990. Rye was mowed immediately after planting beans. Because of extremely wet conditions following planting in 1989 (Table 2), crop emergence in both treatments was very poor and beans were replanted in all plots on June 23, 1989. Wet weather following planting in 1990 (Table 2) also reduced bean establishment, but the experiment was continued with low crop populations.

Rye mulch plots were cultivated twice each year (July 12 and 21, 1989; July 6 and 18, 1990). Conventional treatment plots received one cultivation each year (July 21, 1989 and July 11, 1990). To estimate the competitive effects of weeds surviving herbicide applications and/or cultivation, 5 m^2 weed-free subplots were established in plots of each management treatment in both 1989 and 1990. Weed-free conditions in these subplots were maintained by regular handweeding.

Measurements of soil mineral nitrogen content and soil moisture content were made throughout the growing season in 1989, but not in 1990. Bean leaf tissue was collected at several times during the 1989 and 1990 growing seasons and analyzed for N, P, and K content. Bean leaf area index (m^2 leaf area/m^2 ground area), bean total biomass (aboveground and belowground), and weed aboveground biomass were also measured at several times during the 1989 and 1990 growing seasons. Bean plant density and marketable seed yield were determined for samples collected on October 9, 1989 and October 5, 1990 from (-) handweeding and (+) handweeding subplots within conventional and rye mulch main plots.

Soil NO_3-N levels were significantly higher in the conventional management treatment as compared to the rye mulch management treatment at 20, 60, and 82 days after planting (DAP) in 1989; a similar trend was observed just before planting (Table 3). Soil NH_4-N levels were significantly higher in the rye mulch treatment at -1 and 20

DAP in 1989, but thereafter did not differ significantly between the two management systems (Table 3). Soil moisture content was significantly higher in the rye mulch system at -1, 20, and 82 DAP in 1989; there was no significant difference between the two management systems at 60 DAP (Table 3).

Effects of conventional vs. rye mulch management systems on bean leaf N, P, and K content are presented in Table 4. Early season leaf N concentrations were significantly higher in the conventional management system in both 1989 and 1990. By mid-season in both years, leaf N concentration in the rye mulch system began to surpass that of the conventional system. Leaf P concentrations in the rye mulch system were as high or higher than those in the conventional system in both years. Leaf K concentrations in the conventional system were significantly higher than those in the rye mulch system in 1989; a similar trend was apparent in 1990.

Beans in the conventional management system produced significantly more leaf area and biomass than beans in the rye mulch management system in both 1989 and 1990 (Figures 3 and 4). Weed growth was significantly greater in the rye mulch management system in both years (Figure 5). Weed growth in the conventional system was considerably greater in 1990 than in 1989. This may have been caused by lack of effectiveness of soil-incorporated herbicides related to heavy rainfall in July 1990 (Table 2). The weed flora of the conventional management system was dominated by ladysthumb (Polygonum persicaria), lambsquarters (Chenopodium album), and wild radish (Raphanus raphanistrum) in 1989, and dandelion (Taraxacum officinale), barnyardgrass (Echinochloa crus-galli), and wild radish in 1990. The weed flora of the rye mulch management system was dominated by broadleaf plantain (Plantago major), alsike clover (Trifolium hybridum), and quackgrass (Agropyron repens) in 1989, and broadleaf plaintain, alsike clover, and barnyardgrass in 1990.

Bean plant population density at crop maturity in 1989 was significantly greater in the conventional management system than in the rye mulch system (Table 5). Crop density was not significantly affected by management system in 1990, but was significantly increased by weed removal (Table 5). Crop density in all treatments in both years was lower than the target density of 16 plants/m^2.

Effects of management system (conventional vs. rye mulch) and weed competition (+/- handweeding) on marketable bean seed yields are shown in Table 6. In general, the higher yield levels obtained in the experiment were comparable to the 1987 state average of 1500 kg/ha. In 1989, handweeding had no effect on yield of the conventional management system but significantly increased yield of the rye mulch management system. This indicated adequate weed control in the former system and inadequate weed control in the latter system. Yield of the conventional system was significantly greater than that of the rye mulch system whether or not weeds were removed by hand. This indicated that factors in addition to weed competition limited bean yield in the rye mulch system. Since moisture was more abundant in the rye mulch system (Table 3) and light was not reduced by weed competition in the handweeded subplots, these results indicate that inadequate soil fertility, inadequate soil aeration, or some other soil-related factor limited bean yield in the rye mulch system.

In 1990, weed infestation significantly decreased bean yield in both the conventional and rye mulch management systems (Table 6). The competitive effect of weeds tended to be greater in the rye mulch system than in the conventional management system. There was a strong trend for the conventional management system to produce a higher yield than the rye mulch system. When bean crop density was used as a covariate for comparisons of yields between the two management systems, the conventional system was found to produce a significantly higher bean yield than the rye mulch system.

A partial budget analysis was used to compare the economic effects of switching from the conventional to the rye mulch bean production system used in this experiment (Table 7). Costs and prices were set to follow those encountered at a commercial farm in Freedom, Maine and at local agricultural input suppliers. Results indicated that use of the rye mulch system (without agrichemical inputs) substantially lowered production costs, by $754.44/ha and $569.42/ha in 1989 and 1990, respectively. However, use of the rye mulch system also greatly lowered revenue, by $2582.88/ha and $1658.85/ha in 1989 and 1990, respectively. Net additions to profits were thus $1828.66/ha and $1089.43/ha lower in 1989 and 1990, respectively, in the rye mulch system. Calculated break-even yield levels for the rye mulch system were 86% - 91% of yields obtained from the conventional management system (Table 7). These results indicate that acceptable economic performance of reduced input systems for high value crops, such as Maine Yelloweye beans, is dependent on producing yields comparable to those of conventional management systems.

Table 1. Field operations and materials for rye mulch and conventional bean production systems in Experiment 1.

	Rye Mulch	Conventional
Harvest wheat	X	X
Disk (3x; September)	X	
Plant rye[a]	X	
Herbicide application (pre-plant)[b]		X
Moldboard plow		X
Disk (2x; May)		X
Spike tooth harrow		X
Herbicide application (pre-plant incorporated)[c]		X
Plant beans[d]	X	X
Fertilizer application (at planting)[e]		X
First cultivation	X	X
Second cultivation	X	
Harvest and processing ($0.44/kg)	X	X

a) 125 kg seed/ha
b) Round-Up (glyphosate, 4.7 L/ha)
c) Sonalan (ethalfluralin, 2.3 L/ha) + Amiben (chloramben, 3.4 kg/ha)
d) 112 kg seed/ha
e) 448 kg/ha of 10-20-10

Table 2. Weather data for Stillwater, Maine, during the 1989 and 1990 growing seasons.

	Average Temperature (°C)			Precipitation (mm)		
	1989	1990	30 year average	1989	1990	30 year average
May	14.8	11.4	11.5	186.6	158.1	80.5
June	18.7	18.4	17.0	121.2	140.7	76.7
July	20.7	21.9	20.0	63.0	126.3	87.1
August	19.8	22.0	19.1	112.1	14.7	79.2
September	15.2	15.4	14.4	103.1	88.6	88.9
October	9.7	10.3	8.7	70.0	142.1	93.2

Table 3. Effects of conventional (CONV) vs. rye mulch (RM) management systems on soil mineral nitrogen concentration (mg/kg) and soil moisture concentration (g/kg) at -1, 20, 60, and 82 days after planting in 1989. Data were ln-transformed when appropriate to homogenize variances. NS: not significant (p>.10); t: .10> p>.05; *: p< .05; **: p < .01; ***: p < .001.

	Days After Planting			
	-1	20	60	82
NO_3-N				
CONV	6.23	32.87	8.26	6.30
RM	3.52	2.98	3.80	3.13
CV	26.5%	13.4%	17.1%	23.8%
ANOVA	t	***	**	*
NH_4-N				
CONV	6.02	76.45	2.92	1.23
RM	10.19	4.39	3.46	1.52
CV	23.6%	22.9%	27.4%	20.7%
ANOVA	*	*	NS	NS
H_2O				
CONV	338.2	297.2	359.9	289.4
RM	398.3	333.8	373.1	308.6
CV	5.7	6.7%	3.9%	3.7%
ANOVA	**	*	NS	*

Table 4. Effects of conventional (CONV) vs. rye mulch (RM) management systems on bean leaf N, P, and K concentrations (g/kg dry weight) at 18, 38, 61, and 94 days after planting (DAP) in 1989, and 25, 36, 53, 69, and 98 DAP in 1990. NS: not significant (p>.10); t: .10> p>.05; *: p< .05; **: p < .01; ***: p < .001.

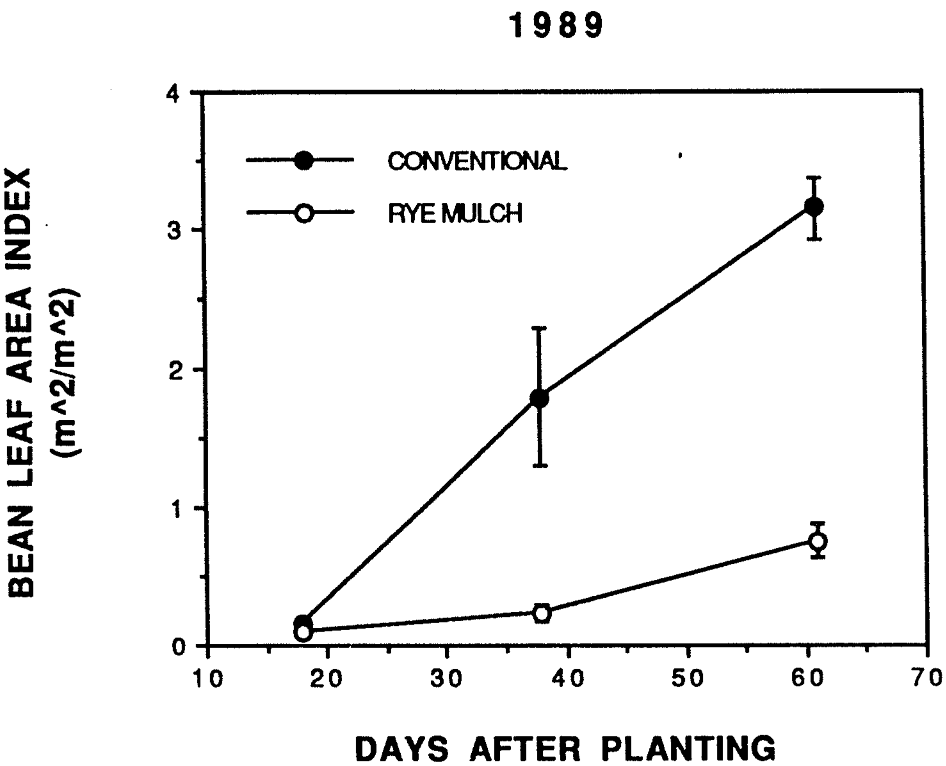
	1989				1990				
	18 DAP	38 DAP	61 DAP	94 DAP	25 DAP	36 DAP	53 DAP	69 DAP	98 DAP
N									
CONV	37.9	40.7	30.3	25.3	40.6	37.6	41.7	34.9	27.5
RM	24.8	29.3	33.2	29.8	23.6	23.8	38.0	35.3	29.5
CV	12.2%	16.2%	7.0%	10.1%	16.4%	8.9%	8.3%	4.5%	25.4%
ANOVA	**	*	t	*	**	***	NS	NS	NS
P									
CONV	2.32	3.79	3.09	2.97	2.88	2.38	2.87	2.91	2.38
RM	2.66	4.34	3.50	3.20	3.07	3.14	2.74	2.75	2.92
CV	8.9%	7.8%	9.6%	10.3%	10.6%	16.2%	8.0%	11.2%	16.9%
ANOVA	*	*	*	NS	NS	t	NS	NS	t
K									
CONV	31.6	28.0	29.0	21.2	26.5	28.8	20.7	26.5	15.1
RM	20.3	21.2	22.2	14.9	17.9	23.7	21.8	24.8	13.4
CV	12.5%	16.0%	8.0%	16.4%	21.1%	20.5%	35.6%	44.4%	52.4%
ANOVA	**	*	**	*	*	NS	NS	NS	NS

Figure 1. Bean leaf area index (m^2 leaf area/m^2 ground area) in conventional vs. rye mulch management systems, 1989 and 1990. Standard errors are shown with vertical bars. Multivariate analysis of variance indicated significant differences between the two systems in both 1989 ($p < .001$) and 1990 ($p < .05$).

Figure 2. Total bean biomass accumulation (g/m^2, aboveground and belowground biomass) in conventional vs. rye mulch management systems, 1989 and 1990. Standard errors are shown with vertical bars. Multivariate analysis of variance indicated significant differences between the two systems in both 1989 ($p < .001$) and 1990 ($p < .05$).

Figure 3. Aboveground weed biomass (g/m^2) in conventional vs. rye mulch management systems in 1989 and 1990. Standard errors are shown with vertical bars. Multivariate analysis of variance indicated significant differences between the two systems in both 1989 ($p < .001$) and 1990 ($p < .01$).

FIGURE 3


1989
CONVENTIONAL
RYE MULCH
BEAN LEAF AREA INDEX (m^2/m^2)
0
1
2
3
4
10
20
30
40
50
60
70
DAYS AFTER PLANTING

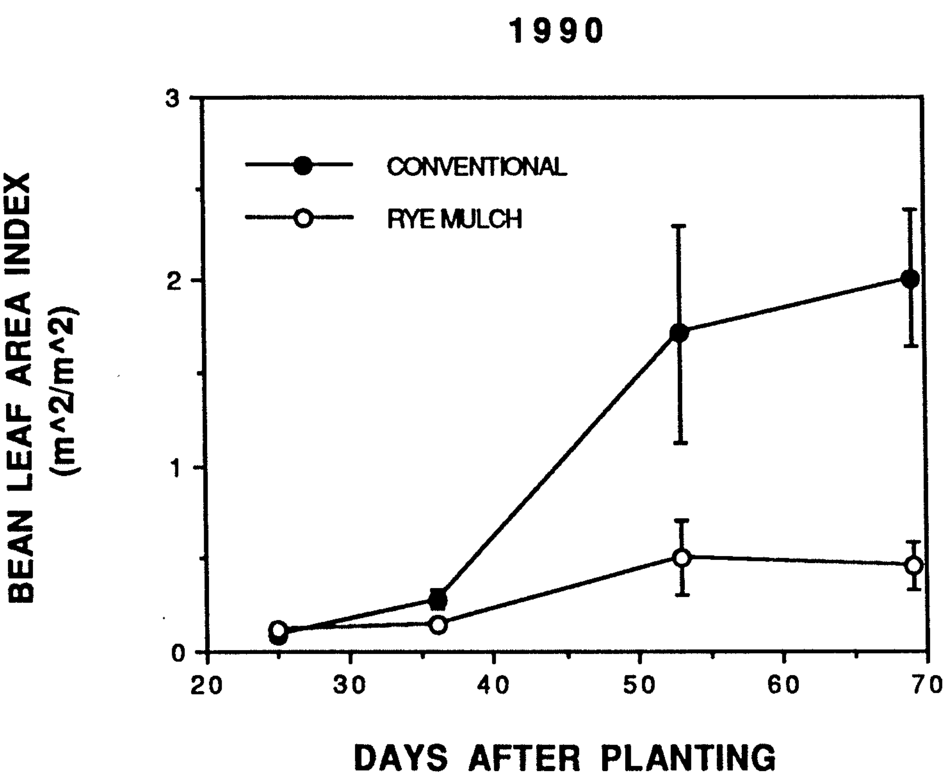
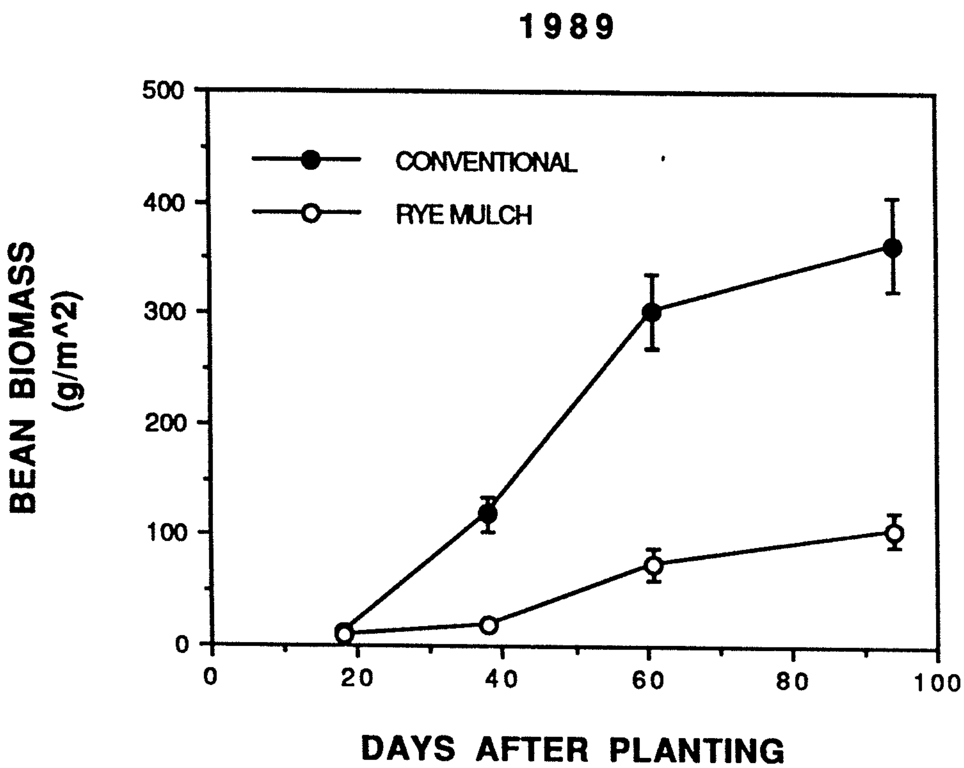

1990
CONVENTIONAL
RYE MULCH
BEAN LEAF AREA INDEX (m^2/m^2)
0
1
2
3
20
30
40
50
60
70
DAYS AFTER PLANTING

FIGURE 4


1989
BEAN BIOMASS
(g/m^2)
500
400
300
200
100
0
CONVENTIONAL
RYE MULCH
0
20
40
60
80
100
DAYS AFTER PLANTING

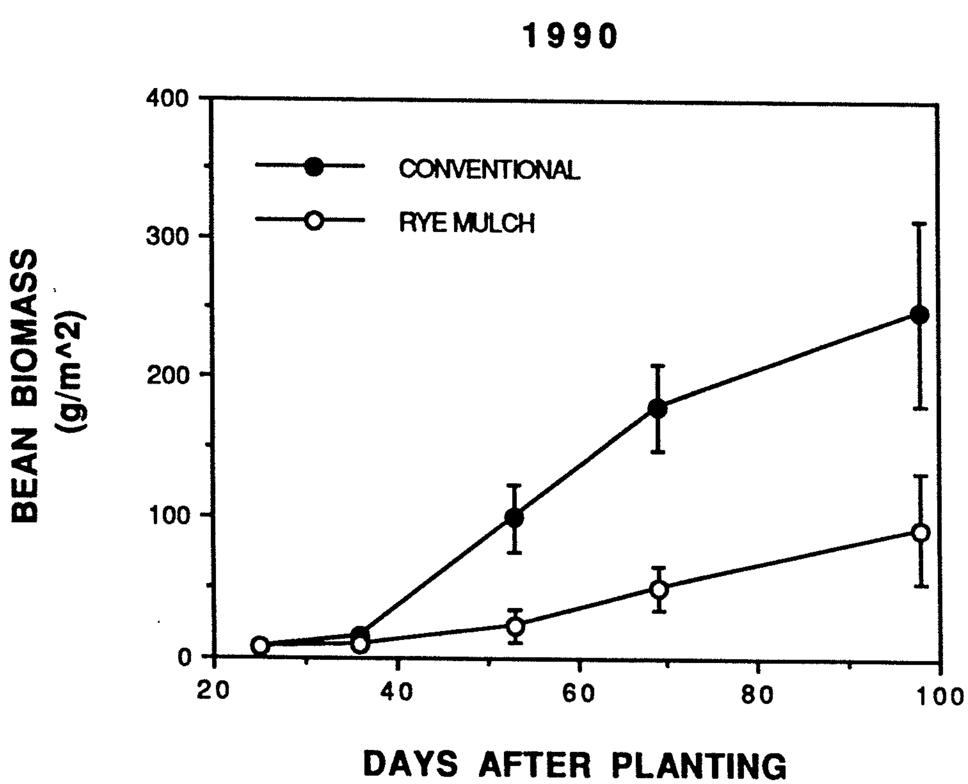

1990
BEAN BIOMASS
(g/m^2)
400
300
200
100
0
CONVENTIONAL
RYE MULCH
20
40
60
80
100
DAYS AFTER PLANTING

FIGURE 5

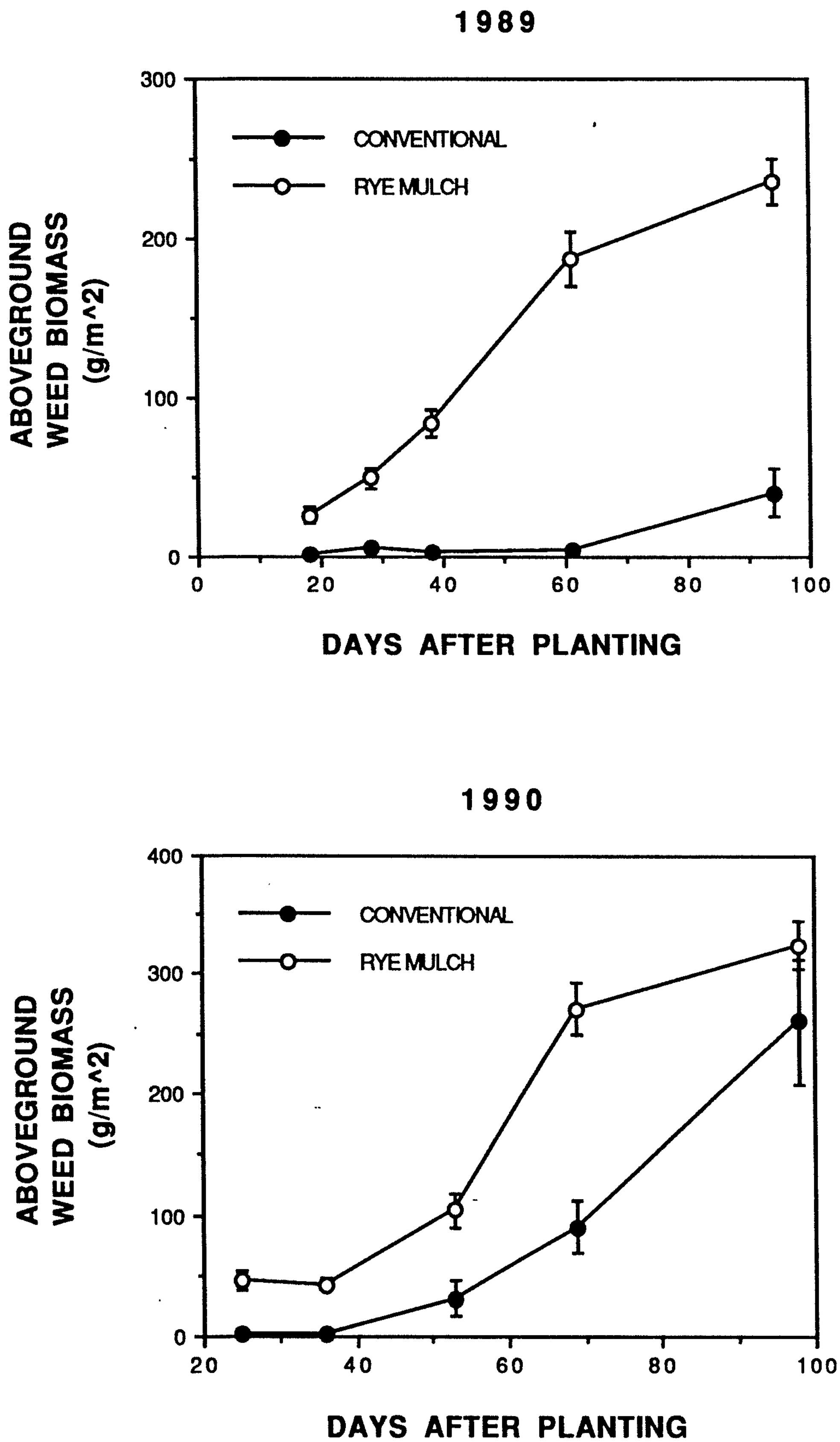

1989
300
200
100
0
0
20
40
60
80
100
CONVENTIONAL
RYE MULCH
ABOVEGROUND
WEED BIOMASS
(g/m^2)
DAYS AFTER PLANTING
1990
400
300
200
100
0
20
40
60
80
100
CONVENTIONAL
RYE MULCH
ABOVEGROUND
WEED BIOMASS
(g/m^2)
DAYS AFTER PLANTING

Table 5. Effects of conventional (CONV) vs. rye mulch (RM) management systems and weed infestation on bean plant density ($\#/m^2$) at 108 and 120 days after planting in 1989 and 1990, respectively. NS: not significant ($p > .10$); *: $p < .05$; **: $p < .01$.

	Bean Density			
	1989		1990	
	CONV	RM	CONV	RM
+ handweeding	14.6	11.4	9.3	9.8
- handweeding	14.6	10.7	7.3	7.8
CV, management system	19.6%		58.7%	
CV, weed infestation	8.8%		18.2%	
ANOVA				
Management system (M)	*		NS	
Weed infestation (W)	NS		**	
MxW	NS		NS	

Table 6. Effects of conventional (CONV) vs. rye mulch (RM) management systems and weed infestation on marketable bean seed yield (kg/ha at 12% moisture). Ln-transformed values are presented in parentheses; t: $.10 > p > .05$; **: $p < .01$; ***: $p < .001$.

	Marketable Bean Yield			
	1989		1990	
	CONV	RM	CONV	RM
+ handweeding	1494.9 (7.305)	854.0 (6.742)	1481.6 (7.242)	1022.5 (6.757)
- handweeding	1553.2 (7.336)	382.0 (5.910)	986.7 (6.488)	234.6 (5.250)
CV, management system	3.0%		14.7%	
CV, weed infestation	2.7%		7.5%	
ANOVA				
Management system (M)	***		t	
Weed infestation (W)	***		***	
MxW	***		t	

Table 7. A partial budget analysis of the effect of using the rye mulch production system instead of the conventional system for bean production in Experiment 1 during 1989 and 1990. In this analysis, neither system received handweeding.

	1989	1990
	-----------$/ha---------------	
Additional Revenue (A)	0	0
Reduced Costs		
moldboard plowing	37.79	37.79
May disking	33.59	33.59
spike tooth harrowing	12.60	12.60
pre-plant herbicide application	111.40	111.40
pre-plant incorporated herbicide application	88.49	88.49
fertilizer	103.74	103.74
reduced processing	516.57	331.77
subtotal (B)	904.18	719.38
Total Additions to Revenue (A+B)	904.18	719.38
Reduced Revenue		
bean value ($2.20/kg) (C)	2582.88	1658.85
Increased Costs		
September disking	50.39	50.39
grain drill ownership	16.21	16.21
plant rye	45.57	45.57
mow rye	12.60	12.60
second cultivation	25.19	25.19
subtotal (D)	149.96	149.96
Total Addition to Cost (C+D)	2732.84	1808.81
Net Addition to Profit (A+B-C-D)	-1828.66	-1089.43
	-----------kg/ha--------------	
Conventional Yield	1553.2	986.7
Rye Mulch Yield	382.0	234.6
Break-Even Rye Mulch Yield	1418.5	852.1

Experiment 2. Nitrogen nutrition, growth and yield of dry beans in conventional vs. rye mulch/reduced tillage production systems.

Results of Experiment 1 indicated that weeds and soil-related factors limited yield of beans produced in a rye mulch/reduced tillage management system that did not include use of synthetic agrichemicals. Experiment 2 was conducted to determine whether adequate bean yields could be obtained from rye mulch production systems if synthetic fertilizers and herbicides were used to improve soil fertility and weed control. Particular attention was focused on crop nutrition and growth. An economic analysis of the conventional vs. rye mulch production systems used in this experiment was also conducted.

Experiment 2 was conducted in 1990 on a Buxton silt loam (fine, illitic, frigid Aquic Dystric Eutrochrept) at the University of Maine's Sustainable Agriculture Research Farm in Stillwater. In this study, inoculated dry beans (Phaseolus vulgaris cv. Maine Yelloweye) were sown i) without tillage into a rye (Secale cereale cv. Aroostook) cover crop, or ii) planted into a bare ground seed bed following conventional tillage operations applied to a winter-killed oat cover crop. The two management treatments were split into subplots of different N fertilizer rates (0, 45, 90, and 135 kg N/ha). The experimental units (i.e., subplots) were 6 rows (0.82 m spacing) x 7.7 m.

A schedule of field operations for the experiment is shown in Table 8. Rye and oat cover crops were planted on August 31, 1989, and all plots were sprayed with glyphosate on June 1, 1990. Winter killed oats/conventional tillage plots were disked on June 4, 1990, and disked again June 6 following application of chloramben and ethalfluralin. Beans were sown in all plots on June 7, 1990. Rye was flail mowed immediately after planting beans. P and K fertilizers were banded mechanically at planting in all plots. Appropriate rates of N fertilizer were placed and covered in the PK band using a pointed hoe following planting. Rye mulch and conventional tillage plots were both cultivated on July 11, 1990. Bean leaf area production, nutrient uptake, and growth were measured at approximately two-week intervals throughout the season. Weed growth was measured 47, 67 and 103 days after planting (DAP) beans. Soil nutrient status was measured immediately before planting beans and 56 DAP. Bean plant density and marketable seed yield were determined for samples collected on October 4, 1990.

No differences in soil NH_4-N, NO_3-N, P and K levels were observed between rye mulch and conventional tillage treatments before bean planting and fertilizer application (Table 9). In contrast, there was significantly less NO_3-N in soils of rye mulch plots as compared to conventional tillage plots at 56 DAP (Table 10). Application of N fertilizer significantly increased soil NO_3-N levels at this date in both rye mulch and conventional tillage treatments, but the increase was more pronounced in conventional tillage plots (Table 10). Rye mulch plots tended to have slightly higher soil NH_4-N levels at 56 DAP. Management system and N fertilizer had no significant effects on mid-season soil P and K levels.

Seasonal mean values of bean leaf N, P and K concentrations are reported in Table 11. All leaves of plants sampled 19, 32, 47, 54, 67, 82 and 103 DAP were used to generate these data. Results indicate that N fertilizer (i) significantly increased leaf N concentration in both rye mulch and conventional tillage systems, (ii) had no effect on leaf P levels, and (iii) significantly increased leaf K levels in the rye mulch system but had no significant effect on the conventional tillage system. Bean leaf P and K levels from the rye mulch system tended to be slightly higher than those from the conventional tillage system. In contrast, bean leaf N concentrations were significantly lower in the rye mulch system as compared to the conventional tillage system. These effects were particularly pronounced in the first half of the growing season (data not shown).

Application of N fertilizer significantly increased maximum leaf area, leaf area duration, and mean relative growth rate of beans (Table 12). Maximum leaf area was significantly lower in the rye mulch system as compared to the conventional tillage system, and similar negative trends were observed for leaf area duration and mean relative growth rate (Table 12).

Weed biomass production was higher in the rye mulch as compared to the conventional tillage system throughout the growing season; N fertilizer had no effect (Table 13). Almost all of the weed biomass was comprised of dandelions, which grew from seeds that blew into the plots from a surrounding meadow several weeks after planting beans. Dandelions grew as an understory covered by the bean canopy and their effect on bean growth and yield was not measured. A second, more aggressive cultivation with disk hillers in addition to sweeps will be used to improve weed control in 1991.

Bean plant density at crop maturity was not affected by management system nor N fertilizer rate (Table 14). Crop density in all treatment was lower than the target density of 16 plants/m^2, probably because wet weather after planting (Table 2) reduced emergence and successful establishment.

Application of N fertilizer significantly increased bean yields in both the rye mulch and conventional tillage systems (Table 15), despite the presence of Rhizobium nodules on bean roots. Analysis of variance results indicated a significant linear trend for the yield increase in response to N fertilizer in both systems; no quadratic effect, indicating a yield plateau, was detected. Beans in the rye mulch system tended to yield 25% less than beans in the conventional tillage system (Table 15). Repetition of this experiment in 1991 should provide additional insight into bean yield response to N fertilizer and to rye mulch/reduced tillage management.

A partial budget analysis was used to compare the effects of using the rye mulch/reduced tillage system instead of the conventional tillage system at each level of N fertilizer application (Table 16). Costs and prices were set to follow those encountered at a commercial farm in Freedom, Maine, and at local agricultural input suppliers, as in Experiment 1. Results indicate that use of the rye mulch/reduced tillage system instead of the conventional system substantially lowered net profits at each N fertilizer level. Averaged over N fertilizer levels, use of the rye mulch system lowered production costs by $308.65/ha, but lowered revenue by $934.77/ha. Net additions to profit were thus $626.13/ha lower, on average, in the rye mulch system. Calculated break-even yield levels for the rye mulch system were very close to yields obtained from the conventional tillage system (Table 16). These results reiterate those of Experiment 1: acceptable economic performance of reduced input systems for high value crops is dependent on producing yields comparable to those of conventional systems.

Table 8. Field operations for rye mulch and conventional management systems of Experiment 2.

	Rye Mulch	Conventional
Disk (2x; August)	X	X
Plant rye or oats[a]	X	X
Herbicide application (pre-plant)[b]	X	X
Disk (3x; May)		X
Spike tooth harrow		X
Herbicide application (pre-plant incorporated)[c]		X
Plant beans[d]	X	X
Fertilizer application (at planting)[e]	X	X
Mow rye	X	
Cultivation (1x)	X	X
Harvest and processing ($0.44/kg)	X	X

a) 125 kg seed/ha for rye; 108 kg/ha for oats
b) Round-Up (glyphosate, 4.7 L/ha)
c) Sonalan (ethalfluralin, 2.3 L/ha) + Amiben (chloramben, 3.4 kg/ha)
d) 112 kg seed/ha
e) All plots received 672 kg/ha of 0-20-20. Ammonium nitrate was applied at 0, 128, 256, and 384 kg/ha to 0N, 45N, 90N, and 135N treatments, respectively.

Table 9. Pre-planting soil nutrient levels (mg/kg) as affected by management system. NS: not significant ($p>.10$).

	NH_4-N	NO_3-N	P	K
Rye mulch	22.34	2.95	4.32	82.55
Conventional	22.50	2.70	4.15	99.50
CV	29.0%	56.6%	23.1%	40.0%
ANOVA				
Management system	NS	NS	NS	NS

Table 10. Mid-season (56 days after planting) soil nutrient levels (mg/kg) as affected by management system and N fertilizer. NS: not significant ($p>.10$); t: $.10>p>.05$; *: $p<.05$; **: $p<.01$; ***: $p<.001$; RM: rye mulch system; CONV: conventional system.

N Fertilizer Rate	NH_4-N		NO_3-N		P		K	
	RM	CONV	RM	CONV	RM	CONV	RM	CONV
0 kg N/ha	22.88	18.60	4.81	8.90	5.94	5.90	98.20	99.40
45 kg N/ha	22.28	20.80	11.24	14.92	5.74	5.98	100.70	91.20
90 kg N/ha	22.58	19.44	10.97	17.24	6.42	5.62	104.70	100.10
135 kg N/ha	21.90	22.22	9.65	25.23	6.34	5.94	103.10	102.40
CV, management system	13.4%		22.2%		18.7%		28.0%	
CV, N fertilizer	11.1%		10.2%		8.2%		18.3%	
ANOVA								
Management system(M)	t		*		NS		NS	
N fertilizer(N)	NS		***		NS		NS	
MxN	NS		t		NS		NS	

Table 11. Seasonal mean values for bean leaf N, P and K concentrations (g/kg dry weight) as affected by management system and N fertilizer. Data were collected 19, 32, 47, 54, 67, 82 and 103 days after planting. NS: not significant ($p>.10$); t: $.10>p>.05$; *: $p<.05$; **: $p<.01$; ***: $p<.001$; RM: rye mulch system; CONV: conventional system.

	N		P		K	
N Fertilizer Rate	RM	CONV	RM	CONV	RM	CONV
0 kg N/ha	30.8	34.6	3.20	2.95	23.8	23.7
45 kg N/ha	33.2	35.8	3.00	2.97	26.8	24.5
90 kg N/ha	35.7	37.8	3.04	3.00	27.5	25.9
135 kg N/ha	35.9	38.1	3.09	2.78	28.5	23.8
CV, tillage/cover crop	6.9%		6.7%		11.1%	
CV, N fertilizer	5.4%		9.3%		8.7%	
ANOVA						
Management (M)	*		t		t	
N fertilizer (N)	***		NS		*	
MxN	NS		NS		t	

Table 12. Maximum bean leaf area (cm^2/plant), leaf area duration (m^2•day/plant), and mean relative growth rate (mg/g/day) as affected by management system and N fertilizer. Data were collected from 19 until 103 days after planting. NS: not significant (p>.10); t: .10>p>.05; *: p<.05; **: p<.01.

	Maximum Leaf Area		Leaf Area Duration		Mean Relative Growth Rate	
N Fertilizer Rate	Rye Mulch	Conventional	Rye Mulch	Conventional	Rye Mulch	Conventional
0 kg N/ha	1179.7	1759.9	5.162	6.728	48.09	55.34
45 kg N/ha	1546.9	2160.3	7.487	7.867	53.52	61.38
90 kg N/ha	2008.2	2827.1	6.844	10.219	55.00	62.09
135 kg N/ha	2151.7	2328.5	8.123	8.369	61.35	59.58
CV, tillage/cover crop	3.7%		22.2%		10.8%	
CV, N fertilizer	5.0%		19.4%		11.0%	
ANOVA						
Management (M)	*		t		t	
N fertilizer (N)	*		**		*	
MxN	NS		t		NS	

Table 13. Weed above ground biomass (g/m^2) as affected by management system and N fertilizer. NS: not significant (p>.10); t:.10>p>.05; *:p<.05; **:p<.01; DAP:days after planting.

	47 DAP		67 DAP		103 DAP	
N Fertilizer Rate	Rye Mulch	Conventional	Rye Mulch	Conventional	Rye Mulch	Conventional
0 kg N/ha	28.04	14.92	94.84	30.64	139.90	115.18
45 kg N/ha	24.74	14.68	77.17	35.14	118.51	78.92
90 kg N/ha	28.36	16.65	90.24	36.98	133.23	89.67
135 kg N/ha	29.93	13.58	108.44	49.92	151.88	109.91
CV, management system	10.3%		42.7%		46.2%	
CV, N fertilizer	17.7%		25.9%		37.3%	
ANOVA						
Management system (M)	**		*		t	
N fertilizer (N)	NS		NS		NS	
MxN	NS		NS		NS	

Table 14. Bean plant density ($\#/m^2$) at 119 days after planting, as affected by management system and N fertilizer. NS: not significant ($p > .10$).

	Bean Density	
N Fertilizer Rate (kg N/ha)	Rye Mulch System	Conventional System
0	10.4	11.3
45	10.4	10.5
90	10.2	11.4
135	10.6	10.5

CV, Management system	12.8%
CV, N fertilizer	10.9%

ANOVA

Management (M)	NS
N fertilizer (N)	NS
M x N	NS

Table 15. Marketable bean seed yields (kg/ha at 12% moisture) as affected by management system and N fertilizer. NS: not significant ($p>.10$); t: $.10>p>.05$; **: $p<.01$.

	Marketable Seed Yield	
N Fertilizer Rate (kg N/ha)	Rye Mulch System	Conventional System
0	968.4	1297.2
45	1295.9	1623.4
90	1251.6	1921.5
135	1565.1	1934.0

CV, Management system	15.9%
CV, N fertilizer	20.0%

ANOVA

Management system (M)	t
N fertilizer (N)	**
MxN	NS

Table 16. A partial budget analysis of the effect of using a rye mulch production system instead of a conventional system for bean production in Experiment 2.

	Fertilizer Treatment (kg N/ha)			
	0	45	90	135
	$/ha			
Additional Revenue (A)	0	0	0	0
Reduced Costs				
plant oats	28.38	28.38	28.38	28.38
May disking	50.39	50.39	50.39	50.39
spike tooth harrow	12.60	12.60	12.60	12.60
pre-plant incorporated herbicides	88.49	88.49	88.49	88.49
reduced processing	145.04	144.50	295.51	162.77
subtotal (B)	324.90	324.36	475.37	342.63
Total Additions to Revenue (A+B)	324.90	324.36	475.37	342.63
Reduced Revenue				
bean value ($2.20/kg) (C)	725.19	722.48	1477.55	813.87
Increased Costs				
plant rye	45.57	45.57	45.57	45.57
mow rye	12.60	12.60	12.60	12.60
subtotal (D)	58.17	58.17	58.17	58.17
Total Addition to Cost (C+D)	783.36	780.65	1535.72	872.04
Net Addition to Profit (A+B-C-D)	-458.46	-456.29	-1060.35	-529.41
	kg/ha			
Conventional Yield	1297.4	1623.7	1921.8	1934.4
Rye Mulch Yield	968.6	1296.1	1251.8	1565.3
Break-Even Rye Mulch Yield	1228.4	1554.7	1852.8	1865.4

Demonstration 1. On-farm evaluation of conventional vs. rye mulch/reduced tillage bean production systems.

Cooperator: Mr. Anthony Neves

Reduced tillage production practices used in conjunction with cover crops have the potential to limit soil erosion, conserve water, and improve soil quality. Compatibility of such approaches with actual farm management needs to be tested, however. This demonstration project was conducted in Freedom, Maine, in 1989 and 1990, to evaluate the performance of conventional vs. rye mulch/reduced tillage bean production systems on a commercial bean farm. Three management treatments were evaluated: 1) conventional bare ground tillage with multiple herbicides and a full rate of fertilizer; 2) direct planting into a rye cover crop with limited herbicide application but a full rate of fertilizer; and 3) direct planting into a rye cover crop with limited herbicide application and no fertilizer. Treatments were unreplicated and applied to strips which were 4 rows (0.82 m spacing) x 125 m. Soil type was a Peru fine sandy loam (coarse-loamy, mixed, frigid Aquic Fragiorthod).

Field operations and materials used in the demonstration are shown in Table 17. Rye was sown in late September, 1988 and 1989, and inoculated Jacob's Cattle (1989) and Yelloweye (1990) beans were sown into bare ground and the rye cover crop on June 2, 1989 and June 5, 1990. A standard bean planter, with no special modification for heavy residue conditions, was used for all treatments and provided adequate seed placement and seed/soil contact. Weed biomass production was measured 27 and 101 days after planting (DAP) in 1989, and 38 and 112 DAP in 1990. Bean plant density and marketable bean seed yield were determined for samples collected 101 DAP in 1989, and 112 DAP in 1990. Use of formal inferential statistics to evaluate results was not appropriate because of the unreplicated nature of the demonstration. However, general trends can be noted.

Weed growth was greater in the rye mulch treatments than in the conventional treatment, particularly early in the 1990 growing season (Table 18). Dominant weed species in all treatments were redroot pigweed (Amaranthus retroflexus), lambsquarters (Chenopodium album), barnyardgrass (Echinochloa crus-galli), and white clover (Trifolium repens). These results suggest that the rye mulch management system, even when used with glyphosate and cultivation, may fail to provide adequate weed control on working farms.

Bean plant density in Demonstration 1 (Table 19) was comparable among treatments, but was much lower in 1990 than 1989. Low crop population probably had a yield-limiting effect and resulted from poor emergence in wet conditions following planting.

Marketable bean seed yields in 1989 and 1990 are shown in Table 20. In 1989, yield from the rye mulch/-fertilizer treatment was 33% lower than that from the conventional treatment. In 1990, yields from the rye mulch/-fertilizer and rye mulch/+fertilizer treatments were 78% lower and 53% lower, respectively, than that from the conventional treatment. These results, in combination with those presented in Table 18, strongly suggest a lack of adequate soil fertility and weed control in the reduced input systems used in this demonstration.

A partial budget analysis was used to evaluate the effects of switching from conventional practices to rye mulch/reduced tillage practices, either with or without application of fertilizer (Table 21); the approach used was the same as in Experiments 1 and 2. Results indicate that use of rye mulch/reduced tillage practices reduced net profits by $870.45/ha (1989) and $881.92/ha (1990) when fertilizer was not applied and by $652.95/ha (1990) when fertilizer was applied. As in Experiments 1 and 2, the reduced input systems did reduce operating costs, but loss of revenue resulting from lower bean yields more than offset any cost savings. Results of this demonstration emphasize conclusions of Experiments 1 and 2: reduced input systems for high value crops must be nearly equal to conventional systems in yields to be equal in profitability.

Table 17. Field operations and materials for rye mulch and conventional bean production systems in Demonstration 1. The rye mulch/+ fertilizer treatment was sown only in 1990; the rye mulch/- fertilizer and conventional treatments were sown in both 1989 and 1990.

	Rye Mulch/-Fertilizer	Rye Mulch/+ Fertilizer	Conventional
Disking (1x; September)	X	X	
Plant rye[a]	X	X	
Herbicide application (pre-plant)[b]	X	X	X
Rock removal			X
Disking (3x; May)			X
Spring tooth harrow			X
Herbicide application (pre-plant incorporated)[c]			X
Plant beans[d]	X	X	X
Fertilizer application (at planting)[e]		X	X
Mow rye	X	X	
Herbicide application (post-emergence)[f]			X
Cultivation (1x)	X	X	X
Pulling/windrowing/combining	X	X	X
Processing ($0.44/kg)	X	X	X

a) 125 kg seed/ha
b) Round-up (glyphosate): 2.3 L/ha
c) Prowl (pendimethalin): 2.3 L/ha
d) 1989: 90 kg seed/ha (Jacob's Cattle); 1990: 67 kg seed/ha (Maine Yelloweye)
e) 560 kg/ha of 10-20-20
f) Basagran (bentazon): 2.3 L/ha

Table 18. Mid-and late-season weed aboveground biomass (g/m^2) in 1989 and 1990. Means and standard deviations of four replicates are presented. DAP: days after planting.

	Weed Biomass			
	1989		1990	
	27 DAP	101 DAP	38 DAP	112 DAP
Conventional	1.24 (2.24)	24.6 (32.3)	0.04 (0.12)	177.6 (64.4)
Rye mulch, + fertilizer	Not sown	Not sown	47.32 (56.32)	316.4 (58.0)
Rye mulch, - fertilizer	1.84 (2.84)	36.1 (18.4)	49.52 (26.64)	274.7 (48.0)

Table 19. Bean plant density (#/m^2) at 108 and 112 days after planting in 1989 and 1990, respectively. Means and standard deviations of four replicate samples are presented.

	Bean Density	
	1989	1990
Conventional	13.1 (1.0)	5.3 (1.1)
Rye mulch, + fertilizer	Not sown	5.2 (0.9)
Rye mulch, - fertilizer	13.6 (2.1)	5.1 (2.1)

Table 20. Marketable bean seed yield (kg/ha at 12% moisture) at 108 and 112 days after planting in 1989 and 1990, respectively. Means and standard deviations of four replicates are presented.

	Marketable Seed Yield	
	1989	1990
Conventional	1905.1 (226.4)	799.6 (173.7)
Rye mulch, + fertilizer	Not sown	376.4 (161.1)
Rye mulch, - fertilizer	1285.2 (165.9)	173.2 (47.7)

Table 21. A partial budget analysis of the effect of switching from conventional production practices to rye mulch production practices in Demonstration 1 during 1989 and 1990.

	1989	1990	
	- Fertilizer	- Fertilizer	+ Fertilizer
	----$/ha----	------------------$/ha	---------------------
Additional Revenue (A)	0	0	0
Reduced Costs			
rocking	25.19	25.19	25.19
May disking	50.39	50.39	50.39
spring tooth harrow	12.60	12.60	12.60
fertilizer application	129.68	129.68	0
preplant incorporated herbicide	33.43	33.43	33.43
post-emergence herbicide	51.88	51.88	51.88
reduced processing	273.43	276.29	186.63
subtotal	576.60	579.46	360.13
Total Additions to Revenue (A+B)	576.60	579.46	360.13
Reduced Revenue			
bean value ($2.20/kg)(C)	1367.14	1381.47	933.17
Increased Costs			
fall disking	16.80	16.80	16.80
grain drill ownership	4.94	4.94	4.94
plant rye	45.57	45.57	45.57
mow rye	12.60	12.60	12.60
subtotal (D)	79.91	79.91	79.91
Total Addition to Cost (C+D)	1447.05	1461.38	1013.08
Net Addition to Profit (A+B-C-D)	-870.45	-881.92	-652.95
	----kg/ha----	------------------kg/ha	-----------------
Conventional yield	1905.1	799.6	799.6
Rye mulch yield	1285.2	173.2	376.4
Break-even rye mulch yield	1778.57	673.0	746.5

LNE 88-07

SUMMARY

Conventional and rye mulch/reduced tillage management systems for producing dry beans (*Phaseolus vulgaris* cv. Maine Yelloweye) were compared in two experiments and one on-farm demonstration conducted in central Maine in 1989 and 1990. Management practices in the conventional system involved preparation of a bare ground seed bed with a moldboard plow and/or disk harrow, and application of herbicides and fertilizers. Management practices in the rye mulch/reduced tillage system involved planting beans directly into a rye cover crop, which was subsequently mowed to form a mulch on the soil surface. No fertilizers or herbicides were used in the rye mulch system of Experiment 1; fertilizers and reduced quantities of herbicide were applied to the rye mulch system of Experiment 2 and the on-farm demonstration.

Marketable bean yields from the rye mulch system of Experiment 1 were 75% and 76% lower than from the conventional system in 1989 and 1990, respectively. Use of the rye mulch system substantially lowered production costs, but also greatly lowered revenues because of lower yields. Net additions to profit were reduced by $754/ha in 1989 and by $569/ha in 1990. Lower yields from the rye mulch system (managed without agrichemicals) were the result of increased weed competition and a soil-related factor. Soil and bean leaf tissue analyses indicated low N and K fertility in the rye mulch system may have reduced bean yields.

Marketable seed yield from the rye mulch system of Experiment 2 was 29% lower than from the conventional system. Lower production costs in the rye mulch system were more than offset by loss in revenue resulting from lower yield, and net addition to profit was $623/ha lower, on average, than in the conventional system. Lower yield from the rye mulch system (managed with limited amounts of agrichemicals) was found to be related to insufficient N fertility. Weed control in the rye mulch system was not as effective as in the conventional system, but the crop maintained dominance over weeds in both systems.

Results of the on-farm demonstration indicated that use of the rye mulch system lowered marketable seed yields by 32% to 78% and lowered net additions to profit by $673/ha to $1778/ha. Application of fertilizer increased yields and economic returns from the rye mulch system, but these increases never reached levels obtained from the conventional system. Weed control in the rye mulch system (managed with limited herbicide application) was effective in 1989, but was not effective in 1990.

RECOMMENDATIONS

1) An important insight gained from this project was that acceptable economic performance of reduced input systems for high value crops is dependent on producing yields comparable to those of conventional management systems, even when production costs are lowered substantially. Rye mulch management systems in this project failed to meet this criterion because of insufficient nitrogen fertility and, in some cases, inadequate weed control. Nitrogen fertility and weed management should continue to be addressed in future research and demonstration projects directed toward improving the profitability of reduced input cropping systems.

2) Cover cropping with rye may create nitrogen deficits for a succeeding bean crop by immobilizing soil nitrogen that would otherwise be available. Use of legume cover crops that could supply adequate amounts of nitrogen to beans should be investigated.

3) When herbicides were not used in the rye mulch system, perennial weed species within the crop row presented a major challenge. A possible solution to this problem might involve use of a small sweep preceding the planter unit down the row; this approach is currently used on commercially available ridge till planters and could be investigated in the context of reduced tillage/cover crop systems for beans and other crops.

4) Factors responsible for inconsistent weed control in the rye mulch system managed with limited herbicide application are not clear and could be the focus of additional research and demonstration efforts. Modifications of planting and cultivation equipment, including use of sweeps preceding the planter and disk hillers, could be investigated in the context of a limited herbicide/reduced tillage/cover crop approach.

5) If weed management in reduced tillage/cover crop systems is judged to be intractable, conventional tillage used in concert with improved cultivation, rotation, green manure, and strip cropping practices may provide an acceptable alternative for improving both weed control and soil conservation without increasing reliance on herbicides or risk.

Project - Related Outreach and Extension Activities
Conducted by Matt Liebman
1989 - 1991

Maine Plant Food Educational Society, Annual Meeting, Bangor, Maine (February 3, 1989). "Sustainable agriculture research activities" (invited presentation).

Sixth Annual Symposium on Ecological Agriculture, Cornell University, Ithaca, New York (April 8, 1989). "Building a university sustainable agriculture program" (invited keynote address).

Maine Dry Bean Growers Association Annual Meeting, Waterville, Maine (April 11, 1989). "Growing beans in rye mulch" (invited presentation).

Maine Endowment for Research, Extension, and Teaching, Agricultural Leadership Conference, Augusta, Maine (April 26, 1989). "What can sustainable agriculture at the University of Maine do for commercial agriculture in our state?" (invited presentation).

University of Maine Cooperative Extension, symposium and field plot tour concerning sustainable agriculture, Orono and Stillwater, Maine (July 8, 1989). "Sustainable agriculture research activities at the University of Maine" (invited presentations).

Northeast Section of the American Dairy Science Association/American Society of Animal Science, symposium on sustainable agriculture, Orono, Maine (July 11, 1989). "Developments in sustainable agriculture at the University of Maine" (invited presentation).

Natural Organic Farmers' Association, 15th Annual Conference, Williamstown, Massachusetts (July 15, 1989). "The University of Maine Sustainable Agriculture Program" (invited presentation).

University of Maine, Sustainable Agriculture Field Day, Stillwater, Maine (August 8, 1989). Field plot tours.

Orono High School, Orono, Maine (November 2, 1989). "Sustainable agriculture practices" (invited presentation).

Departments of Entomology, Plant Pathology, and Plant and Soil Sciences, University of Massachusetts, Amherst (November 28, 1989). "Sustainable agriculture in Maine" (invited presentation).

New England Small Fruit and Vegetable Growers Convention, Symposium on sustainable agriculture, Sturbridge, Massachusetts (November 29, 1989). "Low input sustainable agriculture for vegetable production" (invited presentation).

University of Maine Cooperative Extension and Biology Department of Bowdoin College, Sustainable Agriculture Shortcourse, Brunswick, Maine (January 23, 1990). "Sustainable agriculture: a farming systems approach" (invited presentation).

Weed Science Society of America, symposium on sustainable agriculture, Montreal, Quebec (February 6, 1990). "Ecological approaches for weed management" (invited presentation).

Maine Dry Bean Growers Association, Annual Meeting, Waterville, Maine (April 17, 1990). "Reduced tillage/cover crop systems for Maine Yelloweye beans" (invited presentation).

Maine Agriculture in the Classroom Curriculum Institute, Bryant Pond, Maine (June 26, 1990). "Sustainable agriculture activities at the University of Maine" (invited presentation).

University of Maine, Sustainable Agriculture Field Day, Stillwater, Maine (August 7, 1990). Field plot tour.

National Sustainable Agriculture and Natural Resources Conference, Lincoln, Nebraska (August 16, 1990). "The University of Maine Sustainable Agriculture Program" (invited presentation).

Organic Farmer to Farmer Conference, Orono, Maine (November 3, 1990). "Weed control" (invited presentation).

University of Arizona, Department of Ecology and Evolutionary Biology, Tucson, Arizona (November 6, 1990). "Ecological approaches for weed management" (invited presentation).

Maine Agricultural Trades Show, Augusta, Maine (January 22, 1991). "Stewardship and organic farming" (invited presentation).

University of Maine Cooperative Extension, Sustainable Agriculture Shortcourse, Newport, Maine (February 7, 1991). "Sustainable agriculture: a farming systems approach" (invited presentation).

Maine Dry Bean Growers Association, Annual Meeting, Waterville, Maine (April 11, 1991). "Ongoing research on bean cropping systems including data on nitrogen trials" (invited presentation).

College of the Atlantic, Bar Harbor, Maine (April 29, 1991). "Alternative approaches for weed management" (invited presentation).