TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD TESTING OF COVER CROP SYSTEMS FOR CORN AND SOYBEAN PRODUCTION

FINAL REPORT

June, 1992

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Executive Summary

Experiment 1. Field Testing of Cover Crop Systems

Promising cover crop species including hairy vetch, oilseed radish and winter rye were evaluated on 6 farms in South Western Ontario. Cover crops proved to be economical by either reducing production costs or increasing yields. Oilseed radish appeared to be the most promising new cover crop as it showed potential to reduce production costs, improve weed control and increase corn yields. Hairy vetch provided similar yields and input costs as red clover when used as a legume cover crop prior to corn. Promising rye management systems included using winter rye as a double crop forage before conventionally planted soybeans and using winter rye as a weed suppressing mulch for no-till soybean production.

Experiment 2. Evaluation of the N Contribution of Cover Crops using a Nitrogen Soil Test

Corn grown on plots fertilized with manure and/or cover crops (oilseed radish, red clover and hairy vetch) were sampled biweekly after planting to determine spring soil N transformations and to determine if the N soil test (taken in the top 30 cm of soil at time of sidedress) was a useful indicator of N availability from these sources. Other researchers working in the U.S. corn belt have shown that 21 ppm NO_3-N is the critical N level, above which no N fertilizer response is observed, when legumes and manure are the N sources used for corn production. In this study, N fertilization of sites having NO_3-N levels of 23 ppm produced a corn yield response at two sites. A value of approximately 25 ppm NO_3-N appeared to be a better indicator of fertilizer N response in this one year study. Use of a N soil test appears to be a valuable tool in identifying sites which have an excess supply of N, rather than predicting fertilizer N requirements. It could be a useful tool in helping farmers better understand and manage the N cycle on farms with cover crops and manure as N sources.

Field Testing of Cover Crop Systems for Corn and Soybean Production

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I Introduction

Within a corn-soybean-wheat rotation, several cover crop systems had been evaluated by REAP-Canada as part of the Technology Evaluation and Development Program SWEEP Report #12 Choice and Management of Cover Crop Species and Varieties in Row Crop Dominant Systems (Samson et al., 1990).

Table 1. Cover Cropping Options in a Three Year Cash Crop Rotation

	Year 1	**Year 2**	**Year 3**
Main Crop	CORN	SOYBEAN	WINTER WHEAT
Cover Crop	grass	winter wheat	legume/brassica

These trials have shown the advantages or certain cover crops in improving ground cover, weed control and nutrient cycling on the farm. While this project emphasizes the use of cover crops for corn and soybean production, the inclusion of a winter cereal in the rotation enables a more efficient use of cover crops.

The present study was designed to field test various cover crop and crop sequences: winter rye-soybean, hairy vetch-corn and oilseed radish-corn. These species were chosen for their ability to produce large amounts of above ground biomass for winter ground cover, weed suppression and nutrient cycling. A side-by-side strip comparison technique with six replicates was used to evaluate a cover crop against a control (current practice) on selected farms in Kent, Norfolk, Oxford, and Perth counties.

Our hypothesis was that these cover crop systems would reduce the need for commercial inputs by improving ground cover, weed control, nutrient cycling and forage availability on the farm. In the second year of the project, a more detailed study was conducted on several of the experimental sites. The objective was to evaluate the soil nitrogen test as an indicator of available N from legume and Brassica catch crops. Little published information exists on the use of the N soil test for measuring NO_3-N levels from cover crop or manure N sources.

II. General Materials and Methods

Forage, Cover Crop (Oil Radish, Rye, Red Clover and Hairy Vetch) and Weed Biomass

Biomass determinations were made by hand shearing a one metre square quadrat area of plants at the ground level. Weeds and forage were cleared of crop debris and soil before being dried and weighed. Samples processed during the summer months were dried in solar dryers. Fall harvest samples were oven dried at the Ontario Ministry of Agriculture and Foods' research station located in Woodstock.

Crop Yields

Crop yields were determined both by hand sampling and machine harvesting. Machine harvesting was performed using a commercial combine or a picker sheller in the case of corn at the Wilhelm farm. For the N soil test studies, corn was hand sampled from the centre two rows of each subplot. Hand harvesting of soybeans was done by taking 3 -one metre square quadrates/plot from random sites.

In the case of corn, cobs were shelled, moistures taken and yields adjusted to a 15.5% moisture basis. Soybeans were either oven dried after threshing with a plot combine or moisture levels were taken after threshing and yields adjusted to a 14% moisture basis.

Soil and Plant Analysis

In the fertility trials, sequential sampling was performed for soil nitrates and ammonia on a biweekly basis until the corn reached the growth range identified as optimal for N soil test evaluations in the Northeastern United States (corn at 15-30 cm height). At corn silking the mid third of the corn ear leaf was sampled for N content. The samples were processed by Analytical Services at the University of Guelph.

Statistical Analysis

Analyses of variance were carried out on the data using the Statistical Analysis System (SAS). When the F-test was significant ($P < .05$), the LSD or Duncan's Multiple Range Test was used to compare means.

Field Operations

In Experiments 1.1-1.3 all field operations were performed with commercial farm equipment by the farmer cooperators. Pesticide applications made by the farmer cooperators are expressed as quantity of commercial product applied.

Economic Analysis

A comparison of input costs and yield differences between the control and test treatment was made in Experiments 1.1-1.3. Commodity values were based on average prices cooperating farmers received for their crops. Input and field operation costs were based on prices which the farmer cooperator was comfortable with rather than figures derived by an economist. It was felt that because they base their decisions on these figures, they would be the most accurate in terms of potential for development of the technology.

Weather Conditions

Table 2. Corn Heat Units and Total Precipitation Data from the Elora Research Station

Time Period	Corn Heat Units		Total Precipitation (mm)	
1990		Difference		Difference
May	294	71.3	87.5	9.9
June	589	8.6	84.4	-2.5
July	708	-8.1	60.8	-12.2
August	678	10.2	99.4	27.3
September	418	25.0	67.2	-4.1
October	-		101.4	35.1
November	-		82.6	16.9
Yearly Total	2687	87	899.6	63.7
1991		Difference		Difference
May	394	171	93.6	16.0
June	659	79	26.6	-60.3
July	717	1	140.8	67.8
August	733	65	95.0	22.9
September	439	49	56.6	-14.7
October	-		86.8	20.5
November	-		56.1	-9.6
Yearly Total	2941	341	888.3	52.4

Note: Difference is the amount that Corn Heat Units or total precipitation are above (+) or below (-) the 1951-1980 average value.

III. Experiments

Experiment 1.1 Winter Rye Cover Crop Management Systems

Winter rye has several characteristics which make it suitable for use as a winter cover crop in soybean production systems: it can be planted late, provides excellent weed control, is very winter hardy, grows well at cool temperatures, suppresses weeds, matures early and has a relatively large root system. Several experiments were established to test rye management under different conditions.

Experiment 1.1a) Use of Winter Rye as a Double Crop Forage before Soybeans

One way of giving rye an economic value is to harvest it as a forage prior to soybean planting. Rye has shown potential in increasing total dry matter production when used in a double crop system with corn (Waligorska, 1982; Daynard et al., 1984). However, timing of harvest is important as rye yield increases rapidly after reaching the boot stage while forage quality declines. As well there is a trade-off between planting the main crop on time and increasing the forage yield of the winter cereal. Cereal biomass production is increased approximately 50% by delaying harvest from the flowering to dough stage, while planting the main crop late can result in yield reductions (Twidwell et al., 1985).

Table 3. Summary of Materials and Methods for Experiment 1.1a.

Treatments	
1. Winter rye spring plowed (control) 2. Winter rye harvested as forage and spring plowed (test)	
Statistical Design	
Layout	Side by Side strip comparison
Number of Treatments Number of replications	2 6
General Information	
Cooperator	Larry Bender, Tavistock
Soil Type	Silt Loam
Plot Size	2.1 m x 150 m
Rye seeding rate/date	120 kg/ha / Sept. 15/89
Rye forage harvested	May 28/90
Spring tillage (moldboard plow and secondary cultivation)	May 9 & June 5/90
Soybean seeding rate; date	80 kg/ha in 18 cm rows; June 6/90
Soybeans harvest (4 x 1m^2 quadrat)	October 18/90
Weed biomass (3 x 1 m^2 quadrat)	October 20/90

Results and Discussion

The rye harvested as hay prior to soybean planting yielded 3148 kg/ha. The forage analysis indicated that the rye was low in crude protein and low in digestibility as indicated by the % acid detergent fibre (ADF) (Table 2). The rye was fed as beef cow hay on the farm.

Table 4. Forage Yield and Analysis of Rye Harvested at the Bender Farm

Yield (Dry Matter in kg/ha)	**Moisture** (%)	**Crude Protein** (%)	**Acid Detergent Fibre** (%)	**Net Energy-Lactation**	**Net Energy-Maintenance**	**Net Energy-Gain**
3148	**77.2**	**7.9**	**43.63**	**1.17**	**1.12**	**0.5**

Wet conditions in June and a low soybean population prevented rotary hoeing of the solid seeded soybeans. Hence, the soybeans experienced competition from annual broadleaf weeds such as redroot pigweed and lamb's-quarters. Overall, soybean yields were low due to weed competition and low plant densities. No significant yield differences were observed between treatments. However, weed biomass was significantly lower where the rye was harvested as a forage. Some weeds such as pigweed and lamb's quarters appeared greatly reduced in size. This may have been due to a reduction in available soil nitrogen caused by removing the rye cover crop from the field as forage rather than plowing it in at an early stage. The rye yielded 3148 kg/ha dry matter per hectare and contained 1.26% N. This would amount to approximately 40 kg N/ha removed from the field at rye harvest. The reduced N level may have been the principal factor for the reduced weed growth in this treatment.

One of the advantages the farmer saw of the system was that the rye provided an early forage source which could be used either for hay or early spring pasture. Reducing costs related to producing stored feeds could be a significant advantage of the system if the livestock could be pastured on the rye. As well, rye has been shown to restrict the spread of quack grass which is the most serious weed problem on the Bender farm (Pessala, 1977).

Table 5. Effect of Winter Rye Management on Soybean Yield and Weed Biomass at the Bender Farm

Treatment	**Soybean Yield**	**Weed Biomass**
	(kg/ha at 14% moisture)	Dry Matter (kg/ha)
1. Rye spring plowed (control)	1751 a	1712 a
2. Rye harvested and then spring plowed (test)	1947 a	859 b
C. V.	18%	27%

Means within each column followed by the same letter are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.

Economic Analysis

Harvesting rye as forage provided more net revenue to the farm operator than any potential soybean yield increase associated with this treatment. In the future, the farmer's plans are to use the rye for grazing prior to soybean planting. He has purchased a New Zealand type fencing system which will reduce the costs associated with forage harvesting. Grazing would also reduce the delay in soybean planting that can occur when soybeans are double-cropped after winter rye. Approximately 3-4 days can pass between the time the rye is cut, allowed to dry and removed as baled hay. In the present study, a period of wet weather occurred in the spring of 1990 which delayed seeding of the control plot by 1-2 weeks from the normal seeding date for the area.

Table 6. Economic Evaluation of Rye Management Practices Tested at the Bender Farm

Item	Rye Spring Plowed (control)	Rye Harvested and Spring Plowed (test)
Cost		
Rye harvest (mowing) Rye baling		$20.00/ ha 3148 kg/ha @ $12.50 /tonne= $39.50
Total cost		$59.50/ha
Revenue		
Rye Yield Rye value		3148 kg/ha 3148 @ $35.00/tonne= $110.18/ha
Soybean Yield (kg/ha at 14% moisture)	1751	1947
Yield advantage (kg/ha)		196
Additional soybean value at $230 / tonne		$45.08/ha
Additional Revenue		$155.26/ha

Experiment 1.1b and 1.1c) Use of Winter Rye as a No-till Mulch for Soybean Production

Considerable research has been performed on the use of rye as a no-till mulch in soybean production. In general, soybean yields have not been affected by the use of a rye cover crop. Problems have occurred when soybean germination is poor or when soil fertility levels are low. Modest impacts on yield were observed by Eckert (1988). Over four years he found that rye lowered no-till soybean yields by 105 kg/ha in a corn-soybean sequence and by 126 kg/ha in continuous soybeans. However, some studies have found that rye significantly increases crop yield under conditions of high weed pressure or when the rye is used over longer periods of time (Wruck and Arnold, 1981; Johnson and Webb, 1987).

Rye has little value as a nitrogen source and in the short term offers little potential for increasing yields. Using rye as a no-till mulch to reduce herbicide requirements is one means of giving it an economic value. The rye is killed with a contact herbicide, soybeans are seeded and the field is packed. The rye mulch is effective at keeping weed populations under control if sufficient rye biomass is present on the surface. In experiment 1.1b) this system was compared to a system in which the rye was mowed rather than herbicide- killed. The mow-kill no-till system has been used in other SWEEP studies (Samson et al. 1990) and was developed as a non herbicide option for no-till systems. In Experiment 1.1c) the rye was killed using a herbicide and compared to a conventional no-till soybean system with no rye cover crop.

Experiment 1.1b) Evaluation of Mechanical and Chemical Management of Winter Rye in No-Till Soybeans.

Table 7. Materials and Methods for Experiment 1.1 b

Treatments	
1. Winter rye killed with a contact herbicide (control) 2. Winter rye mow-killed (test)	
Statistical Design	
Layout	Side by side strip comparison
Number of treatments Number of replications	2 6
General Information	
Cooperator	Gary Chipps, Courtland
Soil Type	Sandy loam
Plot Size	4.5 m x 150 m
Rye seeding rate; date	100 kg/ha; November l/ 89
Contact herbicide spraying rate; date	Round-up @ 1 L/ha; May 31 /90
Soybean seeding rate; date	70 kg/ha; June 2
Rye mowing operation	June 4/90
Post emergent herbicide	Poast 1 L/ha + Assist 2 L/ha
Inter-row cultivation	Early July/ 1990
Harvest date (combined by farmer)	October 17/90

Results and Discussion

Rye regrowth occurred in plots which had been mowed and a crabgrass infestation occurred across the entire site. The thin rye mulch appeared to have minimal impact on crabgrass growth. As a result of the weed infestation, the entire plot area was sprayed with a grass herbicide and inter-row cultivated. No significant differences were observed in soybean yields. This may have been due to the broadcast grass herbicide which killed both weeds and rye regrowth. Even with the use of a grass herbicide, the mowed treatment appeared weedy, due mainly to escapes of perennial broadleaf weeds. These appear to be the most significant limitation of the mow-kill system. The farmer cooperator is a no-till farmer and perennial weed pressure is relatively high. Overall the test treatment probably would have provided better results if the rye had produced more spring biomass and if the study was conducted on a farm with no perennial weed pressure.

Table 87. Effect of Rye-kill System on Soybean Yield at the Chipps Farm

Treatment	Yield (kg/ha)
1. Rye herbicide killed (control)	2295 a
2. Rye mow-killed (test)	1899 a
C. V.	30%

Means within each column followed by the same letter are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.

Economic Analysis

The cost of mowing was slightly lower than the cost of applying a low rate of Round-up herbicide. Differences in input costs would probably not be the determining factor for a farmer selecting a rye-kill system. The farmer cooperator suggested that potential yield reductions due to rye regrowth and increased perennial weed pressure would make the system too risky to use at this time.

Table 9. Economic Evaluation of Rye Killing Method at the Chipps Farm.

Item	Rye Herbicide - Killed (control)	Rye Mow-Kill (test)
Cost		
Round-up herbicide (1 L/ha) Herbicide application	$ 12.00/ha $ 13.75/ha	
Rye packing Rye mowing	$ 7.50/ha	 $22.50/ha
Total cost	$ 33.25/ha	$22.5/ha
Revenue		
Soybean yield (kg/ha at 14% moisture) Yield advantage Additional soybean value at $230 / tonne	2295 + 396 kg $ 91.08/ha	1899

Experiment 1.1c) Effect of Cover Crop on No-Till Soybeans at the Smith Farm.

Table 10. Summary of Materials and Methods for Experiment 1.1c

Treatments	
1. No-till soybeans, no cover crop (control) 2. Soybeans no-tilled into winter rye killed with a contact herbicide (test)	
Statistical Design	
Layout	Side by side strip comparison
Number of treatments Number of replications	2 6
General Information	
Cooperator	Doug Smith, Thamesville, Ont.
Soil type	Sandy loam
Plot size	4.5 m x 110 m
Rye seeding rate; date	125 kg/ha (common); October 1/90
Soybean seeding rate; date	NK 1990 at 80 kg/ha; May 23/91
Contact herbicide application rate; date	Round-up (2.5 L/ha) and 2,4-D (1.25 L/ha); May 22/91
Post-emergent herbicide rate	Basagran (2.0 L/ha) + Pinnacle 75 DF (0.011 kg/ha) + Excel (1.36 L/ha)
Harvest (strip combined by farmer)	October 10/91

Results and Discussion

There was no significant effect of the rye cover crop on soybean yield. However the rye resulted in superior weed control (even though both treatments received a comprehensive herbicide program). The main weed escape was nightshade in the bare plots. In a study adjacent to the present one, a 96% reduction in nightshade was identified in rye plots that had not received any residual herbicide (Samson et al., 1992). This was of significant interest to the cooperating farmer as he is currently producing soybeans for human consumption. Their marketability is seriously affected by discolouration by nightshade. The main advantages the farmer cooperator saw of the rye cover crop system were its contribution to long term soil fertility on the farm, moisture conservation and weed control. His main concern was that the rye would dry out the soil before it could be killed.

Table 11. Effect of a Rye Cover Crop on No-Till Soybean Yield at the Smith Farm

Treatments	**Soybean Yield (kg/ha at 14% moisture)**
1. No cover crop (control) 2. Rye cover crop (test)	3213 a 3382 a
C. V.	7.7%

Means within each column followed by the same letter are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.

Economic Analysis

The main difference in production costs was associated with no-till planting the winter rye. The herbicide inputs were included in the analysis to highlight the high cost of herbicides in no-till systems. The input costs of the rye and its seeding were minor compared to those of the herbicides. The farm operator sprayed both treatments with the same herbicide mixture because the rye had produced small amounts of biomass in some areas and having no previous experience with the rye cover crop no-till system, he anticipated serious weed pressure. The weed study adjacent to the present one, indicated that the only weeds which were of any importance in the rye plots were ragweed and pigweed. Rye reduced weed biomass by 80%. Pigweed and ragweed made up approximately 60% of the weed biomass. The weed flora in the bare plots was much more diverse. Instead of using a broad spectrum, post emergent herbicide mixture for weed control on the rye plots, probably Pinnacle (rated excellent for pigweed and fair for ragweed) alone would have provided adequate post-emergent weed control. This would have reduced post emergent herbicide costs by approximately two-thirds and resulted in a more favourable economic analysis for the rye mulch, no-till system. The cooperator believed post emergent cultivation would be a promising alternative to post emergent herbicide for weed control when using the rye cover crop system if the soybeans are row planted.

Table 12. Economic Evaluation of Rye Cover Crop Use in No-Till Soybeans at the Smith Farm

Item	**No Cover Crop (control)**	**Rye Cover Crop (test)**
Cost		
Seed		125 kg/ha @ $100.00/tonne = $12.50
Seeding		$ 30.00/ha
Contact herbicide	$ 31.45/ha	$ 31.45/ha
Contact herbicide application	$ 10.00/ha	$ 10.00/ha
Post emergent herbicide	$ 80.00/ha	$ 80.00/ha
Post emergent herbicide application	$ 10.00/ha	$ 10.00/ha
Total cost	$131.45/ha	$ 173.95/ha
Revenue		
Soybean yield (kg/ha at 14% moisture)	3213	3382
Yield difference (kg/ha)		+ 169 kg
Additional soybean value at $230/tonne		$ 38.87/ha

General Discussion

Of the three rye test systems evaluated, rye harvested as forage was the only one to provide a higher return than the control treatment. In a review on the use of cover crops in integrated crop-livestock systems, Gardner and Faulkner (1991) contend that the successful implementation of a cover crop, unless mandated or subsidized, may only come when the cover crop is an integral component and has immediate economic value to the farmer. They suggest that the integration of livestock production systems with cover crop systems can result in profitable, environmentally sound, and biologically efficient systems for farmers who invest the time and management necessary to make them successful. Using rye as a winter cover crop before soybeans on a livestock farm can affect income in several ways: by reducing weed pressure and/or weed control requirements, and by acting as a supplementary forage thereby increasing livestock feed availability.

Experiment 1.2 Winter Wheat Legume Interseeding and Catch Crop Systems for Corn

Introduction

Red clover interseeded in cereals can provide large quantities of fall biomass and supply much of the N required by corn (Norris, 1981; Bruulsema and Christie, 1987). One of the major problems with clover is that it is susceptible to drought. Another possible limitation is that nitrogen from red clover may not be readily available to corn grown in no-till systems, as shown in a preliminary study by Ngalla and Eckert (1987).

Hairy vetch is a rapidly growing winter annual that can fix large amounts of N. Due to its low lignin content, fine stem and leaves, it decomposes more rapidly than other cover crop species (Wagger, 1987). This characteristic makes it an excellent candidate for use in conservation tillage systems. Several studies in Ontario have shown hairy vetch to produce high corn yields and to surpass other legumes in nitrogen production (Maitland and Christie, 1989; Samson et al., 1990). Establishing winter annual legumes by drilling when the wheat is at the early boot stage has proven to be an effective establishment method (Janke et al. 1987; Samson et al., 1990). However, the wheat crop must be sufficiently competitive in order to prevent the hairy vetch from climbing into the wheat heads.

Table 13. Materials and Methods for Experiment 1.2.

Treatments 1. Red clover frost seeded into winter wheat (control) 2. Hairy vetch drill-seeded into winter wheat in mid-May (test)	
Statistical Design	
Layout Number of treatments Number of replications	Side by side strip comparison 2 6
General Information	
Cooperator	Harry Wilhelm, Tavistock
Soil type	Silt loam
Plot size	7.4 m x 300 m
Red clover seeding rate; date	9 kg/ha; March 20/90
Hairy vetch seeding rate; date	28 kg/ha; May 8/90
Wheat fertilization rate; date	70 kg/ha; May 8/90
Wheat harvest	July 28/90
Cover crop biomass	October 17/90; Ix 1 m^2quadrat/plot
Tillage operation	Moldboard Plow; May 4/91
Corn seeding date	May 14/91
Corn variety; seeding rate	Pioneer 3790; 74,000 seeds/ha
Fertilization	No starter or sidedress
Weed control	Atrazine (2 kg/ha) in a 15 cm. band at planting + 1 rotary hoeing and 2 row crop cultivations
Corn harvest	2 centre rows x field length; Oct. 31/91

Results and Discussion

Both the hairy vetch and red clover cover crops established well in the relatively wet year of 1990. The abundant rainfall in 1990 appeared to be favourable for red clover growth. In drier years, such as 1988 and 1989, red clover produced only half as much biomass as hairy vetch on a silt loam study site (Samson et al., 1990).

Table 14. Biomass and N Production from Cover Crops at the Wilhelm Farm

Cover Crop	**Dry Matter (kg/ha)**	**Estimated *** % N	**N Production (kg/ha)**
1. Red clover	3620 a	3.2%	116
2. Hairy vetch	3452 a	4.3%	148
C.V.	13.5%		

Means within each column followed by the same letter are not significantly different at the 0.05 level according to Duncan's Multiple Range Test.
* estimated from previous studies at the Wilhelm farm (Samson et al., 1990)

Corn Yield

Corn planted on the hairy vetch and red clover strips produced relatively high yields with no additional fertilizer. Yields were very similar with no significant differences being detected when analyzed over the 6 replications. Moisture levels were low at harvest and were not affected by cover crop treatment.

Table 15. Effect of Hairy Vetch and Red Clover on Corn Yield at the Wilhelm Farm.

Cover Crop	Harvest Moisture	Corn Yield (kg/ha at 15.5% moisture)
1. Red clover	20.3%	9421
2. Hairy vetch	20.5%	9101
		LSD $_{0.05}$=929 kg/ha

Economic Analysis

Table 16. Differences in Management Practices between Red Clover and Hairy Vetch Cover Crops at the Wilhelm Farm.

Item	Red Clover	Hairy Vetch
Costs		
Seed cost	9 kg/ha @ $2.20 = $19.80/ha	28 kg/ha @ $1.10/ kg = $30.80/ha
Seeding	$ 20.00/ha	$ 20.00/ha
N fertilization of wheat	$ 20.00/ha	$ 0 (performed at the same time as vetch drilling)
Total cost	$ 59.80/ha	$ 50.80/ha
Revenue		
Corn yield (kg/ha at 15.5% moisture)	9421	9101
Yield difference (kg/ha)	+ 320 kg	
Additional Corn Value at $ 100 / tonne	$ 32.00/ha	

The difference between the two systems will likely vary between the individual farm costs, soil type and season the systems are used on. There was no significant difference in yield between the two treatments over the 6 replications, so including a yield advantage of red clover over the hairy vetch is not entirely accurate. Essentially the production costs of the two systems were similar and the yield differences negligible. As well the study was conducted only over one year. In previous studies at the same farm in 1988 and 1989, the red clover produced only 1/2 as much fall biomass as the hairy vetch (Samson et al., 1990). In the present study, conditions were very wet. The wet summer and fall of 1990 appeared to favour red clover development. The warm wet winter of 1990-91 may have contributed to larger than expected losses of nitrogen from the winter killed hairy vetch (most likely due to denitrification). In the previously mentioned study, high biomass production from hairy vetch at the Wilhelm farm supported high corn yields without additional fertilizer nitrogen.

The economics of the systems can change depending on the availability of time, equipment and management skills. For example, Harry Wilhelm does not own a three point hitch spreader or broadcast fertilizer wagon which would have reduced the cost of applying the red clover and the N fertilizer to the wheat in the red clover plot. In many cases the decision to implement a system is based not so much on economics but rather on other factors. For example, Harry Wilhelm prefers seeding the hairy vetch and applying fertilizer to the wheat in early May because temperatures are warmer. Frost seeding red clover in March or April is a cold job. As well, broadcasting nitrogen in wheat early in the season can cause soil compaction if the ground is not frozen or dry, leaving ruts at harvest time. Also, Mr. Wilhelm applies his nitrogen at a later stage with the hairy vetch seed which he believes minimizes his fertilizer costs compared to applying it in advance of crop requirements. Harry Wilhelm also grows hairy vetch seed and sells the seed for approximately $1.10/kg at the farm gate. Red clover is purchased off the farm from areas in which seed production is more reliable. Hairy vetch contains few weed seeds, unlike red clover which can be contaminated. As well, hairy vetch acts as an excellent rotation crop for the farm which has a large percentage of row crops (corn, white beans and soybeans).

Other farmers may find that the vetch drilling system adds another activity in early May when most farmers are at their peak work load of the year. As well, some farmers who have tried the vetch drilling system in wheat claim it to be too risky as the vetch can climb up into the heads if the wheat crop is not competitive. For Harry Wilhelm this is not a problem because he swaths his wheat before combining and generally grows productive crops.

As of the spring of 1992, Harry Wilhelm plans to continue to use hairy vetch in a wheat-corn sequence. Half the wheat crop will be drilled with vetch in mid-May and the remaining acreage seeded to hairy vetch immediately after wheat harvest. The hairy vetch will be allowed to overwinter and spring plowed in mid-May immediately prior to corn planting.

Experiment 1.3. Oilseed Radish Catch Crop Studies

In Northern Europe, oilseed radish is a popular brassica species used as a fall catch crop following winter cereals. Numerous European studies have been performed on this species and other brassicas such as white mustard (*Sinapsis alba*).Advantages of their use include: improvements in aggregate stability, nutrient cycling, weed control and their positive effect on cereal yields (Hansen and Rasmussen, 1979; Stokholm 1979; Kundler et al., 1985; and Derpsch et al., 1986). A major reason for the widespread use of brassica catch crops in Europe is that they are effective at reducing nitrate leaching (Hansen and Rasmussen, 1979).

Oilseed radish is best suited to livestock farming systems because of the availability of manure. Oilseed radish does not perform well if grown under N deficient conditions. It is best used after winter cereals as they produce little regrowth and are harvested early. Seeding should take place before September 1 or biomass production will be low. Oilseed radish was tested on two farms, one using solid manure (Rivers farm) as a nutrient source and a second using liquid manure (Van Dorp farm).

Results and Discussion

Oilseed radish biomass

In the fall of 1990, higher quantities of oilseed radish biomass were produced at the Van Dorp farm than at the Rivers farm. Lower biomass production at the Rivers farm was attributed to several factors: a later seeding date, the solid manure appeared to have a lower N availability than the liquid manure and a severe quack grass infestation appeared to inhibit oilseed radish growth.

Table 17. Oilseed Radish Biomass Production at the Van Dorp and Rivers Farm in the Fall of 1990.

	Van Dorp Farm	Rivers Farm
Biomass Yield (kg/ha)	3678	2481
Standard deviation	551	503

Table 18. Materials and Methods for Experiment 1.3.

Treatments 1. Manure incorporated (control) 2. Manure incorporated & oilseed radish catch crop seeded (test)		
Statistical Design Layout Side by side strip comparison		
Number of treatments 2 Number of replications 6 **General Information**		
Cooperators	George and John Van Dorp, Woodstock	Kevin Rivers, Beachville
Soil type	Sandy loam	Sandy loam
Plot size	3.3 m x 150 m	4.1 m x 200 m
Manure application rate; date	50,000 L/ha liquid swine manure; Aug. 10/90	25 t/ha solid swine manure; Aug. 18/90
Catch crop seeding rate; date	17 kg/ha; Aug. 20/90	17 kg/ha; Aug. 23/90
Seeding method	Drilled	Drilled
Cover Crop Biomass (1 x 1 m^2 quadrat/ plot)	Oct. 29/90	Oct. 29/90
Tillage Operations	Disking after manure application and in spring, Aer-way pass at corn planting	Chisel plowing and disking after manure application, one cultivation before planting, oil radish plots harrowed after seeding
Corn variety, seeding rate; date	Pioneer 3737; 77,000 seeds/ha (.51 m wide rows); May 13/91	Pioneer 3902; 70,000 seeds/ha (.92 m wide rows); May 11 /91
Contact herbicide rate; date	Round-up @ 1.4 L/ha; May 4/91	Round-up @ 2.5 L/ha; April 24/91
Starter Fertilizer	33 L/ha of liquid fish, 0.28 L/ha of seaweed extract and 2.8 l/ha corn sugar	110 kg/ha 6-24-24 at planting
Side-Dress Fertilizer (control plots only)	60 kg N/ha applied as 28% solution, 4.5 L/ha liquid Ca, and 2.8 L/ha corn sugar	No additional fertilizer applied to control
Residual Weed Control	Metolachlor @ 1.25 L/ha and Banvel @ .62 L/ha at planting	Banvel @ 0.62 L/ha; May 22/91 + 2 inter-row cultivations in June
Corn Harvest	October 16/91; 7 row strip combined by farmer	October 16/91; 4 row strip combined by farmer

Corn Yield

At the Van Dorp farm, no significant differences were identified in corn yield between the two test treatments. The control treatment received 60 kg N/ha in the form of a side dressed 28% solution which probably was responsible for the lack of significant yield differences. In the fertility study, conducted on subplots (Experiment 2.2), yields in control plots were significantly increased by fertilization while no N response was observed on the oilseed radish catch cropped treatment.

At the Rivers farm, yields were significantly increased when oilseed radish was used as a catch crop. The effect was probably due to improved weed control (particularly of annual grass weeds) and better plant populations. Fertility was not a factor, as in the subplots no significant N effects were detected in soil N or in corn ear leaf N.

Table 19. Effect of Oilseed Radish on Corn Yield at the Van Dorp Farm

Cover Crop	Harvest Moisture	Corn Yield (kg/ha at 15.5% moisture)
1. *Control	23.2 %	8186
2. Oilseed radish	22.9%	8400
		LSD $_{0.05}$=516 kg/ha

* Control treatment received an additional 60 kg/ha N side dressed as 28% solution.

Table 20. Effect of Oilseed Radish on Corn Yield at the Rivers Farm.

Cover Crop	Harvest Moisture	Corn Yield (kg/ha at 15.5% moisture)
1. *Control	18.7 %	6497
2. Oilseed radish	18.7 %	7670
		LSD $_{0.05}$=515 kg/ha

* Control treatment received no additional fertilizer than the solid manure and 110 kg/ha 6-26-26 starter at planting.

Economic Analysis

At both farms the oilseed radish provided an economic advantage. At the Van Dorp farm this was primarily due to lower production costs (with the elimination of the N sidedress operation). At the Rivers farm increased returns were primarily due to increased yields associated with the oilseed radish treatment. Even lower production costs might have been achieved at the Van Dorp farm by eliminating the spring Round-up application on the oilseed radish plots (approximately $25-30/ha). The quack grass level was greatly reduced in the oilseed radish strips but Round-up was applied to the entire plot area because the sprayer was not set up to spray only the control.

Table 21. Economic Evaluation of Oilseed Radish as a Catch Crop at the Van Dorp Farm.

Item	No Catch Crop (control)	Oilseed Radish Catch Crop (test)
Cost		
Seed cost		17 kg/ha @ $1.43/kg =$24.31/ha
Seeding		$ 20.00/ha
Sidedress fertilizer	$54.83/ha	-
N Sidedress application	$12.50/ha	-
Total cost	$67.33/ha	$ 44.31 /ha
Revenue		
Corn yield (kg/ha at 15.5% moisture)	8186	8400
Yield difference (kg/ha)		+214 kg
Additional Corn Value at $ 100 / tonne		$ 21.40/ha

Table 22. Economic Evaluation of Oilseed Radish as a Catch Crop at the Rivers Farm.

Item	No Catch Crop (control)	Oilseed Radish Catch Crop (test)
Costs		
Seed cost		17 kg/ha @ $1.43/kg =$24.31/ha
Seeding		$ 20.00/ha
Harrowing		$ 12.50/ha
Total cost		$ 56.8 L/ha
Revenue		
Corn yield (kg/ha at 15.5% moisture)	6497	7670
Yield difference (kg/ha)		+ 1173 kg
Additional corn value at $ 100 / tonne		$ 117.30/ha

Experiment 2. Evaluation of the N contribution of Cover Crops for Corn using a Nitrogen Soil Test

In the 1980's, the N soil test was developed in the Northeastern United States for assessing nitrogen availability for corn (Magdoff et al., 1984). The test involves sampling the surface 30 cm of soil during the early part of the growing season. In the Northeastern United States soil samples are collected when corn plants are 15-30 cm tall (measured from the ground to the centre of the whorl). Late-spring sampling is late enough to reflect the effects of spring weather conditions and early enough to allow additional N application if needed. The Nitrate-N (NO_3-N) present at that time is correlated with the probability of obtaining a yield increase using side dressed nitrogen fertilizer. Numerous optimal ranges of NO_3-N for corn production have been published including: 23-26 ppm in Iowa (Binford et al. 1990), 20-30 ppm in Vermont (Magdoff et al., 1990) and 21-25 ppm in Pennsylvania (Fox et aL, 1989). In general, the best use of the test has been for identifying non-responsive sites rather than predicting N-fertilizer rates.

One of the concerns over the N soil test is that it underestimates N release from organic N forms such as manures or cover crops. Iowa State University (Blackmer et al., 1991) considers that soil NO_3-N between 21-26 ppm as optimal for conventionally fertilized fields but corn fields having received manure should not be expected to respond to N fertilization when NO_3 concentrations are greater than 21 ppm. El-Hout and Blackmer (1990) tested the N soil test on 29 first-year corn fields following alfalfa and found the nitrogen soil test valuable in identifying sites with excess N. A critical level of 21 ppm was identified in the study. However, little information exists on the use of the N soil test with spring incorporated cover crop systems or fields receiving both manure and cover crops. The following studies were conducted to follow NO_3 and ammonia (NH_4) levels in the spring in order to identify biweekly N transformations in the soil and to determine if the N soil test was useful in predicting a response to N fertilizer. Legume cover crops were studied at two sites and oilseed radish catch crops at two sites. One of the sandy loam legume sites was not included in the final report as the site was subjected to a severe drought.

Experiment 2.1. Use of the N soil test in Red Clover and Hairy Vetch Cover Crops

Results and Discussion

Following spring incorporation of the cover crops on May 4, 1991 much of the nitrogen was in the NH_4 form (May 18 sampling). By May 31, the red clover had significantly higher NO_3 levels than the hairy vetch in the top 30 cm of the soil. By June 14, corn was at the correct stage (ie. 15-30 cm height) for sampling according to the N soil test. Sampling was performed at 0-30 and 30-60 cm soil depths because it was believed that the hairy vetch plots might have experienced more N movement downward as the vetch did not overwinter. In the surface 0-30 cm of soil, the red clover plots had reached NO_3-N levels of 23 ppm while the vetch had levels of 15.5 ppm NO_3-N. At the lower sampling depth the red clover and vetch both had relatively low soil NO_3-N levels of 6.2 and 6.6 ppm NO_3-N respectively.

Table 23. Materials and Methods for Experiment 2.1

Main Plot Treatments	1. Red clover frost seeded into winter wheat (control) 2. Hairy vetch drill-seeded into winter wheat in mid-May (test)
Sub Plot Treatments	1. 0 kg N/ha 2. 40 kg N/ha 3. 80 kg N/ha
Statistical Design	
Layout	Side by side strip comparison with fertility treatments distributed randomly within each main plot
Number of treatments Number of replications	2 main plots x 3 sub plots = 6 treatments 4
General Information	
Sub plot size Fertilization Corn planting date Fertilization date	7.4 m x 10 m Ammonia nitrate (0, 40 and 80 kg/ha) May 14/91 May 16/91
N soil test sampling	May 18, May 31, and June 14/91; 0-30 cm soil depth, 10 cores/plot on unfertilized plots)
Ear leaf N sampling	20 leaves /plot, mid 1/3rd of leaf at corn silking
Corn harvest (hand harvest)	Two centre rows x 5 m lengths

Table 24. Effect of Sampling Date and Cover Crop on Soil N at the Wilhelm Farm.

Sampling Date	Cover Crop	NH4-N (mg/kg)	NO_3-N (mg/kg)
May 18 (0-30 cm sampling depth)	Red clover Hairy vetch	6.19 a 4.70 b	9.35 9.83
May 31 (0-30 cm sampling depth)	Red clover Hairy vetch	0.66 0.90	18.48 a 13.00 b
June 14 (0-30 cm sampling depth)	Red clover Hairy vetch	2.26 2.74	23.24 a 15.51 b
June 14 (30-60 cm sampling depth)	Red clover Hairy vetch	1.80 2.06	6.21 6.61

When ear leaf N levels were measured at corn silking, no significant differences were detected between cover crops or N fertilization levels. Corn grain yields showed significant response to N fertilizer. However, corn grain yields were not significantly different between cover crop treatments. Soil N data and corn grain yields at the lower N fertilization levels indicated that red clover provided more N than hairy vetch. However, red clover plots responded to N even when the soil N test was over the 21 ppm level (the level suggested by Blackmer when dealing with organic N forms). One possible reason for the N response was that the high NO_3-N was concentrated in the top 30 cm of soil. Soil NO_3-N levels were relatively low (6 ppm) at a depth of 30-60 cm. As well, the corn yield of 11 t/ha was high for the region. This may have created a larger than normal requirement for soil N.

Table 25. Effect of N Fertilizer and Legume Cover Crops on Corn Yields at the Wilhelm Farm

Fertility Treatment	**Corn Yield (kg/ha at 15.5% Moisture)**		
	Red Clover	**Hairy Vetch**	**Average Across Cover Crops**
1. 0 kg N/ha	9,798	9,177	9,487 b
2. 40 kg N/ha	10,878	10,219	10,550 a
3. 80 kg N/ha	11,029	11,204	11,115a
	LSD $_{0.05}$ =835 kg/ha		LSD $_{0.05}$ =592 kg/ha
Average	10,568	10,200	10,384

Table 26. Effect of Cover Crop and N Fertilization Rate on Corn Ear Leaf N at the Wilhelm Farm.

Fertility Treatment	**Red Clover (%N)**	**Hairy Vetch** (%N)
1. 0 kg N/ha	3.35	3.13
2. 40 kg N/ha	3.29	3.23
3. 80 kg N/ha	3.40	3.22
	LSD $_{0.05}$ = 0.36	
Average	3.34	3.20

Experiment 2.2 Evaluation of the N Soil Test on Oilseed Radish and Manure Fertilized Corn

Table 27. Materials and Methods for Experiment 2.2.

Main Plot Treatments	1. Control 2. Oilseed Radish	
Sub-Plot Treatments	1. 0 kg N/ha 2. 40 kg N/ha 3. 80 kg N/ha	
Statistical Design		
Layout	Side by side strip comparison with fertility treatments randomly distributed within each main plot	
Number of treatments Number of replications	2 main plots x 3 sub plots = 6 4	
General Information	Van Dorp Farm	Rivers Farm
Soil type	Sandy Loam	Sandy Loam
Sub plot size	3.3 m x 10 m	4.1 m x 10 m
Corn Planting	May 13/91	May 11 /91
Fertilization	Ammonia nitrate (0, 40 and 80 kg N /ha)	Ammonia nitrate (0, 40 and 80 kg N /ha)
Fertilization date	May 25/91	May 25/91
N soil test sampling: 0-30 cm soil depth (10 cores / plot on unfertilized plots)	May 6, May 28, and June 10/91	May 11, May 28, and June 10/91
Ear leaf N sampling	20 leaves /plot, mid 1/3rd of leaf at corn silking	20 leaves /plot, mid 1/3rd of leaf at corn silking
Corn harvest	Three centre rows x 5 m lengths	Two centre rows x 5 m lengths

Results and Discussion of the Van Dorp Farm Experiment

At all sampling dates the oilseed radish catch cropped plot had higher soil NO_3-N levels than the control plot. Soil NO_3-N increased most dramatically in the control plot from 8 ppm on May 6 to 23 ppm approximately 1 month after planting (June 10). At the time the soil was sampled for the N test, the control and oilseed radish plots were both above the critical 21 ppm level. In the control, ear leaf N and corn yields both showed a significant response to N fertilizer. The oilseed catch crop treatment showed no significant response to N fertilization. On both treatments, ear leaf N levels at the higher N fertilization rates exceeded 3.5%. This is the upper limit of what is considered normal N concentration in corn.

Table 28. Effect of Sampling Date and Cover Crop on Soil N at the Van Dorp Farm.

Sampling Date	Cover Crop	NH4-N (mg/kg)	NO_3-N (mg/kg)
May 6	Control	2.99	8.18 b
	Oilseed radish	3.04	17.78 a
May 28	Control	5.27	16.08 b
	Oilseed radish	5.33	22.81 a
June 10	Control	3.36	23.10 b
	Oilseed radish	2.57	27.81 a

Table 29. Effect of N Fertilizer and Oilseed Radish Catch Crop on Corn Yields at the Van Dorp Farm.

Nitrogen Treatment	Corn Yield (kg/ha at 15.5% Moisture)		
	Control	Oilseed Radish	Average Across Treatments
1. 0 kg N/ha	8009	9120	8564
2. 40 kg N/ha	8455	9397	8923
3. 80 kg N/ha	9478	9353	9412
		$LSD_{0.05}$ =1381 kg/ha	$LSD_{0.05}$ = 847 kg/ha
Average	8646	9287	

Table 30. Effect of Cover Crop and N Fertilization Rate on Corn Ear Leaf N % at the Van Dom Farm.

Nitrogen Treatment	Control (%N)	Oilseed Radish (%N)
1. 0 kg N/ha	3.27	3.57
2. 40 kg N/ha	3.56	3.63
3. 80 kg N/ha	3.65	3.69
	$LSD_{0.05}$ =0.22	
Average	3.49	3.63

Results and Discussion of the Rivers Farm Experiment

At the Rivers farm, oilseed radish had no effect on soil N levels in the spring. This was not entirely surprising as the solid manure used had a significant amount of straw in it. The oilseed radish biomass production in the fall of 1990 was approximately one third lower than at the Van Dorp farm (Table 18). As well there was significant quack grass growth on this site in the fall which may have affected soil N levels. As was the case at the other two sites, soil NO_3-N levels changed rapidly in the spring period reaching a peak of approximately 20 ppm in both treatments when the corn was 15-30 cm tall. Corn yield and ear leaf N showed a significant response to N on both treatments. Corn yields and soil N levels were almost identical between cover crop treatments when averaged over fertilization levels and sampling dates respectively.

Corn populations in the trial seemed to be affected by both cover crop treatment and N fertilization. With only one spring cultivation performed before corn seeding, the oilseed radish provided a better seedbed and probably resulted in the improved plant stand. Increased N fertilization may have caused additional early weed pressure which reduced plant stand.

Table 31. Effect of Sampling Date and Cover Cron on Soil N at the Rivers Farm.

Sampling Date	Cover Crop	NH_4-N (mg/kg)	NO_3-N (mg/kg)
May 11	Control	5.25	4.55
	Oilseed radish	6.84	5.94
May 28	Control	4.77	16.75
	Oilseed radish	4.88	16.43
June 10	Control	4.05	19.73
	Oilseed radish	3.11	19.95

Table 32. Effect of Cover Crop and N Fertilization on Corn Population at the Rivers Farm

Cover Crop Treatment (main plot)	Corn Population (plants/ha)
1. Control	61,152 b
2. Oilseed radish	63,746 a
Nitrogen Treatment (kg/ha)	
1. 0	65,178 a
2. 40	61,503 ab
3. 80	60,671 b

Table 33. Effect of N Fertilizer and Oilseed Radish Catch Crop on Corn Yields at the Rivers Farm.

Nitrogen Treatment (kg/ha)	Corn Yield (kg/ha at 15.5% Moisture)		
	Control	Oilseed Radish	Average Across Treatments
1. 0	8091	8524	8306
2. 40	8782	8926	8851
3. 80	9528	8926	9227
	$LSD_{0.05}$ = 954 kg/ha		$LSD_{0.05}$ = 586 kg/ha
Average	8798	8792	

Table 34. Effect of Cover Crop and N Fertilization Rate on Corn Ear Leaf N at the Rivers Farm in 1991.

Nitrogen Treatment (kg/ha)	**Control (%N)**	**Oilseed Radish** (%N)
1. 0	3.06	3.12
2. 40	3.22	3.25
3. 80	3.32	3.56
	$LSD_{0.05}$ =0.21	
Average	3.20	3.31

Concluding Discussion

Biweekly sampling for soil NO_3-N indicated that soil N transformations occurred rapidly during the spring. This underscores the need to sample as late as possible in order not to underestimate soil N supply. From the literature, a soil NO_3-N level of approximately 21 ppm has been cited as being the critical N level above which a N fertilizer response is not expected. In this study, two of the three study sites reached soil NO_3-N values of 23 ppm and yet fertility treatments showed significant yield responses. Based on the limited number of sites used in this study, a value of 25 ppm NO_3-N appeared to be a better indicator of fertilizer N response. No fertilizer N response was observed on the site which had received liquid manure and had been catch cropped to oilseed radish the previous fall. The catch crop increased soil N test levels on the farm in which liquid manure was used as a N source, but had no effect on N conservation on the farm in which a straw based solid manure was used. The N soil test appears to be a valuable tool in providing a better understanding of N dynamics in the soil. In the long run it may provide savings in N fertilizer by predicting not only when N is in excess supply, but by using it as a tool in developing farming practices which manage more effectively the biological N cycle on farms.

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V. Appendix of Operations

Experiment 1.2 Wilhelm Farm

Treatments: Test 1: spring drilled red clover into previous year winter wheat crop left to over-winter and then spring plowed to prepare a seedbed for corn on which no supplemental nitrogen was applied.

Test 2: Spring-drilled hairy vetch into previous year winter wheat left to over-winter and then spring-plowed to prepare a seedbed for corn on which no supplemental nitrogen was applied.

Land Preparation

Cover Crops: No separate land preparation was done for either cover crop.
Main Crop (corn): The entire test site was plowed May 4, 1991 using a 90 hp two-wheel drive I-H model tractor pulling a 4 x 16" bottom plow at 6 mph. The same 90 hp tractor was used to disk at 5.5 mph using a 16' wide implement, twice over shallowly, to prepare the seedbed.

Planting

Cover Crops: The red clover was spring drilled into the previously established winter wheat crop in March, 1990 using a 27 hp international tractor with a 9' double disc opener grain drill @ 5 mph. The hairy vetch was drilled into the winter wheat May 8, 1990 using the 27 hp I-H model 200 pulling a 9' double disk opener grain drill at a working speed of 5 mph. The winter wheat was fertilized with 70 kg N (actual) applied as urea in the same operation. The red clover plots required a separate operation for nitrogen fertilization with the grain drill at this time using the same working speed.
Main Crop (corn): The corn was planted May 14, 1991 using the 27 hp tractor to pull the 4 x 36" row I-H plate planter at 3.5 mph. Herbicide was band sprayed over each row concurrently to the planting operation.

Weed Control

There was no separate operation for chemical weed control in either the cover crops or the corn crop. Mechanical weed control operations were not used in the cover crops but were the main line of defense in the corn crop. A single rotary hoe operation just prior to corn emergence was carried out at 8 mph and 12' working width using a 70 hp 2-wheel drive I-H tractor. The entire test area also received two inter-row cultivations in June 1991 using a 27 hp I-H tractor. The working width is 6' and the working speed was 4.5 mph for the first pass and 5.25 mph for the second pass three weeks later.

Harvest

The entire area was combined on October 30 and 31, 1991 using a two row tractor mounted picker sheller (I-H model 234 mounted on the 70 hp tractor and capitalized at $1200). The working speed of 5 mph translated into a harvest rate of 1 acre per hr by the time unloading was factored in. The 27 hp tractor was also required to lift the grain from the harvest tractor drawn gravity wagon into the 10 tonne truck used to haul grain to market.

Experiment 1.3 Van Dorp Farm

Pesticides

Half rate of glyphosate (.561/ acre) at $12.80/L totaling $7.20 acre was applied over the entire test area May 4, 1991 as a preplant burndown to control quack grass (primarily on the control plots). An 85 hp white tractor was used along with a 500 US gallon sprayer with a 43 ' boom for the glyphosate application. The operation was performed at 5 mph with the spray solution being applied at 50 psi and 14 US gallons per acre. A pre-emergent half rate of metolachlor (.5 L/acre and dicamba (.25 L/acre) was applied with the planter. The per litre costs were $18.50 and $22.80 respectively for metolachlor and dicamba. This resulted in a per acre cost of $ 14.95 for these products.

Land Preparation and Fertilisation

Manure was applied uniformly across all the plots at a rate of 4000 U.S. gallons/ acre using a 110 hp 2-WD White tractor at a working rate of 2.5 acres/hour using a 3000 gallon liquid "honey wagon" after the wheat harvest. The manure spreader rented for $ 1.00 acre. The manure contained 1 gallon of molasses (at $1.49 per US gallon) for each 1000 gallons of manure. After the manure application, a disking operation was performed using a 110 hp tractor pulling a 19' wide disk at 5 mph with an 80% field efficiency. In the fall of 1990, 500 lb. per acre of gypsum was applied to the field using a 110 hp with 12 acres per hour being fertilized. The gypsum material cost was $9.55/acre. A spreader rental charge of $3.00 per acre was also incurred. The starter fertilizer used for corn contained 3 gallons/acre of liquid fish, 4 oz./acre of seaweed extract and 1 quart of corn sugar which had a per acre cost of $ 10.95, $ 1.96 and $ 0.95 respectively. The total cost for the starter fertilizer was $ 13.86/ acre. The sidedress fertilizer used on the control plots consisted of 19 gallons per acre of liquid urea (28-0-0-2S), 1 gallon of liquid calcium and 1 quart of corn sugar which had a per acre cost of $ 18.05, $ 3.20 and $ 0.95 respectively. The total cost for the sidedress fertilizer was $ 22.20/ acre. The foliar fertilizer consisted of 1 quart/acre of liquid calcium, 1 quart per acre of liquid fish, 1 quart per acre of corn sugar and 4 oz of seaweed extract which had a per acre cost of $ 0.80, $ 0.93, $ 0.95 and $ 1.96 respectively. The total cost of the foliar fertilizer was $ 3.84/ acre.

Planting

Cover Crops: The oilseed radish was drilled into the test strips with a 9' single disk opener drill using a 28 hp 4-WD White tractor. The control strips were left undisturbed.
Main Crop (corn): The corn was planted in conjunction with an Aerway operation using the 85 hp White tractor. The double frame New Idea-Kinze finger unit planter plants 7 x 20" rows at a time at an average operating speed of 4 mph. The intended corn planting population was 31,000 seeds/acre but a final stand of only 26,200 was achieved. A planter mounted spray boom facilitated the pre-emergent application of herbicide at the time of planting.

Nitrogen sidedress

On June 10, 1991 the 85 hp tractor was used to sidedress 20 gallons per acre of 28% solution using a 3 point hitch mounted tool bar applicator (control plots only). The working speed was 10 mph on 7 rows (11.67 ft) at a time.

Foliar Fertilization

On June 16, 1991 a foliar spray was applied over the entire experimental site using an air blast 3 point hitch mounted sprayer and the 85 hp tractor. Working speed was 5 mph and working width is approximately 200'. Each tank of 55 US gallons covers approximately 25 acres.

Harvest

The field was harvested Oct. 16, 1991 using a 7-row John Deere model 7720, 140 hp diesel combine. Working speed was 3 mph.

Experiment 1.3 Rivers Farm

Seed

Oilseed radish was seeded at 15 lb/acre at a cost of 65 cents/lb or $9.75/acre. The corn was seeded at 27,500 seeds per acre at a cost of $93.60/ 80,000 seeds or $32.18/acre.

Pesticide

Round-up was sprayed across the site on April 24, 1991 to kill a serious quack grass infestation that was throughout the study site. The cost of the chemical was $13.25/L or $13.25/ acre. Banvel was sprayed post-emergent on the study site at a rate of .25 L/acre on May 22, 1991. The cost of the herbicide was $23.25 /litre or $ 5.78/acre.

Weed Control Operations

Both the individual herbicide operations were done using the 45 hp tractor pulling a sprayer at 5 mph with a 30' spray width. Total spray volume was approximately 20 US gallons per acre and one tank does about 15 acres. The entire test area also received a double inter-row cultivation in June. The 45 hp John Deere tractor was used on a 4 row cultivator at a working speed of 4-5 mph.

Fertilizer

Semi composted solid hog manure was applied at rate of approximately 25 tonne/acre across the study site after wheat harvest. A starter fertilizer of 6-24-24 was applied at rate of 100 lb/acre at the time of planting to both treatments.

Land preparation

Manure was applied uniformly across all treatments using a 45 hp 2-wheel drive tractor and 120 bushel spreader. The test area of 3.0 acres received 34 loads taking 20 minutes per load. The entire test area was chisel plowed following the manure application using a 90 hp 4 wheel drive 285 White pulling a 5' wide implement. The chisel plow (3 shanks with 18 " sweeps) was pulled at a working speed of 4.5 mph. The same 90 hp tractor was used to disk at 4.5 mph using 1 12' wide implement once over followed by a single pass cultivation at 4 mph and 18.5' working width. After the oilseed radish seeding, additional harrowing was used to better cover the seeds (oilseed radish plots only). Working speed was 6-7 mph using the 45 hp tractor and 1 12' wide harrow. In the spring, the entire plot area was only cultivated once prior to corn planting. The cultivator had a working width of 18.5' and was pulled by the 90 hp tractor at a speed of 4 mph.

Planting

Cover Crop: The oilseed radish was drilled August 23, 1990 using a 45 hp tractor pulling a 10' wide single disk opener drill at 5 mph.

Main Crop (corn): The corn was planted May 11, 1991 in 36" rows using a 4-row International cyclo air planter pulled by a 60 hp John Deere tractor at 5 mph.

Harvest

The entire plot area was combined on October 16, 1991 using a White 8800 4-row header at a working speed of 3 mph. Because of the low harvest moisture of the corn (18-19%) it was stored directly in an on-farm bin with no commercial drying. Unheated air was forced through the grain to facilitate further drying.