TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EVALUATION OF O.B.A.T.A. APPROACH TO LOW INPUT FARMING

FINAL REPORT

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Mr. and Mrs. Jim House
Mr. and Mrs. Arpad Pasztor
Mr. and Mrs. Dave McIntosh
Mr. and Mrs. Joe Gerber
Mr. and Mrs. Dean Glenney

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EXECUTIVE SUMMARY

Many farmers are seeking alternatives that lessen their dependence on off-farm inputs (especially fertilizers and pesticides) that build soil quality, and that create a healthier environment. This report presents a three year evaluation of the excellent accomplishments of a small group of innovative farmers known as the Ontario Biological Aeration Tillage Association (O.B.A.T.A.). Their quest is to adapt low input farming methods on their farms and to extend promising alternatives to their communities.

The basic components of the O.B.A.T.A. approach are mechanical, biological and reduced chemical inputs. Important sub-components of each of these are summarized as follows. Mechanical tillage implements; a subsoiler used for pre-emergence or post-emergence soil aeration; and other farming implements for spraying, seeding, tillage, etc. The biological component entails kelp, sugar (eg. molasses) and fertilizer; cover crops; crop rotation; and reduced tillage. Reduced rates of herbicides and fertilizers are applied.

The purpose of this project was to evaluate these production practices; the next step is to use the favourable recommendations for extension purposes. The evaluation examines systems approaches to farming. A standard approach, the farmers' routine practice, is compared to the O.B.A.T.A. approach. These both vary considerably from farm to farm in terms of crops grown, availability of manure, and rotation of principal crops. One farmer adopted O.B.A.T.A. methods throughout his farm, so on his land different O.B.A.T.A. practices (comparison of cover crops, different fertilizer applications, tillage practices and manure applications) were examined.

The study was conducted on seven farms distributed across Oxford, Elgin, Haldimand-Norfolk and Waterloo Counties, spanning variable soil and climatic conditions. There were three complete years of results for two fields and several treatments within each field on Mint Klynstra, Jim House and Arpad Pasztor's farms. Various O.B.A.T.A. treatments were tested on John Van Dorp's farm. Joe Gerber, Dave McIntosh and Dean

Glenney were unable to participate during the entire period for various personal reasons. The significant results of the monitoring program are summarized as follows:

Soils

- ★ Soil fertility monitoring (P, K, Mg, Ca, pH and organic matter) revealed a lack of significant differences between the standard and O.B.A.T.A. management treatments. Comparisons were made for each year and between years for each treatment.
- ★ There were no significant differences in soil compaction as measured by vertical penetrometer and bulk density. Pocket penetrometer readings indicate greater compaction in the standard versus O.B.A.T.A. management plots, below the topsoil.
- ★ Most of the O.B.A.T.A. farmers kept a fair amount of crop residue cover on both their standard and O.B.A.T.A. fields (over 50% on average). Two farmers used aeration tillage in the fall regularly, and another was a no till farmer.
- ★ Microbial biomass measurements taken in 1991 were similar to baseline measurements obtained in 1989. Fields with the greatest biomass carbon counts have a history of intensive soil management (i.e. use of manures, cover crops, and kelp and sugar additions etc.). Over the three year period no significant increases in microbial measurements were detected in the O.B.A.T.A. plots when compared with the standard plots.

Crops

- ★ Winter wheat trials were only possible in 1989. Yields were greater on O.B.A.T.A. management plots compared with yields obtained from standard management plots. This may have been a positive response to foliar spraying as this was the only O.B.A.T.A. practice implemented on these fields at that time.

- ★ No measurable differences in soybean yields on O.B.A.T.A. treatment plots in 1989, 1990 and 1991 could be discerned from those yields obtained from standard management plots.
- ★ Corn yields on O.B.A.T.A. treated plots were greater (6%) than standard management plots, based on examination of three fields in 1991. During the first two years O.B.A.T.A. plot yields were slightly lower than those on standard treatments.
- ★ The use of cover crops and aeration tillage (Aer-way®) systems were highly effective in reducing water runoff, soil, sediment and phosphorus losses.

Economics

- ★ There are risks in changing farming practices. While farmers are motivated by environmental and health concerns, an economic incentive is also an excellent motivator. Observations, consideration of inputs and returns have been evaluated in year three and the results show O.B.A.T.A. practices are comparable or superior to conventional practices in terms of economics.

Other

- ★ Soil micro-faunal populations within plots with added kelp and sugar versus standard management plots indicated no significant differences in a one year study.
- ★ The use of kelp, molasses and other sugars, and 71 B fertilizer solution as a seed and foliar treatment in an aeration tillage system does not significantly affect growth or yield of soybeans, based on a two year micro-plot study. Nevertheless, positive responses to these additives were evident on some field scale treatments.

This on-farm research has proven to be very effective in testing and demonstrating alternative production practices. Considerable effort is required in the initial year of such an undertaking to establish good communication and understanding between researchers and farmers. Subsequently, attention is needed to continue consistency and integrity of practices and statistical design. It would be desirable to have at least ten participants to improve the statistical component.

Longer term research is essential for studies of this nature. Both the farmers and researchers agree that the third year is really the first year of reliable data, considering the adjustment period needed for transition in soils, weed control and experience of the co-operator.

An extension component should be added to projects of this type. In the final year of study, Can-Ag Enterprises received funding from SWEEP and Aer-way to produce a video that could be appropriate for extension use.

1. INTRODUCTION

Can-Ag Enterprises was contracted by Supply and Services Canada in June 1989 to conduct a three year study to evaluate the O.B.A.T.A. (Ontario Biological Aeration Tillage Association) approach to low input farming. The study initially involved seven farmers, each with two sets of test fields distributed across southwestern Ontario representing a range of key soil types, farming practices, and agro-climatic conditions (Figure 1). As of the spring 1991, the study was comprised of four farmers and seven research fields. The study was designed to observe the O.B.A.T.A. approach versus standard management practices of the farmers.

O.B.A.T.A. is a farmer-developed concept to adopt innovative farming techniques to improve aeration, reduce chemical inputs, increase nutrient cycling, retain trash cover for erosion reduction, add organic matter and nutrients, and evaluate kelp and molasses or other sugar treatments. It is a systems approach that addresses the following goals of an increasing sector of the farm community: reducing purchased inputs while maintaining or increasing yields, creating a safer and healthier environment, and meeting the needs of the Ontario Ministry of Agriculture and Food's Food Systems 2002 program.

1.1 OBJECTIVES

The goal of this project was to evaluate the O.B.A.T.A. approach to reducing cultivation, chemical inputs, soil erosion, and potential for non-point pollution while maintaining or increasing net returns. The primary objectives of the research were:

1. to monitor inputs versus outputs and erosion control on standard versus O.B.A.T.A. systems;
2. to tailor the O.B.A.T.A. system to suit southwestern Ontario, and thus in turn help to meet SWEEP targets;

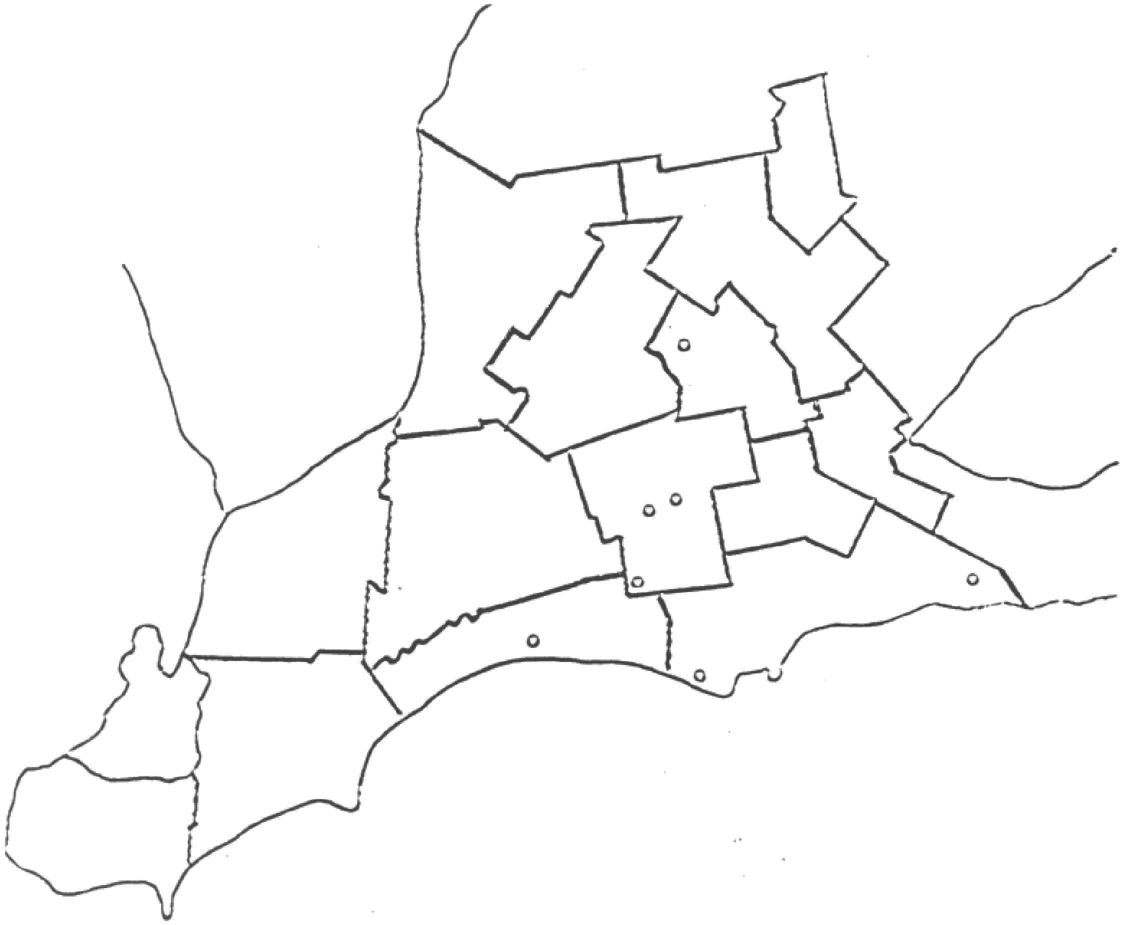

Figure 1.Location of Co-operators' Sites.

3. to study specific components of the O.B.A.T.A. system:
    a. mechanical component
    b. biological component
    c. fertility component
4. to analyze the data and report on the relative merits, associated difficulties, and suggested improvements to farm management under the O.B.A.T.A. system or modifications of it.

1.2 OVERVIEW OF THE THREE SEASONS

The project was initiated in the spring 1989. A plan of agronomic activities was prepared and explained to the farmers along with the study objectives, field plans, and participants' responsibilities. Except for Dean Glenney who withdrew his participation for that year due to excessive amounts of precipitation (which prevented him from planting), the remaining farmers got off to a good start in setting up their O.B.A.T.A treatments and following through until harvest of that year. Farmer interest and their positive attitude towards participating in the study was very encouraging. This first year was a time for learning and adjustment for both parties involved. It was a time for gaining their confidence on research and improving communication with us. The 1989 season was not unusual with respect to precipitation or temperature (Tables 1 and 2). During this year overall winter wheat and soybean yields under the O.B.A.T.A. program were greater than yields obtained from standard management plots. O.B.A.T.A. corn yields were lower with respect to standard corn yields. After harvests residue sprays were applied and the Aer-way® was worked across the various plots where possible. In a couple of cases late harvests prevented the establishment of cover crops as per the farmers' calendar for agronomic events.

In this first year Ecological Services for Planning Ltd. and Agriculture Canada initiated their rainfall simulation experiments in select fields.

Table 1. Precipitation data (mm) for Elgin and Oxford Counties for 1989, 1990, 1991 and 10 year averages.

County	Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Elgin	1989	54	95	119	69	51	63	55	505
	1990	66	107	102	83	139	135	94	726
	1991	78	61	30	73	56	29	114	440
	10 year mean	61	81	86	76	102	86	73	564
Oxford	1989	/	75	84	42	45	51	/	299
	1990	/	105	85	148	98	91	/	528
	1991	/	71	47	128	66	40	/	353
	10 year mean			/	/	/	/	/	452

/ = no available data

Table 2. Corn Heat Units for Elgin and Oxford Counties for 1989, 1990 and 1991.

Elgin		Oxford	
Year	Mean	Year	Mean
1989	3056	1989	3199
1990	3178	1990	3167
1991	3259	1991	3198

Note: Calculated from 11 May to killing frost (-2ºC).

The 1990 season proved to be an unusual summer for the weather was very cool and much wetter compared to the year before (Tables 1 and 2). Corn and soybean yields were comparable or greater in favour for O.B.A.T.A. management plots during this year. Because of greater precipitation that year not all of the farmers could complete their fall O.B.A.T.A. operations such as crop residue spraying or aeration tillage. Timing was a key element with respect to O.B.A.T.A. farming, and the weather sometimes hampered some activities. Ecological Services for Planning Ltd. continued their rainfall simulations in the spring and the fall of this year.

In 1991 three of the farmers could no longer participate in the study thus the number of research fields decreased. This past season the weather continued to be warm and relatively dry. In most areas precipitation arrived in the form of isolated and scattered showers. In some areas the crops suffered a fair amount of drought stress. Soybean yields from O.B.A.T.A. management in 1991 were comparable to the standard yields. O.B.A.T.A. corn yields were greater compared with yields from standard management plots. Farmers completed all of their O.B.A.T.A. operations to schedule and harvest was on time. During this season various aspects of O.B.A.T.A. such as treatment sites, informal farmer interviews, operations such as foliar and crop residue spraying, harvest, and use of the Aer-way for fall aeration tillage were captured with video footage. This was the first year when results showed favourably for O.B.A.T.A. farming. It could be that the farmers (now in their third year of practice) were more confident in themselves and the system. They were more keen and knowledgeable in what they were doing. To farm in such a manner requires dedication to the system and these co-operators were certainly doing their best to comply. Possibly too in some cases the soils may have already started to adjust as some farming techniques were becoming the routine measure (reduced tillage, use of the Aer-way and cover cropping). Farmers such as Jim House are always trying new and innovative ideas for farming that are more environmentally sound and still produce adequate yields.

Other farmers see and take a curious interest into what is being accomplished (as demonstrated by neighbours of farmers who attended the 1991 winter workshop).

Rainfall simulations were carried out only in the spring of 1991. A list of O.B.A.T.A. operations completed by each farmer (for each field) in each year is provided in Table 3.

Table 3.1989, 1990 and 1991 Record of O.B.A.T.A. Activities for Each Field.

Co-operator	Field No.	Year	Crop	Spring Aer-way®	Kelp and Sugar Solution			Cover Crop	Fall Subsoiler	Fall Aer-way®
					Planter	Foliar	Residue			
Van Dorp	1	1989	corn	✓	✓	✓	✓	✓	X	✓
		1990	corn	✓	✓	✓	✓	✓	X	✓
		1991	corn	✓	✓	✓	✓	X	X	✓
	2	1989	winter wheat	X	X	✓	✓	✓	✓	✓
		1990	corn	✓	✓	✓	✓	✓	X	✓
		1991	corn	✓	✓	✓	✓	X	X	✓
Klynstra	1	1989	soybeans	✓	✓	✓	✓	✓	X	✓
		1990	winter wheat	X	X	X	✓	✓	X	✓
		1991	corn	✓	✓	✓	X	X	X	✓
	2	1989	winter wheat	X	X	X	✓	✓	✓	✓
		1990	corn	✓	✓	✓	✓	✓	X	✓
		1991	corn	✓	✓	✓	X	X	X	✓
House	1	1989	winter wheat	X	X	✓	✓	✓	✓	✓
		1990	corn	X	X	✓	X	✓	X	X
		1991	corn-soy	X	X	✓	X	X	X	X
	2	1989	corn	X	X	✓	✓	✓	X	✓
		1990	soybeans	X	X	✓	X	X	X	X
		1991	corn-soy	X	X		X	X	X	X
Pasztor	1	1989	corn	✓	X	✓	X	X	X	X
		1990	corn	X	X	✓	X	X	X	✓
	2	1989	soybeans	X	X	✓	X	✓	X	X
		1990	tomatoes	X	X	X	X	✓	X	X
	3	1990	winter wheat	X	X	X	X	✓	X	X
		1991	corn	X	X	✓	X	X	X	X

Note: ✓ = complete, X = incomplete

Table 3. 1989, 1990 and 1991 Record of O.B.A.T.A. Activities for Each Field (concluded).

Co-operator	Field No.	Year	Crop	Spring Aer-way®	Kelp and Sugar Solution			Cover Crop	Fall Subsoiler	Fall Aer-way®
					Planter	Foliar	Residue			
McIntosh	1	1989	soybeans	✓	✓	✓	✓	✓	X	✓
		1990	corn	✓	X	✓	X	✓	✓	✓
		1991	-	-	-	-	-	-	-	-
	2	1989	corn	✓	X	✓	✓	✓	✓	✓
		1990	soybeans	✓	✓	✓	X	✓	✓	X
		1991	-	-	-	-		-	-	-
Gerber	1	1989	corn	✓	✓	✓	✓	X	✓	✓
		1990	corn	✓	✓	X	X	X	X	✓
		1991	-	-	-	-	-	-	-	-
	2	1989	winter wheat	X	✓	X	✓	X	X	X
		1990	-	-	-	-	-	-	-	-
		1991	-	-	-	-	-	-	-	-
Glenney	1	1989	-	-	-	-	-	-	-	-
		1990	corn	X	X	X	X	X	✓	X
		1991	-	-	-	-	-	-	-	-
	2	1989	-	-	-	-	-	-	-	-
		1990	corn	X	X	X	X	X	✓	X
		1991		-	-	-	-		-	-

Note: ✓ = complete, X = incomplete, - = not applicable

2. LITERATURE REVIEW

This review encompasses mainly the biological component of the O.B.A.T.A. (Ontario Biological Aeration Tillage Association) approach to low-input farming. It emphasizes the role, management, and use of cover crops in crop rotations, soil enhancement, erosion control, and potential for allelopathic influence.

Since the 1940's, agricultural practices have become increasingly dependant on chemical fertilizers and pesticides in North America. At the same time, diverse cropping rotations have declined in popularity, in favour of intensive crop sequences (continuous corn or corn/soybean). In recent years, there has been a growing interest in finding alternative cropping systems because of such concerns as ground and surface water contamination or degradation, an increase of soil erosion, an increase in potential health hazards due to the steady use of chemicals, increased soil compaction problems, a depletion of soil organic matter, and the economic farm crisis of the mid-1980's (Liebhardt et al., 1989, Pennsylvania; Benoit et al., 1962, New Jersey).

The alternatives to conventional practices span a wide spectrum and offer much potential for the conservation of soil, water and energy, while maintaining economic viability. One such approach is to adopt a low-input system. Low-input is the use of internal resources generated on-farm, rather than purchased resources produced externally. This distinction is significant in that many consider 'low-input' to be a contradiction. It is more intensive in management particularly in understanding soil biological processes and crop ecological systems. Pest control can be achieved biologically (eg. biological sprays and control agents), or culturally (eg. mechanical and rotation). Nutrients are supplied by animals or by the use of green manures. The fundamental difference between low-input and conventional systems is the use of more diverse cropping rotations in low-input systems (Liebhardt et al. 1989).

Crop rotation can provide a yield benefit that persists under careful cropping management systems (Crookston and Kurle, 1989, Minnesota). The main reason for the rotation effect is unknown, but may include: stimulation of soil biological activity, lower incidence of disease, nutrient supply, or effects on soil structure. One theory is that a given crop's own residue has an auto-inhibitory effect when that crop is maintained under monoculture, and that residues of alternate crops have a stimulatory effect on one another under rotation.

Continuous cropping in corn and soybean systems cannot be sustained without substantial additions of fertilizer and pesticides (Heichel, 1978; Pimente) et al., 1978). Many studies showed higher yields in corn followed by a hay or small grain crop compared to continuous corn (Smith, 1942, Columbia; Bolton et al., 1976, Canada; Dick and Van Doren, 1985, Ohio; Sahs and Lesoing, 1985, Nebraska). While some studies have shown that the 'rotation effect' of a previous crop on corn is the result of N supply (Shrader et al., 1966; Baldock and Muskgrave, 1980), other investigations indicate that there is a downward trend in corn yields as the frequency of corn in a rotation increases, independent of the fertilizer inputs (Voss and Shrader, 1984, Wisconsin; Smith, 1942). Crookston and Kurle (1989) observed a significant effect of previous crop (rotation effect) on the yield of both corn and soybeans, but the removal or addition of corn residue had no effect on the yield of either crop. This indicated that the yield response of corn and soybean to rotation is not due to effects of decomposing above-ground residue.

2.1 COVER CROPS

Another important facet of the low-input cropping system is the use of animal manures, and green manures or cover crops. These soil amendments replenish nutrients and organic matter in the soil (Power and Doran, 1984, Wisconsin; Rennie, 1982, Canadian prairies). The O.B.A.T.A. approach to low-input farming implements the use of cover cropping. It requires fewer inputs combined with more intensive farm management and can result in a more efficient farming method capable of producing good yields and profits. This approach integrates the mechanical and biological components, as well as reduced chemical practices to result in a reduction in cultivation, chemical inputs, soil erosion, and the potential for non-point source pollution while maintaining or increasing economic returns.

The current movement toward the use of forages (Henkes, 1989) and legumes (Sarrantonio and Scott, 1988, New York State) as cover crops in the adoption of modern cropping systems also harnesses the potential of nutrient cycling, particularly of N. Johnson (1989) reports on some of the cover crops considered to be most popular now being evaluated at the Rhodale Research Centre, P.A. Wheat, rye, and buckwheat, followed by legumes such as clovers or beans, seem to be the most widely used by farmers. Additional cover crops, and those implemented in the O.B.A.T.A. research are: Hairy vetch *(Vicia vi//osa* Roth), Winter rye *(Secale cerea/e L.),* Oilseed radish *(Raphanus sativus,* rar. oleiformis), and Buckwheat *(Fagopyrum esculentum).* These are examined in terms of crop characteristics, effects on soils, and performance of subsequent crops.

2.1.1 Hairy Vetch

Hairy vetch is a winter annual legume, and is the most winter-hardy of the cultivated vetches. It will grow well on a wide range of soil types, providing there is good drainage, and it tolerates drought conditions well. This vetch can fix up to 80 kg N/ha (Johnson, 1989).

If planted in the spring it winter-kills and forms a fibrous mat which protects the soil and suppresses the growth of weeds (Johnson, 1989; Senseman et al., 1988, Arkansas). If planted in late summer or fall, it does not winter-kill, and provides weed competition and winter cover. The following spring it will continue to grow, while the decaying vegetation will add N-rich biomass for that season's crop (Henkes, 1989). It can be plowed under in the summer or fall, and since it is very succulent it readily decomposes.

Hairy vetch is an economically viable cover crop in no-till continuous corn cropping systems because the seed cost equals the cost of the N fertilizer it replaces (Frye and Blevins, 1989). Yields have consistently been higher and increasing annually in the system using hairy vetch winter cover crops compared to continuous corn without cover crops, in which yields have remained constant or slightly reduced.

Mr. Dick Thompson, a leading advocate of alternative agriculture in Boone, Iowa uses no herbicides or primary tillage. He has integrated hairy vetch into a ridge-tillage system for growing corn and soybeans (Henkes, 1989). He aerially seeds a vetch-oats mixture in corn or beans in early September. Oats give quick fall growth for ground cover, and by early May the following year, vetch regrowth has smothered the weeds and added organic matter to the soil. Thompson claims the vetch will release approximately 112 kg N/ha over a period of two years (Henkes, 1989). Hairy vetch was found to supply 153 to 227 kg N/ha, varying with the amount of growth prior to plowing (Mitchell and Teel, 1977) over a two year period as well. Mitchell and Teel (1977) also reported that yields of corn direct-drilled into a killed sod of hairy vetch and crimson clover in combination with annual grasses equalled those of corn fertilized with 112 kg/ha of fertilizer N near Georgetown, Delaware.

Kamprath et al. (1958) studied the residual effects of hairy vetch and observed a positive growth response in corn over a four year period following the vetch cover crop in North Carolina. The study was performed on a sandy soil where leaching losses could be assumed important. Therefore, the long-term benefits from the incorporated vetch suggest a relatively slow release of N (Mitchell and Teel, 1977).

In the State of Kentucky, hairy vetch contributed the fertilizer equivalent of 90 to 100 kg N/ha to a following no-tillage corn crop (Ebelhar et al., 1984), although work by

Huntington et al. (1985) which addressed the timing of N-release from hairy vetch in a no-tillage corn system showed that 50% or more of the N mineralized from the vetch was released after the period of maximum crop uptake.

Sarrantonio and Scott (1988) conducted field studies in Aurora, New York, from 1984 to 1986 to examine the release of inorganic N to corn following hairy vetch that had either been plowed down (conventional tillage) or killed and left on the surface (no-tillage). The 1985 data suggested that the soil inorganic N concentration in vetch treatments was higher under conventional tillage versus no-tillage, and it was more uniformly distributed throughout the plow layer. Both corn yields and N uptake were significantly higher in the no-tillage system probably because of higher soil moisture content in the dry summer (Sarrantonio and Scott, 1988). Vetch did not stimulate significant yield increases over zero N control plots in either tillage system, although there was more N uptake by corn in the vetch treatments. Under no-tillage conditions, 29% of the original N in the above-ground vetch biomass was measured either as soil inorganic N or corn N. Under the conventional tillage system, 56% of the original hairy vetch was measured. The 1986 data suggest, again, higher levels of inorganic N occurring under conventional tillage. Contrary to the 1985 results, corn yields were significantly greater in the conventional treatments compared with the no-tillage treatments at all N levels. Both corn yield and N uptake were significantly greater in vetch treatments than control treatments under both types of tillage (Sarrantonio and Scott, 1988).

In North Carolina, Wagger (1989) initiated a field study to determine changes in plant composition and subsequent patterns of N release resulting from two desiccation dates (early and late) set 2 weeks apart. Averaged over two years, the late desiccation treatment resulted in increases in cover crop dry matter of 39, 41, and 61 % for rye, crimson clover, and hairy vetch, respectively. Corresponding increases in total N content of the respective cover crops were 14, 23, and 41%. The order of N release was hairy vetch > crimson clover > rye. Estimates of N released from each of the three cover crops indicated that the potentially larger available N pool resulting from a delay in desiccation was offset by the slower rate of N release, especially for crimson clover and rye (Wagger, 1989).

2.1.2 Winter Rye

Winter rye is a winter annual grass species, often grown in the northern latitudes, and has proven useful as a rotational species in many cropping systems (Benoit et al. 1962; Osvald, 1953, Stockholm). Rye contributes to the organic matter in the soil, and to decreasing the incidence of soil erosion by providing good ground cover. It suppresses the growth of weeds (Henkes, 1989), and enhances water penetration and retention in the soil (Benoit et al. 1962; Blevins et al. 1971; Tukey, 1969). Rye is highly adaptable to all soil types, and also has good drought tolerance (Johnson, 1989).

It is common to plant rye in the fall, and permit it to continue growth in the early spring. It can then be plowed and disced under before conventional planting (Barnes and Putnam, 1986, Michigan). In a reduced tillage system, rye can be chemically killed in the spring, leaving the residue to remain on the soil surface. The residue left can modify the surrounding soil environment both chemically and physically during seed germination and plant growth (Barnes and Putnam, 1986).

Benoit et al. (1962) investigated the positive influence a rye cover crop had on soil structure in the State of New Jersey. Rye roots were found to be the primary factor responsible for an improved physical condition of the surface soil, which eventually continued into the subsoil. Additions of organic matter consisting of only the rye top growth had negligible measurable effects. It took three years of cover cropping to observe measurable physical differences in the structure of the soil, where the roots and tops together had the most pronounced effect (Benoit et al. 1962).

The use of a winter rye-corn double cropping sequence could improve annual biomass production and reduce the soil erosion potential that exists in southern Ontario (Raimbault et al., 1989). A study from 1982 to 1984 was conducted to determine the potential of this type of sequence, and to evaluate spring tillage systems and management of rye residue on subsequent productivity of corn. Results showed that corn development was delayed and the biomass reduced. The adverse effect of the rye was more pronounced under no-tillage compared with tilled conditions. Removal of the rye residue had a negligible influence on the subsequent corn crop. An allelopathic effect from the rye was one explanation for the reduction in yield of corn. The total biomass yield of rye plus corn was increased relative to corn alone, if the soil was cultivated. Thus, a winter rye-corn sequence would still be of interest especially if advantages such as total biomass production and the potential for decreased soil erosion during the fall and winter are considered.

Moschler et al. (1967) compared several winter cover crops for their effect on sod-planted corn yields during 1962 to 1966 in Virginia. Conventionally tilled corn with cover crop turn-plowed and sod-planted corn were also compared. It was concluded that rye was the most satisfactory for no-tillage corn, because of its superior winter hardiness, susceptibility to herbicide killing, and production of relatively large amounts of persistent mulch. In their studies, the addition of vetch and crimson clover contributed very little to enhance corn grain yields, but did increase mulch forage. In general, highest corn yields occurred where the greatest amounts of cover crop mulch occurred. Planting corn in rye stubble after removal of forage for hay or silage reduced corn yields an average of 47% in some comparisons when rye was left as mulch. Yields of sod-planted corn in rye sod averaged 44% higher than conventionally tilled corn. More soil moisture was found under sod-planted corn than under conventionally tilled corn, especially during the first half of the growing season. It was concluded that corn yields were increased or at least maintained, in comparison to conventional tillage, by sod-planting in rye over a wide range of soil and moisture conditions. with the added advantages of improved soil and water conservation (Moschler et al. 1967).

2.1.3 Red Clover

The number one plowdown crop in Ontario is red clover. seeded in the spring in either winter wheat or spring cereals. This crop does a good job of improving soil structure and of fixing nitrogen from the air through nodules on the roots. Seed cost is reasonable and seed is readily available. Establishing red clover does not harm the yield of the companion crop or the following crop. Thus. there are many good reasons for the continued popularity of red clover as a plowdown.

However. there are situations where. for one reason or another. red clover either does not get seeded in the spring or it fails to establish well. The severe drought of 1988 killed seedling red clover in some wheat fields where it was seeded. Obviously. there is interest in a cover crop that can be seeded after cereal harvest and still provide significant benefits to the soil by the winter. Oilseed radish appears to be the useful crop in this situation.

2.1.4 Oilseed Radish

Another option for cover cropping is the use of oilseed radish. a non-leguminous plant. which could be used much like ryegrass or red clover in some rotations (Henkes, 1989). It has been used for several years in Europe as a cover crop that can be seeded after cereal harvest. It is a relatively new addition to the long list of plants useful as cover crops in Ontario as it has been grown on only a few farms in Ontario as a plowdown cover crop for only a few years now.

Oilseed radish is a plant developed by crossing fodder radish. fodder rape and rapeseed. It was developed only for plowdown and has no other uses. When planted in the spring it can grow to a height of six feet by maturity. Root shape is somewhat variable. like a carrot or parsnip or an overgrown radish. It belongs to the Brassica family and will tolerate fall frosts. but does not survive the winter in Ontario.

On a three acre test plot (in wheat stubble) on a farm near Tavistock. Ontario. oilseed radish was shown to establish well and form a dense canopy cover in only a few weeks time (Henkes. 1989). Experience to date suggests that it could be a useful soil improving crop for late summer seeding.

REAP (Resource Efficient Agricultural Production) sponsor several on-farm experiments in Ontario. One of the scientists of REAP. Mr. Roger Samson. believes that oilseed radish might have its niche where weeds are problematic and where red clover is difficult to establish. Oilseed radish does not fix N. however. Samson believes it will add to the N pool for the following crop by intercepting and recycling N that might otherwise be lost through leaching. It absorbs and holds in the plant nutrients from the soil or from a recent application of manure. This can be particularly important with nitrogen. a nutrient that otherwise usually leaches out of the soil over the winter. This recycling action benefits the soil and helps prevent nitrate accumulation in the ground water (Henkes. 1989). It also reduces the need for farmers to add N fertilizers because the N has been retained by the cover crop.

2.1.5 Buckwheat

There is very little information in the literature regarding the use of buckwheat as a winter cover crop. Nevertheless. this grain has been used successfully as it has several favourable attributes. Buckwheat will grow on most soil types. and has moderate drought tolerance (Johnson. 1989. Pennsylvania). It can tolerate low soil fertility and low soil pH. It can be sown in the spring or summer. and turned under in the summer or the fall. respectively. It has proven to be a good green manure crop and weed inhibitor (Johnson. 1989).

2.2 ALLELOPATHY

Rye has also been observed to be a good weed inhibitor by virtue of its allelopathic influence. Barnes and Putnam (1986) in Michigan State. reported that spring-planted living rye reduced weed biomass by 93% over plots without rye. Residues of fall-planted spring-killed rye decreased total weed biomass over bare-ground controls. Rye residues also reduced total weed biomass by 63% when compared to their control which suggests that allelopathy. in addition to the physical effects of the mulch. did contribute to weed control in these systems. Of the several weed species reduced. key examples are redroot pigweed *(Amaranthus retroflexus),* common lambsquarters *(Chenopodium alba),* and common ragweed *(Ambrosia artemisiifolia L.).* Rye residues appeared to reduce plant growth more than germination or emergence. Phytotoxicity problems occurring where winter rye was present could be due to the accumulation of growth inhibitors in the soil (Barnes and Putnam. 1986).

In northwest Michigan. Smeda and Putnam (1988) reported that rye provided greater early season weed suppression in strawberry fields compared with other grains tested. A high cover crop seeding rate increased weed suppression. and fruit yields were not reduced significantly by the use of rye as a cover crop.

Recently. rye has been the subject of considerable study to assess its role as an allelopathic no-till mulch (Samson. 1989). Short time intervals between the killing of the rye and planting of the subsequent crop are important in obtaining the maximum effect of allelochemicals.

Allelopathic effects have been documented on crop growth and yield (Bhomik and Doll. 1982). Allelochemical effects from rye residue may be by direct contact with tissue fragments or through the soil (Samson. 1989). Hill (1926) noted that the addition of green rye to heavy soils depressed corn growth. while growth was increased in light soils. Roots were more toxic than tops. Patrick and Koch (1958) found that decomposing residues of rye were very inhibitory to the respiration of tobacco seedlings. Patrick (1971) identified several compounds toxic to lettuce and tobacco in decomposing residues of rye. In greenhouse studies. rye root leachates reduced tomato dry weight by about 30% (Barnes and Putnam. 1986). Under simulated no-tillage conditions in the greenhouse. rye residues reduced emergence of lettuce and prosomillet by 58 and 35%. respectively. Phytotoxicity increased as distance from seeds to rye residues decreased. Phytotoxicity decreased in non-sterile soil. indicating that some secondary compounds were degraded by microorganisms (Barnes and Putnam. 1986). In contrast. Worsham (1984) in North Carolina. discovered that certain bacteria present on some weed seeds can change the allelopathic compounds to forms that have greater potency against weeds; a process termed 'biomagnification'.

2.3 BIOLOGICAL SOIL LIFE

The majority of biochemical transformations in the soil result from microbial activity (Wainwright. 1978). Microorganisms mineralize. oxidize. reduce. and immobilize elements in the soil. as well as indirectly influence their solubilities (Alexander. 1977). Any compound (or activity) which changes the number or activity of a microbial population could affect the soil biochemical processes and ultimately influence soil fertility and plant growth.

The use of chemical fertilizers and pesticides known to be harmful to microorganisms and other life forms (Wolf. 1977) is further reason to move towards an alternative cropping system with reduced inputs. The use of crop conservation tillage systems and the associated reduction in tillage. return of crop residues to the soil surface. control of residue placement. and reduction in chemical use is increasingly recognized as influencing the soil fertility. organic matter (Cole et aL. 1987. Wisconsin; Doran and Smith. 1987. Wisconsin). as well as microbial population dynamics.

Reduced tillage production systems significantly alter the distribution of plant available nutrients (Follet and Peterson. 1988) and organic compounds. including the microbial biomass C and N (Carter and Rennie. 1982). With no-tillage. Carter and Rennie

(1984) observed immobilization of added fertilizer N into the microbial biomass mainly in the 0 to 5 cm depth with less in the 5 to 10 cm depth.

The type of tillage also affects crop residue placement. Tillage can influence C and N cycling by limiting or regulating biological activity because of changes in water. oxygen. temperature. accessibility of C and N substrates. and the habits for activity of plants. microflora. and microfauna (Doran and Smith. 1987. Wisconsin). Crop residues serve as substrate (C. N. etc.) that is converted to microbial biomass and soil organic matter. Crop residue placement is reported to regulate N cycling in cropping systems (House et al.. 1984).

Follett and Schimel (1989) studied changes in microbial biomass dynamics and N cycling in Nebraska under three tillage systems: no-tillage. stubble mulch. and moldboard plow. They concluded that there was a decrease in microbial biomass with increased tillage activity. Results suggested that C available for microbial growth declined with increased tillage activity. Greater tillage reduced the soils capability to immobilize and conserve mineral N.

Also in Nebraska. Doran (1980) investigated the influence of corn residues remaining on the soil surface with reduced tillage on the population and kinds of soil microorganisms. It was found that the effects of corn residue on soil microbial populations for corn production were closely related to the placement of residue. soil water. and pH regimes. Populations of bacteria. actinomycetes, and fungi increased two to six times because of mulching due to the increased availability of soil water and nutrients. Counts of nitrifying and denitrifying microorganisms in the surface soil increased two to twenty times and three to forty-three times. respectively. in plots with corn stover. Residues influenced the response of microorganisms to the application of both lime and herbicides. The residue reduced the inhibitory effect of herbicides on nitrifier populations.

Drury and associates (1991) studied the effects of several crops on soil biomass C and biomass N contents. their within season variability. and the relationship between changes in soil biomass C. biomass N and soil structure. It was found that reed canary grass resulted in greater biomass C contents than both the corn and soybean at all four sampling dates. Soil biomass C under alfalfa was significantly greater than under corn and soybean for both the first and last sampling dates. Forage species did not affect the soil biomass N content. No consistent effects of the no-crop treatment on biomass N content or biomass N were observed between sampling dates (Drury et al.. 1991). Reed canary grass resulted in greater soil biomass C/N over the alfalfa. corn. and orchard grass plots. This suggested that fungal activity. and therefore soil structure. may be preferentially enhanced in the presence of reed canary grass. This research demonstrated the influence of forage species and seasonal variability on concurrent changes in microbial biomass and soil structural properties.

Doran (1987) reported that fertilizer placement below the biologically rich surface soil layer and rotational tillage may improve the short term N use efficiency and crop growth in reduced tillage production systems in Nebraska.

An evaluation of microbial populations and activities and their relationship to N cycling in soils under organic and conventional farm management was conducted in 1981 and 1982 in eastern Nebraska (Fraser et al.. 1988). It was found that chemical properties of the soil were significantly influenced by chemical management. primarily by the addition of manure in the organic management system. Soil microbial biomass. bacterial. and fungal counts were greater in the soils planted with cover crop (oats. clover). and treatments which received manure. Increases in microbial populations and their activities increased with increasing soil organic C (Fraser et al.. 1988).

The use of cover cropping can influence the macro-organisms associated with the soil cropping environment as well. Earthworms are indispensable organisms for maintaining a healthy soil. They perforate and granulate by ingesting the soil and organic matter. by excreting casts. and making tunnels. Earthworms are important in maintaining good physical conditions wherever they are abundant (Slater and Hopp. 1947). Hopp and Linder (1947) found that earthworms were killed on bare cropped land by fall freezes. Under good insulative protection. however. the earthworms survived the low temperatures and were highly active.

Slater and Hopp (1947) found that fall protection using various cover cropping practices was necessary for the overwintering success of earthworm populations in Maryland. In comparisons of cultivated land with and without residues or mulches. protection by coverage was generally associated with larger earthworm populations. higher water stability of the soil aggregates. and more rapid infiltration (Slater and Hopp. 1947). Fall protection appeared to be a major factor in maintaining large earthworm populations in tilled soils.

Allowing plant or crop residues to remain on the surface. or be incorporated into the soil can have a dramatic influence on the beneficial and pest species of arthropods in that field. Smith et al. (1988) investigated the impact on arthropods when a rye cover crop was used in a soybean production system (eg. no rye cover crop. rye plowed and disced into the soil, rye disced only. and rye left on the soil surface) in Ohio State. The study indicated that the use of rye had a variable impact on certain arthropod populations. depending on the species and also on the management of the rye. Knowing the effect that a cover crop might impose on arthropods may assist growers in better managing their crop. As growers increase the implementation of alternative cropping systems. the population dynamics of many arthropods will be influenced.

2.4 SEAWEED: PLANT GROWTH AND YIELD

Historical records show that the use of seaweeds in agriculture is a very old and widespread practice wherever there are readily available sources. This involves their use as food for animals. as manure for the soil (Chapman. 1980). and more recently as additions to enhance plant growth. Seaweed meals and liquid extracts used in agriculture and horticulture are made from brown seaweeds which grow in temperate waters and around the coasts of Europe (north of Brittany) where they grow quite dense. Three types are used: *Ascophyllum nodosum, Fucus vesiculosus,* and *Fucus serrates* (Stephenson. 1974). Seaweeds provide traces of nearly every mineral element found in the earth's crust. Seaweeds contain all the major and minor plant nutrients. all trace elements (in forms readily available for plant use). alginic acid. vitamins. auxins. at least two gibberellins, and antibiotics. Of the seaweed contents listed after nutrients and trace elements. the first (alginic acid). is a soil conditioner. the remainder are best described as plant conditioners (Stephenson. 1974).

It is a matter of common experience that seaweed. and seaweed products. improve the water-holding characteristics of soil and help the formation of crumb structure (Stephenson. 1974). They do this because the alginic acid in the seaweed combines with metallic radicals in the soil to form a polymer with greatly increased molecular weight. of the type known as 'cross-linked'. One might describe the process more simply by saying that the salts formed by alginic acid with soil metals swell when wet and retain moisture quite strongly. so aiding the soil in forming a crumb structure.

Vitamins known to be present in the brown seaweeds include vitamin C (ascorbic acid). Vitamin A is not present. but its precursor. beta-carotene. is. as well as fucoxanthin, which may also be a precursor of Vitamin A. The B group vitamins which are present consist of B, (thiamine). $\mathbf{B_2}$ (riboflavin). B_{12}. as well as pantothenic acid. folic acid. and folinic acid. Vitamin E (tocopherol), Vitamin K. and other growth-promoting substances are also found in brown seaweeds (Stephenson. 1974).

One of the basic auxins in seaweed is indoyl-acetic acid. Two other auxins (to date unidentified) have been found to encourage the growth of more cells. They differ from more familiar types of auxin which simply enlarge the cells without increasing their number. One of the auxins also stimulates growth in both the stems and roots of plants. This is different from indolylacetic acid which causes the cells to elongate but not divide. It is believed that the plants treated with foliar sprays containing seaweed are themselves stimulated to produce more vitamins and growth hormones than would otherwise be the case (Stephenson. 1974).

At least two gibberellins (which are hormones that simply encourage plant growth and do not have growth-controlling properties like auxins) have been identified in seaweed. They behave like those gibberellins which research workers have numbered A_3 and A_7. They may in fact be Vitamins A1 and A_4 (Stephenson. 1974).

The matter of antibiotics in seaweed is debatable. not because there is a doubt that seaweed contains therapeutic substances. but because the precise nature of these substances is unknown. For convenience. they are termed antibiotics. There is evidence of seaweed extract having discouraging effects on aphids and red mites. As well. certain fungal infections seem to be affected by seaweed extracts. for example. *Botrytis* on strawberries. The treated strawberry plants show a great reduction in infection and give a higher yield (Chapman. 1980). Other documented accounts reveal that foliar sprayed plants are much less susceptible to attack by mildew (eg. turnips). or Verticillium wilt on carnation flowers (Chapman. 1980).

Foliar spraying is an important part of the O.B.A.T.A. system of operations with regards to plant development. One reason is that nutrients in solution are absorbed through a plant's leaves more rapidly than through the roots. When nitrogen in the form of urea is sprayed on a large range of horticultural plants. 50% of the nitrogen is absorbed within twenty-four hours. Like the nitrogen. nutrients offered in the form of a foliar spray are more quickly available and more effective (Chapman. 1980).

Liquid seaweed extract can be sprayed on the soil. or sprayed on foliage (as done by O.B.A.T.A. farmers). It can be applied in concentrate or diluted form. or mixed with weedkillers. fungicides. or insecticides (Stephenson. 1974). Liquid extract is used to give immediate stimulation. The extracts which can be absorbed by the plants through their leaves. as well as through the roots. may be fully effective. as plant nutrients. within hours. The minerals. plant nutrients. auxins etc. are absorbed through the skin of the leaf and then directly into the sap of the plant. Thus. they are readily available for plant use. When applied to the leaves. the extract also causes the plant to increase its uptake of soil nutrients through the roots. however. the mechanism which causes this effect is not understood (Stephenson. 1974).

The ready absorption of nutrients from the foliar spray is enhanced because the cellulose-type content of the seaweed has already been broken down (due to previous processing in making the extract). Experience further suggests that a plants' needs for trace elements can be satisfied at lower concentrations if those elements are offered to the leaves in the form of a spray. rather than being offered through the soil to the roots (Stephenson. 1974).

Seaweed sprays may stimulate metabolic processes in the leaf and so enable the plant to exploit leaf-locked nutrients for it is known that trace elements absorbed from the soil and delivered by the plant to the leaf tissue. can become immobilized there (Stephenson. 1974).

Over the last thirty to forty years numerous trials have been conducted with dried seaweed meal or liquid extract on a range of crops. especially in the United Kingdom. One of these crops were McIntosh apple trees which produced larger and more abundant fruit with a hay or seaweed mulch than with the use of sawdust or grass.

Another study at Clemson University in South Carolina. using a range of crops and two alternative seaweed meal (Norwegian) treatments of 114 kg per 0.4 ha and 288 kg per 0.4 ha with a basal dressing of 456 kg per 0.4 ha artificial fertilizer produced both gains and losses. A study of residual fertility showed that application at 280 kg/ha was more effective. Not all crops were affected. For example. it was found that a crop such as cotton does not respond to the application of seaweed.

Looking at fruits. application of liquid seaweed extract has given increased yield in strawberry crops (19 - 133%). peaches and blackcurrants. the last named giving increases of 12 and 27% in two experiments with the use of a very dilute solution (1 in 400) three times at two week intervals (Stephenson. 1974).

The effect of seaweed extract varies with the type of plant for which it is used. In the case of soybeans there is no increase in yield but there is an increase in the protein content (Senn and Kingman. 1977). The same increase in protein has been reported for pasture grass. and this increase is reflected in the meat quality of the animals that graze the grass.

2.5 SOIL EROSION. NITRATE LEACHING AND TILLAGE

The implementation of an alternative low-input cropping system may also aid in the ongoing problem of soil erosion. Each year soil erosion costs farmers approximately $99/ha (U.S.) in lost nutrients according to the USDA (Hofstetter, 1988. Pennsylvania). Cover cropping is an attractive low-cost method to reduce or stop this trend. For as little as $25/ha (U.S.). a grower can establish cover crops that not only cease the loss of soil. but also reduce the fertilizer bill (Hofstetter, 1988. Pennsylvania). Cover crops prevent erosion in two ways. First. when the crop is growing. the foliage canopy acts as an umbrella. protecting the soil from the full impact of rain and retards surface runoff. Secondly. plowing the crop under adds organic matter to the soil. thus increasing its permeability and water storage capacity. The water then penetrates more rapidly which results in a decrease in runoff and erosion (Pieters and McKee. 1938. southern states).

"Wischmeier and Smith (1978) used several factors to describe runoff and erosion losses from agricultural fields. Their Universal Soil Loss Equation (USLE) combined these factors to predict long term average annual soil losses from farm fields for specified conditions. A description of the five USLE factors follow:

R - Rainfall and Runoff factor: this describes the effect of raindrop impact and the rain's associated amount and rate of runoff. Rainfall erosion indices and the temporal distribution of rainfall erosion have been calculated for Canada east of the Rocky Mts. (Wall et al. 1983).

K - Soil Erodibility Factor: this describes the soil's natural susceptibility to erosion. An annual K value may be obtained from a nomograph which relates % silt + very fine sand. percent sand % O.M.. soil structure and permeability class to erodibility. An attempt has been made to characterize K and seasonal differences in K with soil properties such as shear strength. antecedent moisture. and aggregate stability (Wall et al. 1988) (Coote et al. 1988).

LS - Topographic factor: this factor incorporates the effects of length and steepness of the slope and specifically is the expected soil loss relative to that from a uniform 9% slope. 22.1 m long.

C - Cover and Management Factor: This includes the combined effects of cover and management and considers rotation. previous cover. and the length of time between successive crop canopies. It is the soil loss relative to clean-tilled continuous fallow. The C factor is particular to locality since its value combines expected periods of highly erosive rainfall with corresponding periods of plant cover. The year is divided into crop-stage periods according to percent cover; approximate time frames of the corresponding crop stage periods are shown:

rough fallow (Apr.. May)

seedbed (May)

establishment (June)

development (July. Aug.)

maturing crop (Sept. Oct.)

residue or stubble (Nov.-Apr.)

The C factor considers crop canopy. residue mulch and the effects of incorporation of residues into the soil surface by tillage.

P - Support Practice Factor: this describes the soil loss with a support practice such as contouring or strip cropping on the contour. relative to loss with up and down slope cultivation.

Although the USLE was designed to predict long-term average annual erosion rates. in application. the equation has been modified and used to predict soil loss from a single rainfall event (Foster. 1988). In this application a single C factor based on soil cover and rainfall erosivity at the time of the storm is made" (Ecological Services for Planning Ltd.. 1990).

In addition to preventing the surface loss of soil and accompanying nutrients by erosion. cover crops can decrease leaching of N. Schrieffer (1984. Iowa) reported that the loss of broadcast N in corn is approximately 40 to 60%. The leaching of substantial quantities of nitrogen is a serious loss in the farming system and can increase the risk of pollution in drain water and ground water.

Grass cover crops hold very good potential as a means to control and reduce nitrate leaching in corn production systems. Groffman et al. (1987). found that well established fall rye cover crops significantly reduced nitrate leaching in early spring compared to legume cover crops. The authors suggested that rye is an effective scavenger of nitrates. better so than clover.

Scott et al. (1987) examined the effect of ten different intercrops and cover crops in a continuous corn silage system in New York State and found that annual ryegrass and rye consistently lowered ear leaf nitrogen compared to non-intercropped plots. This demonstrates the potential of grass cover crops to capture residual soil N. This could prevent N leaching after corn silage harvest. If the following crop was a nitrogen fixing legume such as soybeans. the system could be used to advantage without reducing the following crops yield.

The most important role that cover crops can have in reducing nitrate leaching may come from enabling producers to switch from fertilizer N sources to legume based N supplies for field crops. In Georgia. Varco et al. (1987) showed that total recovery of N from hairy vetch was two to three times greater than from applied N fertilizer. It was stated that potential nitrogen losses were greater with fertilizer N than legume N. but that further studies should be conducted.

A number of studies have recently compared the impact of tilling in the residues of legumes versus leaving them on the soil surface in a no-till situation. Almost all studies have found N uptake is reduced in no-tillage systems. In an Ontario study. Alder and Sheard (1987) found legume N uptake and total N uptake to be reduced by 24 and 30%. respectively. in no-till corn versus systems in which legume residues were incorporated. Over a two year period. legume N uptake from tilling in hairy vetch was 30% higher than leaving the residues on the surface (Varco et al.. 1987). The majority of studies have also found yields maintained or greater under tilled conditions (Alder and Sheard, 1987; Koerner and Power. 1987. Georgia; Varco et al.. 1987).

2.6 CONVENTIONAL VERSUS ORGANIC FARMING

Farmers are searching for less expensive chemical inputs for crop production (Harwood. 1984). Legumes in crop rotations can substitute for synthetic fertilizers by supplying N. Manures. sludge. composted materials. and rock phosphate can serve as inexpensive nutrient sources as well. Sahs and Lesoing (1985) initiated a field experiment in Nebraska to compare the value of manure and crop rotations versus the use of fertilizers and pesticides on soil characteristics and crop yields in grain production. Results indicated that corn yields in the rotational systems definitely increased in comparison with continuous corn. Weeds were the major inhibitors to corn and soybeans on the treatments with no herbicides. When heat and drought stress was present. yields of corn grown with manure only and in crop rotation were comparable to yields of corn grown in rotation with synthetic fertilizer plus herbicide. and much better than yields for continuous corn with synthetic fertilizer. herbicide. and insecticide. But under ideal growing conditions. yields of corn treated with herbicide. synthetic fertilizer. and insecticide were greater than organic treatment yields (Sahs and Lesoing, 1985).

In an extensive five year farm study which began in 1974 and compared organic versus conventional farming in Wisconsin. Lockeretz et al. (1984) found that while corn and soybean yields were not significantly different between systems. wheat yields were much lower in the organic system. Net returns. however. were approximately equal. and energy consumption and soil erosion were lower in the low-input system. Non-organic rotational systems. as well as an organic system in which manure is assumed to be freely available. out-performed continuous corn (Helmers et al. 1984. Nebraska). When and where manure is assumed to be freely available. combining manure applications with a crop rotation involving legumes can be an effective crop management system.

Liebhardt et al. (1989) initiated a five year cropping system in 1981 in east-central Pennsylvania. to study the transition from a conventional agricultural cropping system which uses pesticides and fertilizers to a low-input system. The alternative low-input rotations were 'low-input with livestock' and 'low-input with cash grain'. Corn grain yields in the low-input systems were 75% of the conventional yields in 1981 to 1984. but yields were not significantly different in 1985. Weed competition and insufficient N limited low-input corn yields during the first four years. Soybean yields in the low-input systems were equal to or greater than conventional yields all five years. It was concluded that a favourable transition from conventional cropping to low-input systems is feasible. but only if crop rotations are used which include crops that demand less N and are competitive with weeds. such as small grain. soybean. or legume hay. It was recommended that corn should be avoided the initial three to four years (Liebhardt et al. 1989. Pennsylvania).

With increased production costs and soil erosion problems. especially under continuous cropping systems. farmers should be aware of alternative farming methods. Manuring. rotations. and the use of cover crop practices could benefit farming operations in the long run. Producers already use many of these practices that will maintain. if not increase. future soil productivity. The extent of their use is commensurate with manure availability. economic feasibility. and application of the most appropriate management cultural practices.

Organic farmers using low-energy inputs may compete financially with conventional farmers by using crop rotations. legumes. and adequate amounts of manure on corn. Economic analyses of net returns suggest that rotational cropping systems are more competitive with conventional cropping systems than generally believed (Helmers et al.. 1984). From both an economic and environmental standpoint. every field crop production system should be modified to include the use of a cover crop either before and after harvest.

3. MATERIALS AND METHODS

3.1 SOILS

A baseline soil survey was completed on all sites (eleven) in 1989 and on two additional sites (Dean Glenney's) in 1990. These surveys involved the gathering of necessary information about the landscape and the agronomic practices through literature review. field verification and primary data collection.

The surveys focused on soil characterization and variability throughout the fields and they were done to describe texture. organic matter. soil structure. permeability. compaction. moisture regime. earthworm abundance. trash cover and soil erodibility as well as microbial activity in the soils.

Composite soil samples were taken from the topsoil for measurement of fertility. pH. organic matter and particle size analysis (about twenty samples from the 0-10 and 10-20 cm intervals). Horizon profiles were determined from holes that were dug using an auger to a depth of 100 cm along various points on a survey grid.

An observation pit was dug for each of the primary treatments to view soil structure. Compaction determinations were completed by taking bulk density measurements (two replications each per A. AB. and B soil horizons at a treatment pit). pocket penetrometer measurements (six replications for the topsoil. compact and subsoil layers per treatment pit) and Dickey-john® penetrometer readings (six replications per treatment site for six 0-8 cm intervals as well as overall field measurements). Three methods for measuring compaction were used because this gave the most complete picture for compaction in the fields. Conditions were such that in 1989 the pocket penetrometer was not performed. Visual compaction ratings (derived from Can-Ag's compaction studies) were also used in the descriptive process. Crop residue estimations were completed using the knotted rope method. These procedures were repeated in the fall 1991 for all participating research fields (seven altogether) to allow comparison with baseline data.

The objective of the microbial biomass study was to annually compare microbial biomass in the upper twenty cm of soil in the standard and O.B.A.T.A. management treatments at benchmark micro-plots on a cross-section of farms. soils and crops. Soil samples were taken from nine. seven. and six fields in the springs of 1989. 1990 and 1991. respectively. Composite soil samples were derived from plots (9 m^2 grids) at 0-10 cm and 10-20 cm (using an auger) resulting in sixteen sub-samples from each of the two depths. Three replications (sets of composite samples) were collected for each of the two treatments. The micro-plots were marked so as to allow repeated composite sampling in the sample place each spring from 1989 to 1991.

3.2 AGRONOMIC PRACTICES

Each spring. field manuals were supplied to the co-operators to record their equipment type and size. the number of operations performed in the field. and the date of the operation as well as all necessary inputs. Inputs included fertilizer. pesticides. seed. and molasses (sugars) and kelp. Each fall. yields were recorded for each field by the farmers. The majority of yields were measured using a weigh wagon provided by Agriculture Canada from the Harrow Research Station. Harrow, Ontario.

3.3 ECONOMICS

Records of farm operations and inputs kept by each farmer were given to Can-Ag Enterprises at the end of each growing season. These records were sorted and organized into various tables for greater legibility. Basic economic evaluation was performed on the basis of inputs and outputs considering the various aspects of standard and O.B.A.T.A. operations.

3.4 EXPERIMENTAL DESIGN AND STATISTICS

The O.B.A.T.A. program has various components that integrate to become a complete package. The study was structured to observe and assess the package with variations occurring only in certain aspects of the program such as the role of cover crops. the need for subsoiling. the need for kelp or sugar and the rate and placement of fertilizers. At most sites there were at least two treatments. one plot of land with the O.B.A.T.A. system of operations and one with the farmer's conventional methods. There was one replication of each treatment per field and the treatments were set up in a randomized fashion within the test field.

A split plot design was used to examine specialized aspects (i.e. with and without subsoiling or cover crops) that vary in the O.B.A.T.A. system. Any farming variations in the regular farming methods could also be incorporated with this approach.

3.4.1 Statistical Analyses of Soil Data

Fertility values (P. K. Mg. Ca. pH and percent organic matter) from selected fields (Mint Klynstra's two fields. Jim House's two fields and Arpad Pasztor's research field) over the three year period were statistically analyzed using analysis of variance procedure (ANOVA) to determine if there were measurable differences between the standard and O.B.A.T.A. treatments within each year and to examine if changes were measurable between years. Only those sites where direct comparisons were possible between both types of treatments were used in the analyses.

The ANOVA and t-test were performed on soil compaction data (Dickey-john® penetrometer pocket penetrometer and bulk density values) to determine if there were significant measurable differences in compaction between treatments within years and if compaction changed from 1989 to 1991 for the different management plots.

The analysis of variance was also used for the biological carbon content (Bio-C µg/g) of soil samples collected to determine if measurable differences existed between conventional and O.B.A.T.A. treatments. as well as between soil depths 0-10 and 10-20 cm for all years.

Comparisons were also done to determine if differences existed between years with respect to microbial biomass content in the soil.

The Duncan's Multiple Range Test (DMRT) was used where required to separate the means for statistical comparisons. Statistical analyses for all rainfall simulation data were completed by Ecological Services for Planning Ltd. and are briefly presented in this report.

3.5 ADDITIONAL STUDIES

Several small studies with a direct link to the O.B.A.T.A. research continued from 1989 through into the 1990 crop season. but. most were not repeated in the 1991 season. These are explained next.

3.5.1 Study of the Effect of Kelp, Molasses, 71B Fertilizer Solution on Soybean Crop Growth and Yield

During 1989 and 1990 Conservation Management Systems (CMS) conducted a study to determine the effects of kelp. molasses. and 71B fertilizer (1990 only) on soybean plant growth and seed yield when used within the O.B.A.T.A. system (aeration tillage system) of farm management. Two sites were selected for this research. one at Mint Klynstra's. the other at Dave McIntosh's, both in Oxford County.

First year treatments consisted of a foliar application of kelp only. a foliar application of molasses only. a foliar application of kelp and molasses. and finally. the control with no foliar application. In 1990. the treatments were the same as in 1989 with the addition of two more treatments; a foliar application of 71B fertilizer solution only. and a foliar application of kelp molasses. and 71B fertilizer solution. Numerous aspects of soybean plant development were recorded throughout both seasons ending with yield determinations.

3.5.2 Effect of Kelp and Molasses Treatments on Soil Micro-Fauna

Dr. A.D. Tomlin of Agriculture Canada at the Packs Lane Research Station in London. Ontario had set up several micro-plots in 1989 to observe the effects of kelp and molasses on soil faunal populations. The study continued through into the 1990 season. Unfortunately. a very high population of corn rootworm infested the plots in the first year of experimentation. The resulting crop damage affected data obtained in the second year. For 1990. growth of the corn was severely stunted. rendering yield estimates and soil faunal analyses useless. The corn was badly damaged because treated corn seed could not be used in the study due to the experimental design. Dr. Tomlin and colleagues did not resume research in 1991 due to these inherent problems.

3.5.3 Rainfall Simulation

In September 1989 rainfall simulation trials were conducted by Ecological Services for Planning Ltd. at John Van Dorp's farm in his second field after winter wheat harvest. Three treatments were set up: first. conventional or standard management (moldboard plow); second. Aer-way® tillage; and third. Aer-way® tillage plus subsoiling. Another' rainfall simulation experiment took place at Jim House's farm (field #1 in winter wheat stubble) in September 1989. This simulation was conducted by Agriculture Canada and had four treatments: moldboard plow, no till, Aer-way®, and chisel and disk management.

In 1990 a greater number of rainfall simulation experiments were set up to investigate runoff and associated losses at different times of the year. The trials were conducted by Ecological Services for Planning Ltd. at three farms belonging to John Van Dorp, Mint Klynstra, and Joe Gerber. At John Van Dorp's farm (field #2) rainfall simulation was used to test the effects of tillage methods on the amount of runoff. soil. and phosphorus losses. On Mint Klynstra's farm (field #2) rainfall simulation was used to test the effects of cover crops in an aeration tillage system on the amount of runoff. soil. and phosphorus losses. At Joe Gerber's farm. these same parameters were measured to test the effects of aeration tillage on his field. The 1990 rainfall simulations were conducted in May. June. and November to represent the spring. summer and fall seasons.

During May 1991 rainfall simulation experiments were completed at John Van Dorp's (field #1) and Mint Klynstra's (field #2) by Ecological Services for Planning Ltd.

4. RESULTS AND DISCUSSION

4.1 SOILS

4.1.1 Fertility

The purpose of monitoring soil fertility was to determine fertility status under each farming system. Soil fertility samples were collected each spring (prior to spring applications of fertilizers) and fall on all fields. Amounts of nutrients applied to standard and O.B.A.T.A. treatments were the same for each farmer. but differed among farmers. No significant differences were found to exist between standard and O.B.A.T.A. management treatments in terms of levels of P, K, Mg, Ca, or pH in 1989, 1990 or 1991 (Table 4).

Levels of nutrients were compared between years 1989. 1990 and 1991 for each treatment (standard and O.B.A.T.A.). The mean level of K in standard plots in 1990 (184 mg/kg) was found to be significantly greater than that detected in 1991 (114 mg/kg) (F=3.92; df=2,22; P=0.0367; n=7. n=10). Likewise. the mean level of K for O.B.A.T.A. plots was significantly greater in 1990 (164 mg/kg) compared with 1991 (109 mg/kg) (F=6.74; df=2,22; P=0.0058; n=7. n=10) (Table 4). No other measurable changes were detected for levels of nutrients within standard or O.B.A.T.A. management treatments between years.

Considering data obtained from fields active the entire study. it was determined that for M. Klynstra. levels of phosphorus were significantly greater in 1990 (38 mg/kg) compared with 1989 or 1991 (both 20 mg/kg) (F=8.67; df=2,11; P=0.0170; n=4) (Table 5). Levels of magnesium in 1989 (342 mg/kg) were found to be measurably greater compared with 1991 levels (183 mg/kg) (F=7.33; df=2,11; P=0.0245; n=4) (Table 5). Calcium levels were found to be significantly greater in 1989 (2633 mg/kg) when compared with 1990 and 1991 levels (1773 and 1785 mg/kg. respectively) (F=9.34; df=2,11; P=0.0144; n=4) (Table 5).

Levels of nutrients in Jim House's fields remained relatively similar over the years with the exception of magnesium where significantly lower levels were detected

Table 4. Mean fertility values for nutrients measured in standard and O.B.A.T.A. management plots in 1989, 1990 and 1991.

Nutrients (mg/kg)	1989		1990		1991	
	standard	O.B.A.T.A.	standard	O.B.A.T.A.	standard	O.B.A.T.A
P	30a	30a	26a	31a	24a	22a
K	148ab	146a	184a	164a	114b	109b
Mg	202a	196a	205a	204a	275a	263a
Ca	2149a	2118a	1942a	1839a	1981a	1810a
pH	6.9a	6.7a	7.0a	6.9a	6.8a	6.9a
% O.M.	3.6a	3.4a	4.4a	4.6a	3.6a	3.5a

Values followed by a different letter within each year for each nutrient are significantly different ($P \leq 0.05$).

Values followed by a different letter within each treatment for each nutrient between years are significantly different ($P \leq 0.05$).

Table 5. Comparison of mean fertility values for nutrients measured in 1989, 1990 and 1991.

Farmer	Year	Nutrients (mg/kg)					
		P (n=4)	K (n=4)	Mg (n=4)	Ca (n=4)	pH (n=4)	%O.M. (n=4)
M. Klynstra	1989	20b	165a	342a	2633a	6.9a	4.8a
	1990	38a	232a	268ab	1773b	7.1a	5.2a
	1991	20b	108a	183b	1785b	6.7a	5.1a
J. House	1989	21a	149a	171a	2991a	6.7a	3.3a
	1990	23a	149a	209a	2297a	6.6a	4.2a
	1991	18a	97a	126b	1862a	6.7a	3.2a
A. Pasztor	1989	46a	143a	96a	1082a	6.9a	2.3a
	1990	48a	150a	103a	824a	6.4a	4.5a
	1991	35a	68b	71a	1025a	7.3a	1.7a

Values followed by a different letter in each sub-column are significantly different ($P \leq 0.05$).
Note: mean values for Arpad Pasztor (1990 and 1991) are n=2.

in 1991 (126 mg/kg) (F=13.99; df=2,11; E=0.0055; n=4). For Arpad Pasztor, levels of potassium (68 mg/kg) were measurably lower in 1991 compared with 1989 (143 mg/kg) and 1990 (150 mg/kg) (F=27.3; df=2,7; P=0.0353; n=2. n=4) (Table 5).

No significant differences concerning changes in percent organic matter were detected between standard and O.B.A.T.A. management treatments for any year: 1989 (F=0.269; df=1.11; P=0.6259; n=6). 1990 (F=0.755; df=1.9; P=0.4340; n=5). and 1991 (F=1.00; df=1.19; P=0.3434; n=10) (Table 4). As well. no significant increases could be detected in O.B.A.T.A. management plots over the period of the study: M. Klynstra (F=0.0432; df=2.5; P=0.9583; n=2). J. House (F=3.186; df=2.5; P=0.1811; n=2) and A. Pasztor (F=1.179; df=2.3; P=0.5457; n=2. n=1) (Table 6).

Likewise, there were no measurable changes in percent organic matter of standard management plots over the period of the study (Table 6). These findings were consistent with all sites across soils ranging from 2 to 6% organic matter. Fluctuations with 1990 percent organic matter results were probably due to lab error as the 1991 values compare very closely to the initial baseline survey.

The statistics revealed that very little impact on fertility across a range of managements and soils. resulted from the implementation of the O.B.A.T.A. program. The key elements. phosphorus and organic matter levels. varied only slightly over the three year study. Over time. increased residue and residue decomposition (an important element of O.B.A.T.A.) may increase the organic matter levels. Phosphorus levels ranged from medium to very high (according to the Ontario Ministry of Agriculture and Food guidelines) across the study fields. Though phosphorus levels did not significantly change in our study. they have the potential to be maintained with less inputs under proper management. Increasing residue will decrease erosion of phosphorus ladened soil particles as well as increasing organic matter and thus improving the availability of soil phosphorus. In addition. the proper choice of cover crop will provide a phosphorus recycler instead of a consumer.

Table 6. Comparison of percent organic matter for standard and O.B.A.T.A. management treatments in 1989. 1990 and 1991 for M. Klynstra. J. House and A. Pasztor.

March 10, 2005Farmer	Year	% Organic Matter	
		standard (n=2)	O.B.A.T.A. (n=2)
M. Klynstra	1989	4.9	4.8
	1990	5.3	5.0
	1991	5.3	4.9
J. House	1989	3.8	2.9
	1990	3.7	4.1
	1991	3.3	3.1
A. Pasztor	1989	2.1	2.4
	1990	4.1	4.9
	1991	1.6	1.8

Note : No significant differences between treatments for each year. or between years for each treatment ($P \leq 0.05$).

For A. Pasztor's 1990 and 1991 treatment values. n=1; 1990 and 1991 overall values. n=2.

4.1.2 Compaction

The purpose for monitoring soil compaction was to determine if there were any measurable changes in either the standard or O.B.A.T.A. treatments over the period of the study. Data were gathered using the Dickey-john® penetrometer. pocket penetrometer and by taking bulk density measurements at prepared observation pit sites.

Dickey-john® compaction rating comparisons between the two years (1989 and 1991) were completed for fields using data from the observation pits. Dickey-john® penetrometer readings in the 0-200, 201-350 and 351-400+ kg/cm^2 were considered low. medium and high, respectively, for compaction rating.

Using standard and O.B.A.T.A. data from the 16-32 cm depth for Mint's first field. compaction appeared to significantly increase from 1989 to 1991. In the standard area compaction ratings increased from 236 kg/cm^2 in 1989 to 353 kg/cm^2 in 1991 (F=84.63; df=1.55; P=0.0000; n=28) (Table 7). In the O.B.A.T.A. area ratings increased from 252 kg/cm^2 in 1989 to 356 kg/cm^2 in 1991 (F=71.31; df=1.55; P=0.0000; n=28). In Mint's second field the same trend was observed. The mean standard compaction estimate rose from 233 kg/cm^2 in 1989 to 375 kg/cm^2 in 1991 (F=113.05; df=1.39; P=0.0000; n=12. n=28). The mean O.B.A.T.A. estimate rose from 238 kg/cm^2 in 1989 to 373 kg/cm^2 in 1991 (F=91.45; df=1.39; P=0.0000; n=12. n=28). Looking more closely at individual sites for each soil depth. Dickey-john® penetrometer readings revealed that for most soil depths in both treatment areas. 1989 had significantly less compaction compared with 1991 (Table 8).

The converse was found to be true in Arpad Pasztor's research field in 1991 (Table 7). In 1989 the compaction rating was significantly greater in the standard area (411 kg/cm^2) compared with that of 1991 (364 kg/cm^2) (F=3.94; df=1.55; P=0.0521; n=24). In the O.B.A.T.A. area there were no significant differences in compaction between the two years (438 versus 396 kg/cm^2. respectively) (F=6.35; df=1.47; P=0.0152; n=24). Table 8 reveals where the measurable differences in compaction exist in each soil layer.

Table 7. Comparison of mean standard and O.B.A.T.A. Dickey-john® penetrometer readings at the 16-32 cm depth for 1989 and 1991.

Farmer	Field No.	Year	Compaction Ratings (kg/cm^2)	
			standard	O.B.A.T.A.
M. Klynstra	1	1989	236b (n=28)	252b (n=28)
		1991	353a (n=28)	356a (n=28)
	2	1989	233b (n=12)	238b (n=12)
		1991	375a (n=28)	373a (n=28)
A. Pasztor	1	1989	411a (n=24)	438a (n=24)
		1991	364b (n=24)	396a (n=24)

Values followed by a different letter in each sub-column are significantly different ($P \leq 0.05$).

Table 8. Comparison of mean standard and O.B.A.T.A. Dickey-john® penetrometer readings between 1989 and 1991 for each soil depth.

Farmer	Field	Depth (cm)	Standard		O.B.A.T.A.	
			1989 n=14	1991 n=14	1989 n=14	1991 n=14
M. Klynstra	1	0-8	10b	159a	3b	161a
		8-16	154b	250a	156b	261a
		16-24	206b	332a	223b	338a
		24-32	264b	373a	280b	375a
		32-40	293b	379a	327b	386a
		40-48	353a	384a	363a	393a
			n=6	n=14	n=6	n=14
	2	0-8	117b	154a	100b	146a
		8-16	150b	250a	150b	259a
		16-24	208b	355a	217b	355a
		24-32	258b	395a	258b	391a
		32-40	292b	400a	308b	400a
		40-48	367b	400a	375b	400a
			n=12	n=12	n=12	n=12
A. Pasztor	1	0-8	122a	104a	129a	121a
		8-16	222a	217a	238a	271a
		16-24	388a	342a	388a	392a
		24-32	434a	385b	488a	400b
		32-40	403a	385a	500a	394b
		40-48	391a	365a	492a	352b

Values followed by a different letter for each farmer within each treatment are significantly different ($P \leq 0.05$).

General comparisons of Dickey-john®compaction ratings were made between the standard versus O.B.A.T.A. areas at the 16-32 cm depth for fields in 1991. In most cases no measurable differences were detected between the different treatments in terms of compaction (Table 9). In Mint Klynstra's first field the plowed section had the greatest mean compaction rating (381 kg/cm^2) compared with the standard section which was Aer-wayed (353 kg/cm^2). and the O.B.A.T.A. section that was Aer-wayed (356 kg/cm^2) (F=2.27; df=2.67; P=0.1110; n=12. n=28. n=28) (Table 9). This observation was not found in his second field where greatest compaction was observed in the standard section which was Aer-wayed (375 kg/cm^2) compared with the plowed section (356 kg/cm^2) (E=1.34; df=2.71; P=0.2676; n=28; n=16). The O.B.A.T.A. section (also Aer-wayed) had a mean compaction reading of 373 kg/cm2 which was not significantly different from the plowed estimate (F=1.34; df=2.71; P=0.2676; n=28; n=16) (Table 9).

For both of Jim House's fields the standard management treatments had higher mean compaction ratings compared with the O.B.A.T.A. management plots. For his first field the standard mean was 381 kg/cm^2 versus the O.B.A.T.A. mean of 383 kg/cm^2 (F=0.0274; df=1.59; P=0.8691; n=24. n=36) (Table 9). For his second field the standard mean was 394 kg/cm^2versus the O.B.A.T.A. mean of 392 kg/cm^2 (F=0.085; df=1.59; P=0.7710; n=24. n=36). The converse was true for Arpad Pasztor's field where the O.B.A.T.A plot had a higher compaction rating (396 kg/cm^2) compared with the standard treatment (364 kg/cm^2) (E=15.12; df=1.47; P=0.1139; n=24) (Table 9).

Comparisons were also made between the standard and O.B.A.T.A. management plots for compaction at each soil layer (0-48 cm. 8 cm increments) for each field in 1991 (Table 10). In general. no measurable differences between treatments could be discerned at any soil depth. The only significant result was found in Arpad's field at the 16-24 cm level where the O.B.A.T.A plot had a mean compaction reading of 392 kg/cm^2 and the standard

Table 9. Comparison of Dickey-john® penetrometer readings at the 16-32 cm depth between treatments for each field in 1991.

Farmer	Field No.	Treatment	Mean (kg/cm^2)
M. Klynstra	1	standard (n=28)	353a
		O.B.A.T.A.	356a
		plow (n=12)	381a
	2	standard (n=28)	375a
		O.B.A.T.A.	373a
		plow (n=16)	356a
J. House	1	standard (n=24)	381a
		O.B.A.T.A. (n=36)	383a
	2	standard (n=24)	394a
		O.B.A.T.A. (n=36)	392a
A. Pasztor	1	standard (n=24)	364a
		O.B.A.T.A. (n=24)	396a

Values followed by the same letter in each sub-column are not significantly different ($P \leq 0.05$).

Table 10. Comparison of 1991 Dickey-john® penetrometer readings (kg/cm^2) between treatments for various soil depths.

Farmer	Field No.	Treatment	Soil Depth (cm)					
			0-8	8-16	16-24	24-32	32-40	40-48
M. Klynstra	1	standard (n=14)	159a	250a	332a	373a	379a	384a
		O.B.A.T.A.	161a	261a	338a	375a	386a	393a
		plow (n=6)	163a	254a	367a	396a	400a	400a
	2	standard (n=14)	154a	250a	355a	395a	400a	400a
		O.B.A.T.A.	146a	259a	355a	391 a	400a	400a
		plow (n=8)	163a	253a	331a	381a	400a	400a
J. House	1	standard (n=6)	225a	279a	366a	396a	400a	400a
		O.B.A.T.A. (n=6)	183a	250a	366a	396a	400a	400a
	2	standard (n=12)	233a	325a	388a	400a	400a	400a
		O.B.A.T.A. (n=18)	215a	331 a	386a	399a	400a	400a
A. Pasztor	1	standard (n=12)	104a	217a	342b	385a	385a	365a
		O.B.A.T.A. (n=12)	121a	271a	392a	400a	394a	352a

Values followed by a different letter in the same sub-column are significantly different ($P \leq 0.05$).

had a mean reading of 342 kg/cm^2 (F=14.14; df=1.23; P=0.0011; n=12) indicating greater compaction in the O.B.A.T.A. plot (Table 10).

Comparisons were performed using pocket penetrometer data for 1991. Standard data alone were used to compare between the soil layers and it was observed that the AB and B horizons had significantly greater compaction (3.48 kg/cm^2 for AB horizon, 3.53 kg/cm^2 for B horizon) compared with the topsoil layer or A horizon (1.53 kg/cm^2) (F=347.2; df=2.89; P=0.0000; n=30). Pocket penetrometer readings for the A. AB and B soil horizons of the O.B.A.T.A. treatments (1.4, 3.45 and 3.25 kg/cm^2, respectively) were lower or comparable with those of the standard treatments (1.53, 3.48 and 3.53 kg/cm^2, respectively) and each horizon was significantly different from the other (F=597.3; df=2.89; P=0.0000; n=30) (Figure 2).

When the two treatments were compared using data from each horizon. the only significant difference found was in the B horizon. The standard had a higher mean reading of 3.53 kg/cm^2 and the O.B.A.T.A. area had a lower mean reading of 3.25 kg/cm^2 (F=23.9; df=1.59; P=0.0000; n=30) (Figure 2).

Analyses of soil bulk density data revealed that for 1991, in Mint's first field, the standard area had significantly greater bulk density compared with O.B.A.T.A. in the A horizon (1.34 g/cm^3 versus 1.23 g/cm^3, respectively) (F=21.2; df=1.3; P=0.0442; n=2) (Table 11). The opposite was found to be true in his second field where the standard had a mean of 1.27 g/cm^3 compared with the O.B.A.T.A. mean which was 1.38 g/cm^3 (F=26.8; df=1.3; P=0.0352; n=2) (Table 11). No other significant differences were found in the A horizon of other fields in 1991.

With respect to the AB horizon or compact layer in 1991, in Mint's second field, the O.B.A.T.A. treated area had a higher mean bulk density reading of 1.53 g/cm^3 compared with the standard (1.43 g/cm^3) (F=25.0; df=1.3; P=0.0377; n=2). On the other hand, in Jim's first field the standard mean bulk density was higher (1.64 g/cm^3) and the O.B.A.T.A. mean

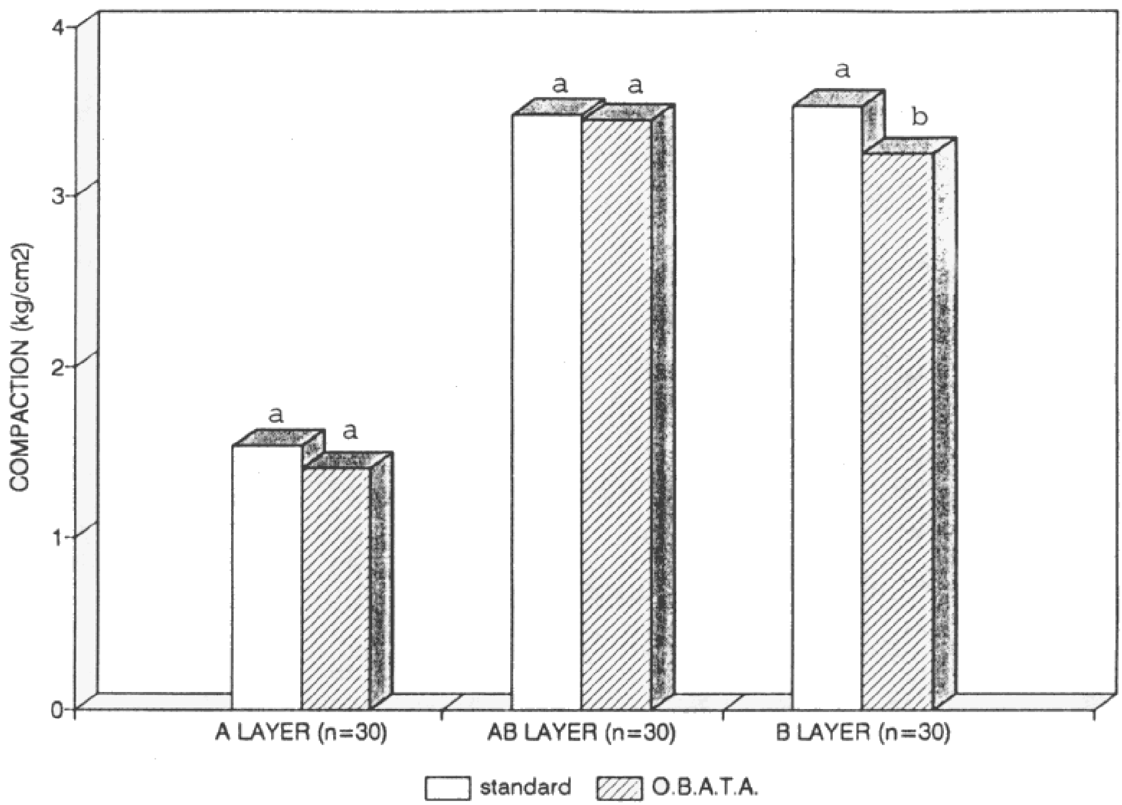

Figure 2. 1991 Pocket Penetrometer Comparisons.

Table 11. Comparison of mean bulk density values (g/cm^3) obtained in 1989 and 1991.

Year	Field No.	Soil Layer	M. Klynstra		J. House		A. Pasztor	
			standard	O.B.A.T.A.	standard	O.B.A.T.A.	standard	O.B.A.T.A
1989 (n=1)	1	A	1.32a	1.38a	-	-	-	-
		AB	1.44a	1.49a	1.55a	1.57a	-	-
		B	1.71a	1.68a	1.60a	1.51a	-	-
	2	A	1.26a	1.27a	1.29a	1.45a	-	-
		AB	1.42a	1.39a	1.44a	1.45a	-	-
		B	1.48a	1.47a	1.37a	1.45a	-	-
1991 (n=2)	1	A	1.34a	1.23b	1.57a	1.53a	1.37a	1.41a
		AB	1.47a	1.50a	1.64a	1.53b	1.56a	1.57a
		B	1.73a	1.66a	1.66a	1.62a	1.48a	1.51a
	2	A	1.27b	1.38a	1.51a	1.47a	-	-
		AB	1.43b	1.53a	1.44a	1.37a	-	-
		B	1.53a	1.60a	1.65a	1.60a	-	-

Values followed by a different letter in the same row for each farmer are significantly different ($P \leq 0.05$). Overall mean values followed by a different letter in the same column are significantly different ($P \leq 0.05$).

reading was lower (1.53 g/cm^3) (F=52.0; df=1.3; P=0.0019; n=2). No other significant measurements between treatments were found in the AB horizon for 1991. No significant differences were detected between treatments in the B horizon for any fields in 1991.

It is worthwhile to note that in 1989, in general, greater bulk density ratings were found in O.B.A.T.A. management plots as opposed to standard management plots. However, for all soil horizons in 1991 the opposite was true. Bulk density ratings for O.B.A.T.A. management plots were generally lower when compared with standard management bulk density measurements.

4.1.3 Microbial Biomass

The purpose of measuring microbial biomass was to compare values in 1990 and 1991 to baseline measurements taken in 1989. This was another tool used to measure changes in the soil due to standard or O.B.A.T.A. management treatments. Measurements were taken each spring from the two treatments at benchmark points of participating fields.

Measurements obtained in 1989 were initial or baseline readings. Microbial biomass measurements in 1991 were more similar to those values obtained in 1989 for both standard and O.B.A.T.A. management plots compared with 1990 values. Considering standard treatments first. 1990 was the year with the lowest soil microbial biomass content (1989=218 µg/g, 1990=180 µg/g and 1991=189 µg/g) (F=2.06; df=2.101; P=0.1323; n=42. n=42, n=18 respectively) (Figure 3). The same trend was observed for O.B.A.T.A. treatments in that 1990 had lowest mean levels and 1989 had greatest mean levels (1989=197 µg/g, 1990=144 µg/g, and 1991=179 µg/g) (F=2.75; df=2.101; P=0.0691; n=42. n=42, n=18 respectively) (Figure 3).

Over the three year period, in standard management plots, there remained significantly greater microbial biomass in the 0-10 cm range (247 µg/g) as opposed to the 10-20 cm range (168 µg/g) (F=6.64; df=1.53; P=0.0142; n=27) (Figure 4). Likewise, there was significantly greater microbial biomass in O.B.A.T.A. management plots detected at

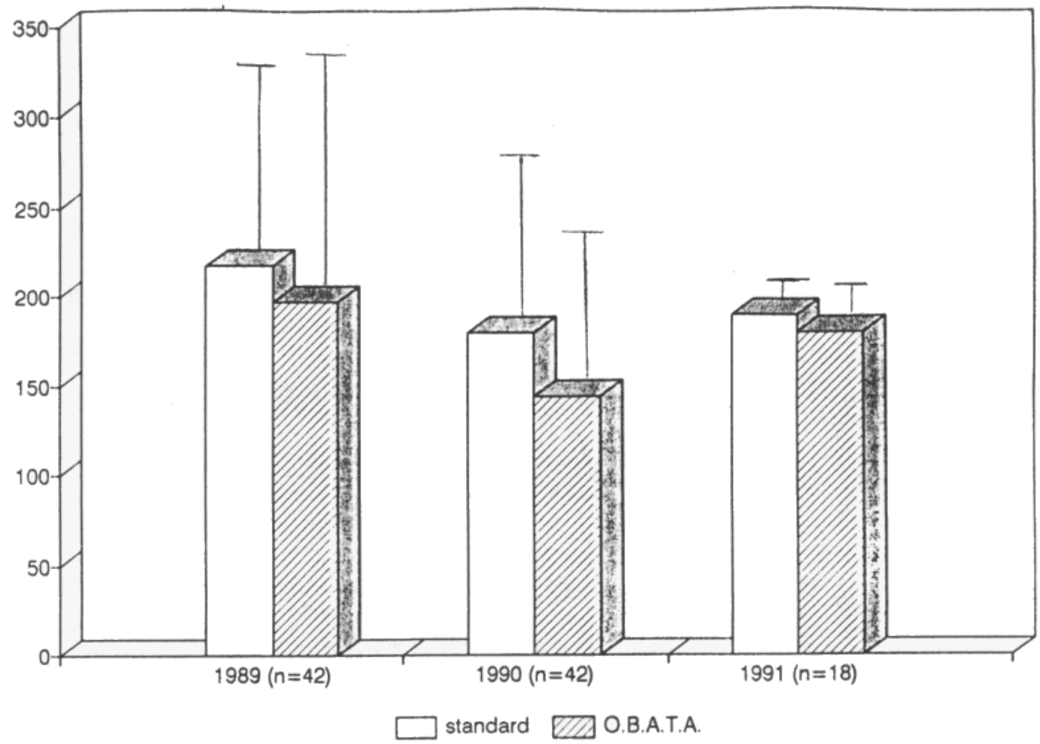

Figure 3. Microbial biomass measurements of standard and O.B.A.T.A. management treatments for 1989. 1990 and 1991.

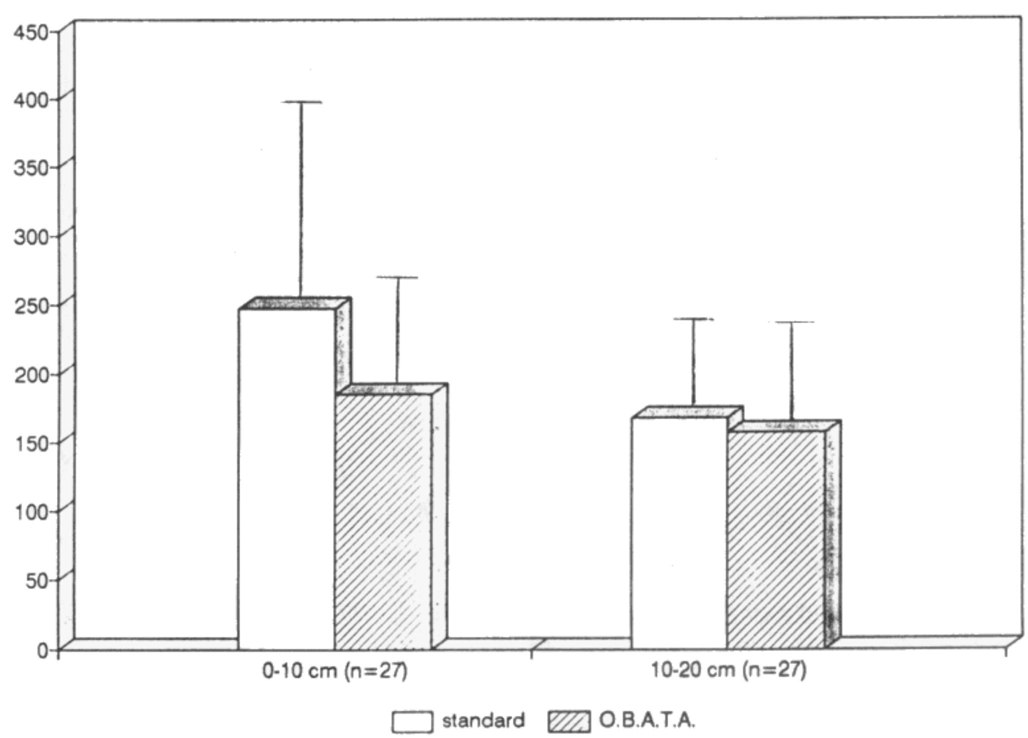

Figure 4. Microbial biomass measurements for 0-10 and 10-20 cm depths over the three year period.

the 0-10 cm depth (185 µg/g) versus 157 µg/g at the 10-20 cm range (F=4.45; df=1.53; P=0.040; n=27) (Figure 4).

Case study analyses were conducted on three sites active in the program for the entire study: Mint Klynstra's second field and both of Jim House's fields. In general, 1989 was the year with the most microbial biomass recorded compared with 1990 and 1991.

For the standard plots in Mint's field. significantly more biomass carbon was observed in 1989 (297 µg/g) compared with 1990 (176 µg/g) or 1991 (202 µg/g) (F=10.53; df=2.17; P=0.0035; n=6) (Table 12). Likewise. significantly more biomass carbon was determined in the O.B.A.T.A. plots in 1989 (346 µg/g) compared with 1990 (181 µg/g) or 1991 (200 µg/g) (F=44.50; df=2.17; P=0.0000; n=6) (Table 12).

No measurable changes in biomass carbon could be determined over the years in the standard plots (F=2.29; df=2.17; P=0.1433; n=6) and the O.B.A.T.A. plots (F=2.78; df=2.17; P=0.1019; n=6) of J. House's first field (Table 12). For the standard plots in Jim's second field, significantly less biomass carbon was found in 1990 (108 µg/g) compared with 1989 (215 µg/g) and 1991 (190 µg/g) (F=8.00; df=2.17; P=0.0062; n=6). The same trend was observed in the O.B.A.T.A. plots (F=4.63; df=2.17; P=0.0323; n=6) of field #2 (Table 12). The overall trend for biomass carbon over the three year period was generally greatest microbial content in 1989 and least in 1990 for Mint's field (F=40.0; df=2.35; P=0.0000; n=12) and both of Jim's fields: #1 (F=3.30; df=2.35; P=0.0556; n=12) and #2 (F=11.6; df=2.35; P=0.0004; n=12) (Table 12).

With respect to depth. an overall significant difference was detected in M. Klynstra's second field between the 0-10 cm (249 µg/g) and 10-20 cm (217 µg/g) depths (F=5.18; df=1.35; P=0.0330; n=18) (Table 13). On closer examination. this measurable difference was attributable to the significant finding in the O.B.A.T.A. treated areas (260 versus 224 µg/g, respectively)

Table 12. Comparison of microbial biomass between years for three fields.

Farmer	Field No.	Year	Microbial Biomass (µg/g)		
			standard (n=6)	O.B.A.T.A. (n=6)	Overall (n=12)
M. Klynstra	2	1989	297a	346a	322a
		1990	176b	181b	178b
		1991	202b	200b	199b
J. House	1	1989	223a	131a	177a
		1990	155a	106a	130b
		1991	174a	181a	177a
	2	1989	215a	152a	184a
		1990	108b	85b	96b
		1991	190a	158a	174a

Values in the same sub-column followed by a different letter are significantly different ($P \leq 0.05$).

Table 13. Microbial biomass comparison between depths for three fields.

Farmer	Field No.	Depth (cm)	Microbial Biomass (µg/g)		
			standard	O.B.A.T.A.	Overall
M. Klynstra	2	0-10	240a	260a	249a
		10-20	210a	224b	217b
J. House	1	0-10	220a	155a	188a
		10-20	148b	123a	135b
	2	0-10	197a	139a	168a
		10-20	145b	125a	135b

Values followed by a different letter in the same sub-column are significantly different ($P \leq 0.05$).

(F=5.36; df=1.17; F=0.0431; n=9) (Table 13). Considering Jim's first field, overall, significantly more biological carbon content was found in the 0-10 cm range (188 µg/g) as opposed to the 10-20 cm range (135 µg/g) (F=9.25; df=1.35; P=0.0060; n=18) (Table 13). Only measurements in the standard treatments (220 µg/g at 0-10 cm and 148 µg/g at 10-20 cm) were found to be significantly different (F=7.39; df=1.17; P=0.0187; n=9).

Likewise for Jim's second field. greater overall biomass carbon was determined closer to the soil surface (168 µg/g at 0-10 cm and 135 µg/g at 10-20 cm) (F=4.12; df=1.35; P=0.0546; n=18) (Table 13). Again. only measurements in the standard treatment area were found to be significantly different between depths (197 versus 145 µg/g, respectively) that attributed to this large difference in biomass carbon (F=5.07; df=1.17; P=0.0439; n=9) (Table 13).

There was a significant difference in biological carbon content in the standard treatment areas between the two depths (more located in the 0-10 cm zone). However. for the most part. in the O.B.A.T.A. treatment areas there seemed to be no obvious differences in biomass content between the two ranges of depth (Table 13).

The greatest microbial biomass measurements were determined for J. Gerber's research field and Mint Klynstra's second field over the three year period (Figure 5). Joe applied manure and used kelp and molasses additions as part of his crop and soil management practice and these operations may have contributed to the boosted levels of microbial life detected in his field in 1989 and 1990. Mint Klynstra was also applying manure as part of his management practice. He also applied kelp and sugar solutions as seed treatments. foliar sprays and residue sprays for some years now. As well. Mint has established cover crops to aid in soil regeneration. To date. it does appear that he has accumulated a good build-up of microbial life in his soil (Figure 5).

In general. the lowest counts of microbial biomass were observed for Arpad Pasztor's two fields (Figure 5). These sites lay on very sandy soil and did not have

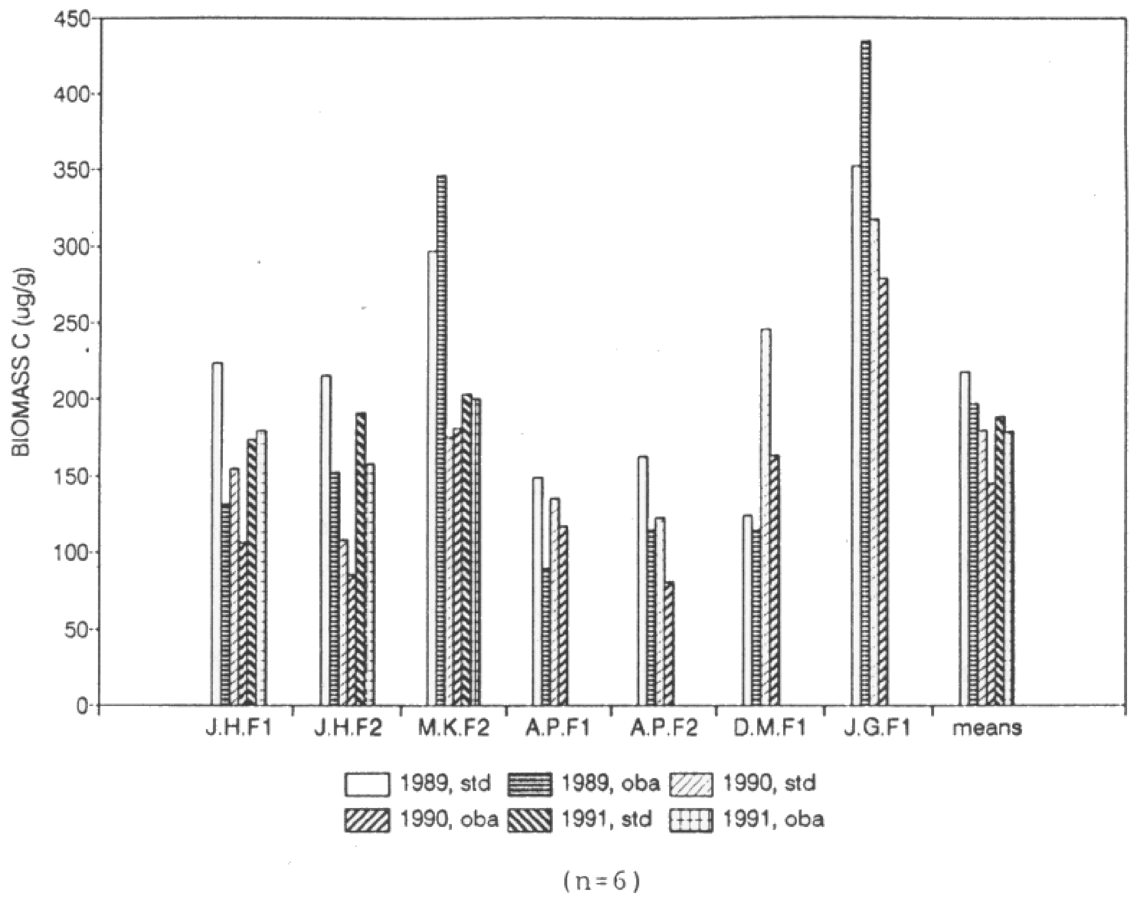

Figure 5. Microbial biomass of standard and O.B.A.T.A. treatments for all fields from 1989 to 1991.

applications of manure or use of kelp and sugar as part of regular farm management.

Microbial biomass is a such a variable parameter to measure. It fluctuates depending on time of sampling, moisture or temperature conditions of the soil, type of soil tillage, previous crop grown etc. Because of these varying factors it is questionable as to how useful a measure the microbial biomass of the soil is. It could take many years of careful soil management and research to find measurable changes for this parameter in the soil profile. To date. no visible trends in microbial biomass development could be observed.

4.2 AGRONOMY

4.2.1 Crop Yields

The purpose for monitoring crop yields was to determine if differences could be measured in yields between standard and O.B.A.T.A. management plots for each year of the study. Yields were taken every fall for each treatment by the farmers.

Figure 6 shows 1989 winter wheat yields for two fields. M. Klynstra's second field (Oxford county) and J. House's first field (Elgin county). On M. Klynstra's site. the O.B.A.T.A. plot yielded higher (54 bu/ac, n=1) compared with the standard plot (51 bu/ac, n=1). On J. House's site. the O.B.A.T.A. plot yielded greater (59 bu/ac, n=1) compared with the standard plot (52 bu/ac, n=1). When treatment yields were compared with their county averages. O.B.A.T.A. plots yielded similar to or greater than the county averages (Figure 6). The only O.B.A.T.A. practice implemented on the wheat fields at this point was a May foliar spray of kelp. molasses and 71B fertilizer. In general. considering the two winter wheat sites. although O.B.A.T.A. plots yielded 5 bu/ac more over standard sites. no significant difference could be detected between the standard (52 bu/ac) and O.B.A.T.A. (57 bu/ac) management winter wheat yields ($t=3.19$; $df=2$; $P=0.0858$; $n=2$) for 1989.

Figure 7 shows mean soybean yields for 1989. 1990 and 1991 for O.B.A.T.A. and standard management treatments. In 1989, O.B.A.T.A. plots (41 bu/ac) yielded greater

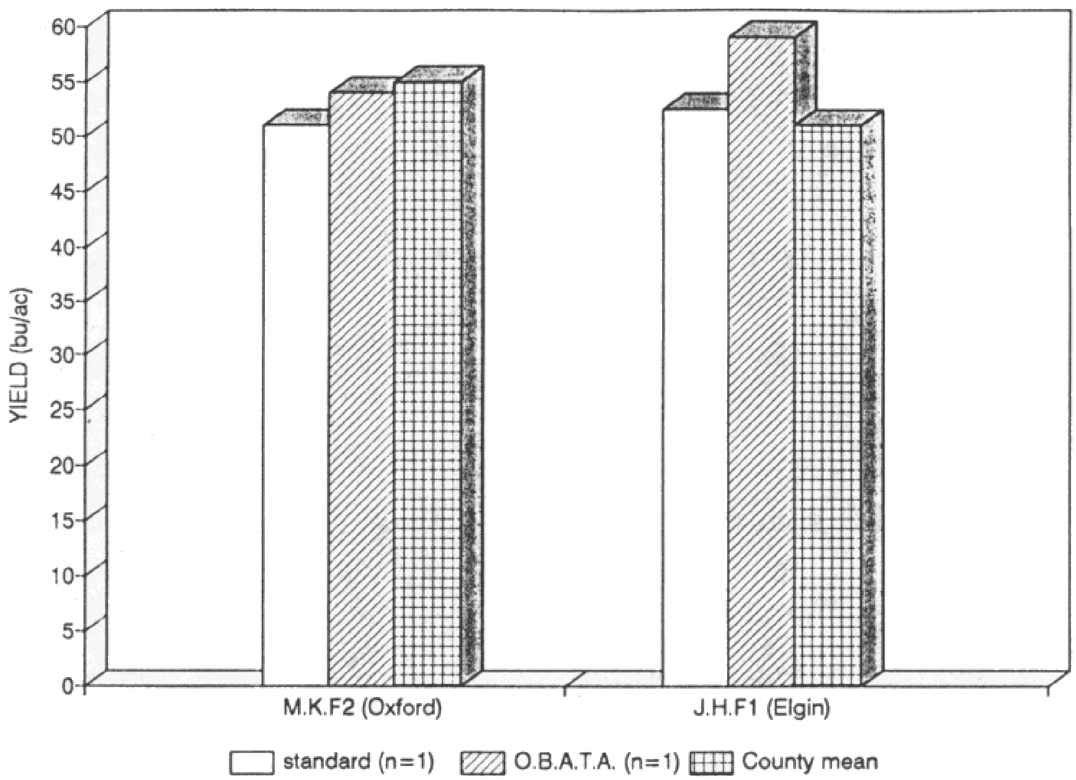

Figure 6. Comparison of standard and O.B.A.T.A. winter wheat yields with Oxford and Elgin county mean yields for 1989.

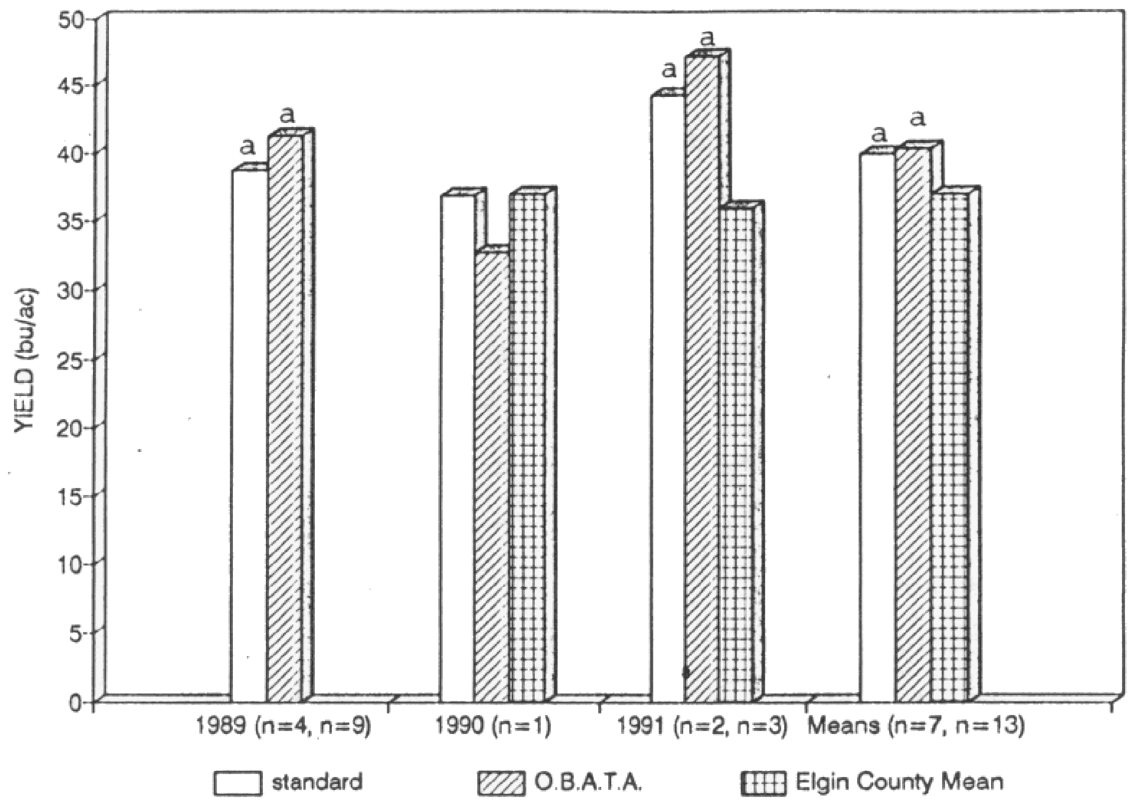

Figure 7. Comparison of standard. O.B.A.T.A. and Elgin county mean soybean yields for 1989. 1990 and 1991.

compared with the standard plots (39 bu/ac) (t=1.59; df=11; P=0.1411; n=9. n=4). In 1990, J. House's standard plots had the highest yields (37 versus 33 bu/ac, n=1). In 1991, O.B.A.T.A. plots from J. House's fields yielded greater compared with the standard plots (47 versus 44 bu/ac) (t=1.17; df=3; P=0.3249; n=3, n=2). The overall mean yields for the three year period are relatively the same (40 bu/ac for standard management and 42 bu/ac for O.B.A.T.A. management) (F=0.327; df=1.19; P=0.5746; n=7, n=13. respectively).

Mean soybean yields for Elgin county in 1990 and 1991 were used for comparison purposes with soybean yields obtained from J. House's research sites. In 1990. the standard treatment in Jim's first field (37 bu/ac, n=1) yielded similar to the county mean (37 bu/ac). O.B.A.T.A. yielded lower having a value of 33 bu/ac (n=1). In 1991. standard (44 bu/ac, n=2) and O.B.A.T.A. (47 bu/ac, n=3) management plots both out performed the Elgin county mean (36 bu/ac). The overall mean yield for the county was less than the standard and O.B.A.T.A. mean yields (Figure 7).

Figure 8 shows corn yields from 1989. 1990 and 1991. In 1989. corn yields were significantly higher in the standard management plots (127 versus 101 bu/ac) (t=5.98; df=7; P=0.0005; n=4. n=5). In 1990. standard (119 bu/ac) and O.B.A.T.A yields (121 bu/ac) were comparable (t=0.801; df=16; P=0.4348; n=7, n=11). In 1991. O.B.A.T.A. management plots were 6 bu/ac greater (160 bu/ac) compared with the standard plots (154 bu/ac) (t=1.75; df=11; P=0.1083; n=8, n=5). The overall mean yields for the three year period were relatively the same (132 bu/ac for standard management and 130 bu/ac for O.B.A.T.A. management) (F=0.028; df=1.39; P=0.8678; n=16, n=24. respectively). No comparisons were made with county means as mean yields were obtained from various counties combined (Oxford, Elgin and Haldimand-Norfolk).

All the fields in 1991 were planted to corn with the exception of Jim House who strip cropped with corn and soybeans on both his fields. Corn yields obtained from John

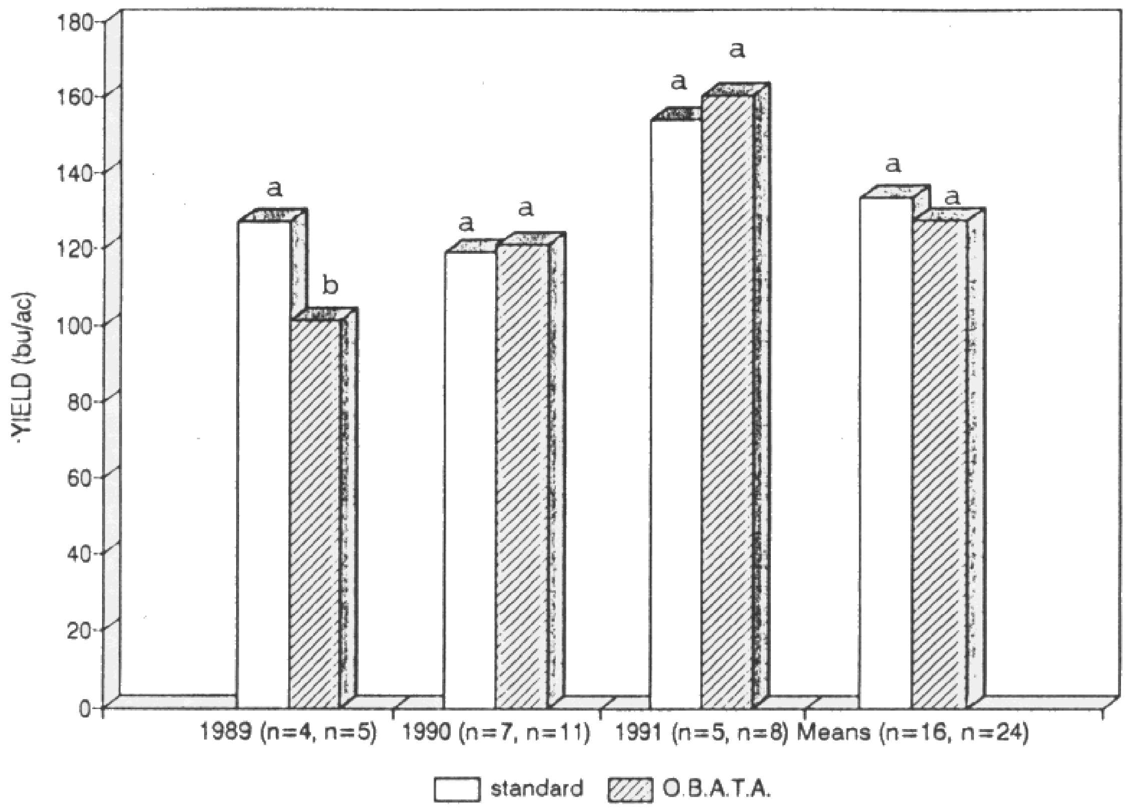

Figure 8. Comparison of standard and O.B.A.T.A. mean corn yields for 1989. 1990 and 1991.

Van Dorp's first field in 1991 showed no real differences between his O.B.A.T.A. plots: Aer-way® alone (104.0 bu/ac, n=1) versus Aer-way® + disk once (102.5 bu/ac, n=1) versus Aer-way® + disk twice (104.0 bu/ac, n=1) (Table 14). All yields were relatively similar. In his second field where there were no formal treatments in 1991. John recorded yields from his 1990 cover crop areas. Yields ranged from 108.0 bu/ac in the red clover section to 120.0 bu/ac in the summer-planted hairy vetch plot (Table 14). Those plots which were burdened with weeds such as lambsquarters. ragweed and grasses (red clover and spring-planted hairy vetch plots) yielded the lowest (Table 14). The summer-planted hairy vetch and oilseed radish plots which were located lower on the slope of the hill had less weed problems and had the greatest yields.

Yields obtained from Mint Klynstra's first field showed favourable results for O.B.A.T.A.. His standard treatment (Aer-way, no foliar spray) yielded 144.0 bu/ac (n=1). His O.B.A.T.A. treatments ranged from 149.4 to 155.5 bu/ac (n=1) (Table 14). Similar results were observed in Mint's second field. The lowest yield was obtained from his standard plot (129.2 bu/ac, n=1: Aer-way®, no foliar spray) and the highest yield from his O.B.A.T.A. plot (Aer-way®, foliar spray) at 136.4 bu/ac (n=1), about a 7 bu/ac difference (Table 14).

Data obtained from Jim House's fields revealed greater yields in both fields from all O.B.A.T.A. plots in both the corn and soybean crops (Table 14). In field #1 the standard corn yield was 159.6 bu/ac (n=1) versus 174.7 bu/ac (n=1) in the O.B.A.T.A. plot; there being a 15 bu/ac difference in favour of O.B.A.T.A. (Table 14). In Jim's second field the corn yield was 220.8 bu/ac (n=1) in the standard plot versus 248.2 bu/ac (n=1) in the O.B.A.T.A. plot (27 bu/ac difference). His soybeans ranged from 49.8 bu/ac (n=1, standard) to 51.6 bu/ac (n=1, O.B.A.T.A.) in his field #1, and 38.8 to 39.6 bu/ac (n=1). standard versus O.B.A.T.A., respectively, in his second field (Table 14). Arpad Pasztor's study plots in 1991 consisted of a standard and an O.B.A.T.A. management treatment. A June foliar spray was the only difference between the two treatments. Both corn plots

Table 14. 1991 Crop Yields (bu/ac).

Farmer	Crop	Field	Treatment	Yield (n=1)
J. Van Dorp	corn	1	Aer-way®alone	104.0
			Aer-way®+ disk (lx)	102.5
			Aer-way®+ disk (2x)	104.0
		2	1990 red clover	108.0
			1990 spring planted	112.0
			1990 summer planted	120.0
			1990 oilseed radish	115.0
M. Klynstra	corn	1	standard (Aer-way® no foliar spray)	144.0
			O.B.A.T.A. (oilseed radish. foliar spray)	155.5
			O.B.A.T.A. (hairy vetch-oats. foliar spray)	149.4
		2	standard (Aer-way. no foliar spray)	129.2
			O.B.A.T.A. (Aer-way. foliar spray)	136.4
J. House	corn	1	standard	159.6
			O.B.A.T.A.	174.7
		2	standard	220.8
			O.B.A.T.A.	248.2
	soybean	1	standard	49.8
			O.B.A.T.A. (foliar spray)	51.6
			O.B.A.T.A. (no foliar spray)	50.2
		2	standard	38.8
			O.B.A.T.A.	39.6
A. Pasztor	corn	1	standard	116
			O.B.A.T.A.	116.0

the two treatments. Both corn plots yielded 116.0 bu/ac (n=1) in 1991. thus indicating no real difference between treatments in terms of yield (Table 14).

Overall. 1991 O.B.A.T.A. yields for corn (166 bu/ac) were consistently greater compared with the corresponding standard yields for corn (154 bu/ac) (F=0.159; df=1.9; P=0.7005; n=5) and for soybeans (44 versus 46 bu/ac respectively) (F=0.0255; df =1.3; P=0.8878; n=2).

4.3 ECONOMICS

Basic economic evaluation was performed on the basis of inputs and outputs considering the different aspects of standard and O.B.A.T.A. operations. The resultant values are estimations of what could be expected in terms of investments and returns.

4.3.1 Alternative Inputs

The O.B.A.T.A. approach to farming has four alternative inputs compared with conventional farming. These include the seed treatment in the spring at planting. foliar spraying during early to middle summer, cover crop establishment during middle to late summer or fall, and residue spraying after harvest.

Treatments vary with respect to ingredients (types, amounts etc.) and therefore vary in costs. The seed treatment includes kelp and molasses or other type of sugar and costs \$6/ac (\$15/ha) on average (Table 15). The foliar spray is more expensive (about \$13/ac or \$33/ha) as it may contain a variety of ingredients depending on the farmers' choice (kelp. sugar, fish emulsion, fertilizer etc.). The residue spray consists of kelp and sugar (eg. molasses) and the cost on average would be \$6/ac (\$15/ha). The total cost for these treatments (if all were completed for the season) would be approximately \$25/ac or \$62/ha (Table 15). Table 15 also lists the additional benefits of using kelp and sugar as part of the O.B.A.T.A. system of farming.

Table 15. Costs and Potential Benefits Associated with O.B.A.T.A. Seed, Foliar and Residue Treatments.

Treatment	Average Cost/ac ($)	Average Cost/ha ($)
seed treatment	6	15
foliar spray	13	33
residue spray	6	15
TOTAL	25	62

Potential Benefits

- kelp is a growth promoter
- acts as a tonic where plants take up more nutrients from the soil

- molasses or sugar acts as an energy source
- molasses. in particular. is rich in natural minerals. enzymes and amino acids
- aids in controlling some fungal diseases (Fusarium sp.)
- with increased sugar levels in plants. may directly feed and enhance biological life

- changes in soil biological life affect soil biochemical processes and ultimately influence soil fertility and plant growth

Increased management is required to properly implement a cover crop program but the demonstrated benefits will lead to improved soil sustainability. The purchase of cover crop seed is an alternative expense. Examples of cover crops. prices and seeding rates used by co-operators in this study are given in Table 16. Costs per acre ranged from $8/ac ($20/ha) for oats or rye to $38/ac ($94/ha) for hairy vetch.

Table 16 also lists all the additional benefits of using cover crops as part of the O.B.A.T.A. farming practice. Some of the more important benefits are soil structure improvement. suppression of weed growth. and improved water penetration and retention in the soil etc..

4.3.2 Reduced Inputs

Several operations were similar on standard and O.B.A.T.A. management treatments such as herbicide application. planting and combining during this study. Reduced inputs applicable to O.B.A.T.A. were fertilizer applications and tillage.

Table 16 lists many of the benefits for using cover crops in the O.B.A.T.A. farm system. One of the benefits to using cover crops is that some can scavenge nutrients for later release to principal crops (eg. oilseed radish). The cover crop chosen may be able to fix nitrogen. or can actively be a phosphorus recycler. For example, fertilizer costs could be reduced once nitrogen fixing cover crops are properly incorporated in the rotation. Cover crops help to maintain good levels of nutrients in the soil (alone or with animal manures). By adding organic matter. cover crops assist in replenishing lost nutrients in the soil. Thus, there is the potential that the farmer could reduce or eliminate some fertilizer applications. because the cover crop becomes a substitute for the fertilizer.

Costs associated with tillage differ depending on the implement used, and the tillage tools themselves vary beginning with price. The moldboard costs the most at $13,000 (five furrow) in price. The soil saver which costs less is $8,500 (ten foot), and the Aer-way®

Table 16. Costs Associated with the Use of Cover Crops.

Cover crop	Cost/lb ($)	Examples of Seeding Rates (lb/ac)	Average Cost/ac ($)	Average Cost/ha ($)
hairy vetch	1.50	25	38	94
oilseed radish	0.91	18	16	40
red clover	1.50	14	21	53
rye	0.10	75	8	20
ryegrass	0.75	35	26	65
oats	0.18	44	8	20
buckwheat	0.25	75	19	48

<u>Potential Benefits</u>

- scavenge nutrients for later release to principal crops
- nitrogen fixation
- adds biomass and thereby builds soil organic matter thus improving soil structure
- replenish nutrients and organic matter

- suppresses the growth of weeds (through competition for resources, smothering mat over surface of the soil. allelopathic capabilities of some cover crops)

- influence macro-organisms in the soil (eg. earthworms, better survival under ground cover, the greater the population of earthworms. the healthier the soil)

- foliage canopy acts as an umbrella (reduces the impact of precipitation and retards surface runoff)
- protects the soil by an increase ground cover, thus decreasing soil loss

- enhances water penetration/retention in the soil
- recycling action of nitrogen benefits soil. prevents accumulation in the ground water

which costs the least is priced at $5,800 (ten foot) with an optional $2,200 for wheels (total of $8,000 with wheels, ten foot width).

The operation costs are also different when the three implements are compared. It costs the farmer $15.45/acre ($10.00-$20.00 range) to operate the moldboard. To operate the soil saver is a little less expensive being $13.88/acre ($6.00-$18.00 range). and to operate the Aer-way® costs $8.00/acre ($6.00-$14.00 range) (1991 Ontario Custom Farmwork Rates, Farm and Country Magazine, 12 May 1992 issue). A farmer would have to purchase or rent the Aer-way® but he could use his conventional seed drill and most other implements without changes. Farmers save on energy costs in that the Aer-way® implement requires less drawbar horsepower than other conservation tillage implements. All in all. the Aer-way® represents the tillage implement with the least amount of cost to the farmer (costs: moldboard > soil saver > Aer-way®).

Reduced cultivation is another example of overall reduced tillage in the O.B.A.T.A. program. The growth of cover crops help to suppress weeds through competition with weed growth for resources such as light. water and space. Some cover crops have allelopathic abilities (eg. rye) that stunt weed growth. thus there is the potential for less cultivation in those fields with established cover crops.

4.3.3 Crop Returns

Returns on O.B.A.T.A. treatments were comparable with standard treatments over the three years. O.B.A.T.A. returns in 1991 were superior compared with conventional returns based on 1991 average corn yields and a 1991 price of $112.69/tonne. Table 17 shows that returns in favour of O.B.A.T.A. management could range up to $78/ac or $195/ha more (the average being $18/ac or $45/ha). The main difference between standard and O.B.A.T.A. treatments in 1991 was foliar spraying (average of $13/ac or $33/ha additional cost). Extending the study would be necessary to determine if this

Table 17. Potential Returns for Standard and O.B.A.T.A. Corn Yields in 1991.

Farmer	Field #	Standard Yield (bu/ac)	Standard Price/ac* ($)	O.B.A.T.A. Yield (bu/ac)	O.B.A.T.A. Price/ac* ($)	Difference Price/ac* ($)
M. Klynstra	1	144.4	414	155.5	445	31
				149.4	427	14
	2	129.2	370	136.4	390	20
				142.4	408	38
J. House	1	159.6	456	174.7	500	44
	2	220.8	632	248.2	710	78
A. Pasztor	1	116	332	116	332	0
Average		153.9	441	160.4	459	32**

* Based on corn price of $112.69/tonne and 39.37 dry bu/tonne.

** $32/acre = $80/ha

increase from the O.B.A.T.A. treatment was a continuing trend derived from improved management of the O.B.A.T.A. system and improved soil conditions.

4.3.4 Summary

The results show that O.B.A.T.A. practices can be superior to conventional practices in terms of economics. With respect to crop yields. gross returns increased by $80/hectare more for O.B.A.T.A.. The amount of alternative inputs and resulting net returns would depend on the farmer with the O.B.A.T.A. system. Overall. in 1991 the O.B.A.T.A. system proved to be comparable to or better than the standard management system in terms of yields and profits.

When potential soil losses were converted into dollars (see Soil Erosion section for greater detail). the moldboard tillage system lost an amount equivalent to $81 /ha/yr, $51 ha/yr for the chisel plow, $31 ha/yr for the Aer-way® and finally, $18/ha/yr for the no-till system on 9-15 % slopes.

The O.B.A.T.A. approach to farming has many additional positive aspects in the long term. Table 18 gives examples of these benefits. such as. enhanced soil conservation and improvement of soil structure. but it is difficult to assign dollar values to these in a short term study. In terms of economics. the bottom line at this time appears to be: comparable expenses. comparable or slightly higher returns. greater security in a more diversified cropping base. and much better soil conservation.

4.4 ADDITIONAL STUDIES

4.4.1 Kelp and Molasses Studies

As mentioned previously, two additional studies were conducted in 1989-1990 to observe the effects of kelp and molasses. Conservation Management Systems (CMS) experiments researched soybean plant development and seed yield. It was concluded that the use of kelp and/or molasses and/or 71B fertilizer solution as a seed or foliar treatment

Table 18. General Benefits of the O.B.A.T.A. System of Farming.

- reduced tillage
- reduced chemical inputs
- reduced soil erosion
- reduced the potential for non-point pollution (phosphorus, nitrogen, pesticides)

- control soil and/or water degradation
- enhanced soil conservation
- improve on soil structure
- increase percent organic matter
- maintain good levels of nutrients in the soil (through the use of animal manures and cover crops)

- foster researcher and farmer interaction
- promote public/private sector co-operation

on a one year application basis did not significantly affect the growth and yield of soybeans when included as part of the Aer-way® crop production system. From the side-by-side comparison trials it was determined that the use of a seed treatment of kelp and molasses plus foliar application did not significantly affect soybean plant growth or seed yield on a one year application basis. Their findings indicated no significant differences in yields at either site.

The other study conducted by Dr. Tomlin from Agriculture Canada at Pack's Lane Research Facilities in London, Ontario looked at yield and soil micro-fauna populations with and without kelp and molasses treatments. In 1989 there was no significant difference in yields and no apparent difference in fauna populations. To date they have not found any significance difference in yields and/or soil faunal populations between plots with or without kelp and molasses. Studies were not continued in 1991 due to inherent problems with the research.

4.4.2 Rainfall Simulation

In 1989, 1990, and 1991 rainfall simulation experiments were conducted by Ecological Services for Planning Ltd. and Agriculture Canada (1989 only) at various co-operator's sites. The purpose of these experiments was to determine the effectiveness of cover crops and aeration tillage systems in reducing water runoff, soil, sediment and phosphorus losses. The findings presented here are general and abbreviated. For more detailed information see the Yearly Reports for Rainfall Simulation prepared by Ecological Services for Planning Ltd.

In 1989, rainfall simulation tests conducted on 18-19 September 1989 on John Van Dorp's field (silt loam texture) revealed that soil and phosphorus losses were approximately five times greater on moldboard plowed plots as opposed to plots that were Aer-wayed alone or Aer-wayed and subsoiled (Table 19). In May. June and November 1990, runoff volume was consistently higher from the plowed plot at John's site. In June, runoff

Table 19. Data from Rainfall Simulations Testing the Effects of Tillage Methods on Runoff. Sediment. and Phosphorus Losses Conducted at the Farm of John Van Dorp by E.S.P. Ltd. from 1989 to 1991.

Date	Tillage	% Slope	% Residue Cover	Runoff Volume (L/m^2)	Soil Loss (g/m^2)	Sediment P Loss	Ortho P Loss (mg/m^2)
18-19 Sept. 1989	moldboard (Sept.'89)	17	4	2.8a	8.6a	13.0a	0.33a
	Aer-way	13	37	0.62b	1.9b	2.8b	0.12a
	Aer-way®+ subsoiler (Aug.'89)	13	38	0.80b	1.7b	2.6b	0.16a
2-3 May 1990	moldboard (Sept.'89)	13.8a	10c	2.4a	51.4a	52.2a	3.0a
	Aer-way	9.8a	46b	0.5a	1.1a	2.1a	12.2a
	Aer-way®+ subsoiler	9.7b	93a	0.8a	0.8a	1.3a	2.6a
4 June 1990	moldboard (Sept.'89)	11.0a	2b	25.9a	413.4a	405.3a	-
	Aer-way	8.8a	10b	12.4b	83.5b	86.7b	-
	Aer-way®(May'90) Aer-way®+ subsoiler	10.3a	57a	1.5c	7.2b	11.7b	-
6-7 Nov. 1990	no till (plowed Sept.'89)	10.0	92	30.7	4.5	4.4	-
	Aer-way®	9.5	86	19.6	4.4	4.6	-
13 May 1991	Aer-way®	6.3a	42a	3.0a	1.2a	1.39a	2.45a
	disk	6.0a	45a	0.5b	0.2b	0.21b	0.58b
	Aer way®+ disk	5.3a	28a	0.7b	0.3b	0.32b	0.27b

Means in each sub-column followed by the same letter are not significantly different.

Note: rainfall simulations were conducted in 1989-1990 on field #2 in and 1991 on field #1.

measured from the plowed treatment was double that of the aeration tilled (Aer-way® only) treatment, and twenty times that of the 'Aer-way®+ subsoiler' treatment. In November. runoff volume from the plowed treatment was 28% greater compared with the 'Aer-way® only' treatment (Table 19).

More sediment P was lost from the plowed treatment than from the other two during the May and June 1990 simulations at John's rainfall simulation site. In June. phosphorus loss from the plowed treatment was significantly higher than the other two treatments (Table 19). The large differences in sediment P loss between treatments in May and June indicate that Aer-way® tillage can be an effective practice for soil and phosphorus conservation. The June 1990 results show reductions in P loss of 79% compared to fall plowing (Table 19). Where the previous year's hairy vetch crop had not been killed by the Aer-way®, the average reduction in P loss was 97% compared to moldboard plowing.

Only one of the orthophosphate-P concentrations in June 1990 and none in November 1990 were above the 0.01 mg/L detection limit at John's. In May 1990, the highest losses of orthophosphate-P were from the Aer-wayed treatment, but the difference was not significant (Table 19).

On John's farm, sediment loss from the plowed soil was greater than from reduced tillage treatments for the May, June, and November 1990 simulations (Table 19). Sediment concentration in the runoff water was highest from the plowed treatment in May and June 1990, probably due to the lower soil cover. In November 1990. runoff water from the no till treatment (plowed in September 1989) was lower in sediment content than from the 'Aer-way® treatment (Table 19).

Rainfall simulation tests conducted on 13 May 1991 in John Van Dorp's first field revealed that runoff volume was significantly greater on the Aer-way® alone treatment compared with disk alone or Aer-way® and disk treatments (Table 19). Soil loss, sediment P loss and Ortho P loss were also all significantly greater in the Aer-wayed strip compared with the other treatments which included the disk.

In May 1990 at Mint's site, runoff was very low from all areas of cover crops (Table 20). All of the treatments were providing excellent erosion control. None of the cover crops resulted in significantly different amounts of runoff in May, June, or November 1990. For Mint, soil loss from the clover treatment in November was significantly greater than that from the hairy vetch site. The high soil loss from the clover treatment in November 1990 was due to a greater amount of runoff and a sediment concentration (more than twice that from any of the other treatments) (Table 20). For Mint, the average P loss from the hairy vetch treatment in June 1990 was nearly ten times less than the oilseed radish and approximately six times less than the rye and clover treatments (Table 20). In November 1990, the clover treatment lost more sediment phosphorus than the other treatments since it generated more runoff with a higher sediment concentration. In June and November. orthophosphate-P was detected in the runoff from the rye and clover treatments at Mint's. The loss of orthophosphate-P was highest from the clover treatment (Table 20).

On Mint Klynstra's field, percent residue cover was significantly greater on the Aer-wayed strip compared with the moldboard plowed strip (8 May 1991). However. there was more runoff and Ortho P loss recorded coming off the strip that was aeration tilled (Table 20). On the other hand. soil loss and sediment P loss were greater in the moldboard plowed plot compared with the Aer-wayed plot.

Similar to results on John Van Dorp's site, rainfall simulation conducted by Agriculture Canada on 5-6 September 1989 in Jim House's first field (loam texture. slope: 6-7%) revealed that soil losses were at least eleven times greater on moldboard plowed plots as opposed to no till or Aer-wayed plots (Table 21). Figure 9 shows soil losses for the four tillage systems. The moldboard plow created, by far, the most soil runoff. The other three systems produced losses similar to each other. The enlarged difference here was caused by the high rainfall intensity created by the rainfall simulator.

On Joe's site. the aeration tillage treatment had a rougher surface and more cracks in the soil than the standard treatment. Although the difference was not statistically

Table 20. Data from Rainfall Simulations Testing the Effects of Cover Crops in an Aeration Tillage System and Tillage Methodson Runoff. Sediment, and Phosphorus Losses Conducted at the Farm of Mint Klynstra by E.S.P. Ltd. from 1990 to 1991.

Date	Cover Crop	% Slope	% Residue Cover	Runoff Volume	Soil Loss (g/m^2)	Sediment P Loss	Ortho P Loss ($m^g/m2$)
7-9 May 1990	hairy vetch	6.5a	97a	0.10a	1.3a	1.4a	-
	oilseed radish	6.3a	65b	0.10a	0.7b	0.9a	-
	rye	6.2a	93a	0.05a	0.2a	0.2a	-
	clover	5.5a	98a	0.07a	0.2a	0.3a	-
5-6 June 1990	hairy vetch	2.8a	58a	2.2a	6.3a	6.8a	< 0.2c
	oilseed radish	2.0a	23b	7.6a	61.5a	63.6a	< 0.8bc
	rye	3.8a	39ab	4.2a	30.6a	41.1a	3.7ab
	clover	4.3a	57a	8.8a	28.1a	40.9a	5.3a
20-21 Nov. 1990	hairy vetch	3.5a	79a	12.2a	1.2b	1.lb	< 0.5a
	oilseed radish	3.8a	63a	17.6a	4.8ab	5.2ab	< 1.7a
	rye	4.5a	78a	15.8a	3.9ab	4.1 ab	5.9a
	clover	4.0a	66a	23.7a	14.1a	15.6a	18.0a
8 May 1991	Aer-way®	4.0a	90a	12.6a	0.5a	0.47a	3.63a
	moldboard	4.3a	5b	3.5a	5.1a	3.31a	0.13b

Means in each sub-column followed by the same letter are not significantly different.
Note: rainfall simulations were conducted in Mint's field #2.

Table 21. Data from Rainfall Simulations Testing the Effects of Tillage Methods on Runoff and Sediment Losses Conducted at the Farm of Jim House (field #1) by Agriculture Canada in 1989.

Date	Tillage	% Slope	Time to Runoff (sec)	Runoff Volume (L)	Average Concentration of Sediment (g/L)	Total Sediment mass (g)
5-6 Sept. 1989	moldboard	6-7	540	9.9	57.32	567
	no till	6-7	270	27.6	1.74	48
	Aer-way®	6-7	971	2.5	6.61	16
	chisel/disk	6-7	660	5.4	8.94	48

Table 22. Data from Rainfall Simulations Testing the Effects of Tillage Methods on Runoff. Soil. and Phosphorus Losses Conducted at the Farm of Joe Gerber by E.S.P. Ltd. in 1990.

Date	Tillage	% Slope	% Residue Cover	Runoff Volume	Soil Loss (g/m^2)	Sediment P Loss (mg/m^2)
25 May 1990	moldboard	3.2a	10b	7.7a	60.8a	56.2a
	Aer-way®	3.0a	15a	3.5a	24.7a	20.3a

Means in the same column with different letters are significantly different.

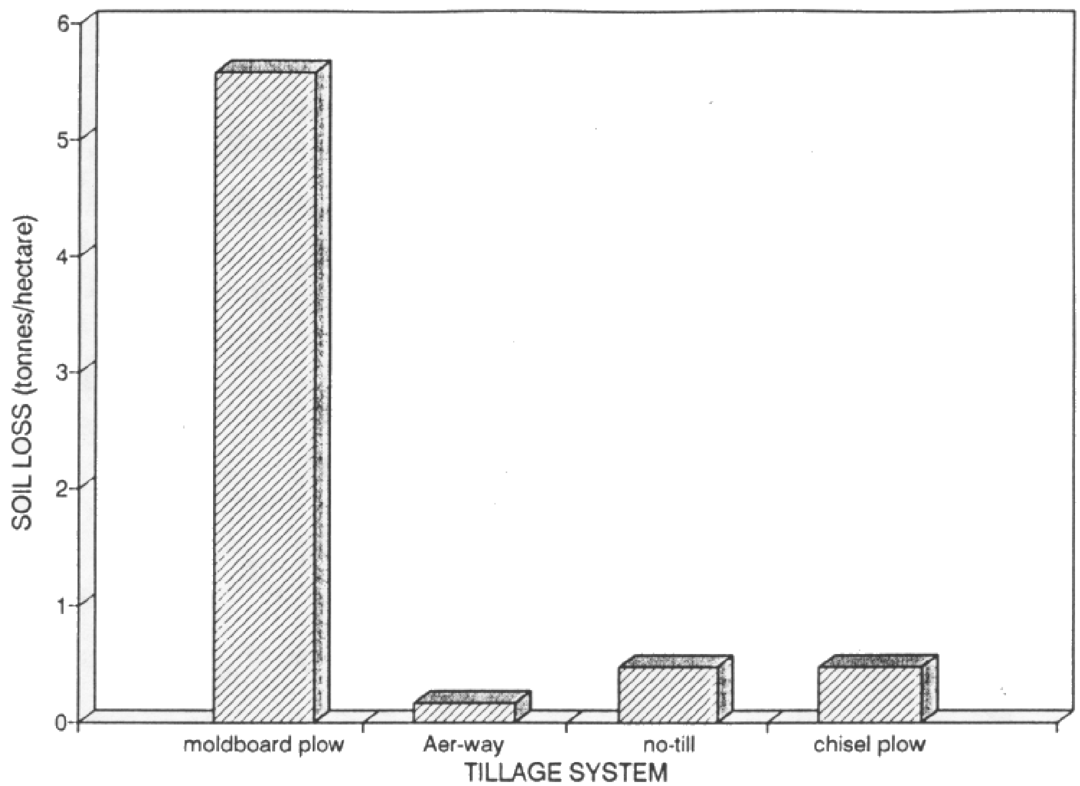

Figure 9. Rainfall Simulation Soil Loss at Jim House's Site on 5-6 September 1989.

significant, the average runoff and sediment loss from the standard management treatment was more than twice that of the aeration tillage treatment (Table 22). On Joe's site. although the numbers obtained were not significantly different. the standard management treatment averaged almost three times as much sediment phosphorus loss as the aeration tillage treatment. Orthophosphate-P concentrations in the runoff from both treatments were below the 0.01 mg/L level of detection (Table 22).

In conclusion, considering the three years of data collected from the various treatments, it is clear that O.B.A.T.A. plots helped to reduce erosion problems and enhance soil and water conservation. The use of cover crops and aeration tillage (Aer-way®) systems were highly effective in reducing water runoff, soil, sediment and phosphorus losses.

5. FERTILITY RESULTS UNDER A COVER CROP PROGRAM

Several farmers had cover crops that were either tilled into the soil in the late fall or retained on the soil surface over the winter months. John Van Dorp's field #2 was planted into three types of cover crops, clover, hairy vetch (spring- and fall-planted), and oilseed radish. The spring-planted hairy vetch was drilled into the winter wheat in May 1989. the rest were planted after the 1989 wheat crop harvest. Fertility samples were taken in the late fall 1989 and in the following spring before planting. The purpose was to see if the cover crops had any effect on the fertility levels of the field. possibly resulting in less purchased fertilizer requirements for the following principle crop. One of the most important aspects to investigate is the nitrogen produced by these cover crops. Looking at Table 23. it can be seen that oilseed radish has provided the most pounds of nitrogen per acre at John's. This is thought to be due to the oilseed radish's ability to scavenge the available N in the soil in the fall. then release it back to the soil in the spring upon plant decomposition. particularly the root. At this site. treatment location with regards to field slope is also an important factor. The oilseed radish treatment was at the bottom of the slope where deposition of eroded materials could contribute significantly to the overall fertility here. The organic matter content. though. was only slightly higher here than at the other treatments. The two hairy vetch treatments had the next two highest levels of nitrogen, followed by the clover treatment. This demonstrates that there are other cover crops available to farmers for use in or after winter wheat that have the ability to produce high levels of nitrogen.

Additional spring sampling would give a better understanding of the nitrogen availability from these crops, since possibly one or two weeks after this sampling date the nitrogen release from the crop breakdown may increase (up side of the release curve) especially for the vetch and clover. The oilseed radish winter kills and therefore was much further advanced in decomposition at the time of sampling which could mean the nitrogen level is at its peak or on the downside of the curve.

Table 23. Nutrient analysis for John Van Dorp's field #2 for fall 1989 and spring 1990.

Nutrients (ppm)	Red Clover (top slope)	Oilseed Radish (bottom slope)	Hairy vetch fall 1989 (bot/mid slope)	Hairy vetch spring 1990 (top/mid slope)
P (f)	32	43	40	32
(s)	23	34	22	13
K (f)	152	224	161	121
(s)	146	147	129	84
Mg (f)	200	193	218	214
(s)	139	113	113	167
Ca (f)	1939	1237	2623	1742
(s)	1634	1000	1220	1386
pH	6.2	5.6	5.9	6.1
% O.M.	3.4	3.8	3.2	3.4
N (kg/ha)	96	128	104	106

Note: (f) = fall 1989; (s) = spring 1990

Mint Klynstra also established cover crops into and after winter wheat. These included winter rye, clover, oilseed radish, and hairy vetch (both spring- and fall-planted). Once again the oilseed radish treatment had the most pounds of nitrogen per acre at spring sampling (Table 24). The spring-planted hairy vetch was next followed by the clover.

The fall-planted vetch had a zero value as did the standard treatment with the winter rye. The fall-planted vetch had a fairly good stand and had obvious nodules on the roots. so the resulting value is of a surprise. As mentioned before, this could be a problem with sampling date in regards to when the nitrogen from the vetch will become available.

Phosphorus also provided some interesting, if not questionable results with the treatments fertility analysis. The oilseed radish treatment was the only treatment to increase the phosphorus level from fall to spring sampling. the other treatments decreased. Since phosphorus is quite stable in the soil and crop uptake is quite small, large increases or decreases in the available P (over a winter period) should be considered questionable. The P values were provided by the Olsen Sodium Bicarbonate test which measures available P which can be extracted by the plants. A better method to determine if available P increased due to the scavenging of P, than decomposition by the oilseed radish, might be a water soluble test. It is possible that the humus extracts or organic acids could contribute to higher dissolution of P.

Jim House planted three cover crops following wheat harvest: red clover, oilseed radish and buckwheat. These fields were then soil saved in the late fall. Analysis from spring soil sampling showed the highest available N with the clover treatment, followed by the standard treatment and lastly the oilseed radish treatment (a sample was not collected from the buckwheat plot) (Table 25).

Table 24. Nutrient analysis for Mint Klynstra's field #2 for fall 1989 and spring 1990.

Nutrients (ppm)	Rye (standard)	Red Clover	Oilseed Radish	Hairy vetch (fall 1989)	Hairy vetch (spring 1990)
P (f) (s)	26 18	20 15	23 28	18 12	- 17
K (f) (s)	251 157	168 143	165 175	170 130	- 164
Mg (f) (s)	356 240	341 186	347 223	326 177	- 329
Ca (f) (s)	2440 1930	2488 2460	2690 1930	2622 2010	- 2200
pH	7.0	6.9	7.0	6.9	6.8
% O.M.	4.5	4.1	4.4	4.1	-
N (kg/ha)	0	15	39	0	25

Note: (f) = fall 1989; (s) = spring 1990

Table 25. Available nitrogen for Jim House's field #1, 1990.

Treatment*	Available N (kg/ha)
Standard	10.0
O.B.A.T.A. (Clover)	37.0
O.B.A.T.A. (Oilseed radish)	3.0

*Note: no manure applied

The poor performance of the oilseed radish is probably a three-fold problem. One reason being the poor emergence of the radish in the fall, secondly the cover crop was turned into the soil in the late fall, therefore a lot of nitrogen might have been lost over the winter. Thirdly. this crop did not receive any manure. whereas both John and Mint's oilseed radish did. The radish seems to thrive on a nitrogen source and since there was not much available N in the soil. the growth was poor and its N return upon decomposition was low.

Overall. cover crops result in numerous benefits to the farmer:

- nitrogen addition from leguminous plants (eg. John, Jim and Mint’s soil analysis)
- nutrient recycling. particularly nitrogen and phosphorus (eg. resulting soil analysis from oilseed radish application)
- addition of organic matter (long term)
- erosion reduction (refer to rainfall simulation data)
- improved soil structure (both Jim and Mint reported improved soil tilth after cover crops)
- economic gain: depending on seed and purchased nitrogen costs as well as nitrogen produced. The above mentioned benefits have intangible costs but lead to economic gain

Increased management is required to properly implement a cover crop program but the demonstrated benefits will lead to improved sustainability of agricultural production.

6. SOIL EROSION

6.1 ESTIMATION OF SOIL EROSION

Wischmeier and Smith (1978) used several factors to describe runoff and erosion losses from agricultural fields. Their Universal Soil Loss Equation (U.S.L.E.) combined these factors to predict long term average annual soil losses from farm fields for specified conditions. The U.S.L.E. is **A=R x K X LS x C** and its factors are defined in Table 26. The Can-Ag study area is also defined in Table 26 with estimated values for the various equation factors.

Table 27 gives two examples for the application of the U.S.L.E. to the Can-Ag study area (both standard and O.B.A.T.A. treatments). Example 1 is a loam textured soil with 2-5% slopes. Under the conventional system. soil erosion was estimated to be 9.7 tonnes/ha/yr, which is considered slight erosion. Under the O.B.A.T.A. system soil erosion was estimated to be 3.2 tonnes/ha/yr. This is considered to be negligible erosion (Table 27).

Example 2 is also a loam soil with 9-15% slopes. Under conventional management. soil erosion was estimated to be 48 tonnes/ha/yr (very severe erosion). For the O.B.A.T.A. treatment area. erosion was estimated to be 16 tonnes/ha/yr, considered to be moderately severe erosion (Table 27). It is clear from these situations that under O.B.A.T.A. management. soil erosion is reduced.

Table 27 also gives estimates for annual losses in dollars per hectare for soil valued at $1.65/tonne. In Example 1, under the conventional system. the annual loss/hectare was estimated to be $16.01, and for O.B.A.T.A. the loss was estimated to be much less at $5.28. For Example 2, under the conventional system, the annual loss/hectare was estimated to be $79.20, and for O.B.A.T.A. it was comparatively lower at $26.40.

Figure 10 shows calculated yearly soil loss on a 9-15% slope for the four tillage systems. The crop factor was the only component of the equation to change, based on the surface residue associated with each system. The moldboard plow produced the most

Table 26. The Universal Soil Loss Equation and the Can-Ag Study Area.

The Universal Soil Loss Equation

A = amount of soil loss in tons/acre/yr (metric x 2.24 = tonne/ha/yr)
R = rainfall factor
K = soil erodibility factor (depends on texture, organic matter, structure. permeability)
LS = length and steepness of slope
C = crop factor (canopy, trash, crop stages, management practices and timing of operations).

The Can-Ag Study Area

R = 80+10
K = approx. 0.30 (loam, clay loam, silty clay loam, very fine sandy loam)
= approx. 0.20 (fine sandy loam, sandy clay loam, clay)
LS = 0.4 for 2-5% slopes (very gently undulating) = 2.0 for 9-15% slopes (gently rolling)
C = 0.45 (fall plowing, corn, beans)
= 0.30 (spring plowing, corn, beans)
(fall disc, winter wheat)
(fall plow, oats, barley)

= 0.15 (spring disc, grain)
(spring plow, corn after meadow)
(fall plow, sod before barley).

Table 27. Two Examples for the Application of the Universal Soil Loss Equation to the Can-Ag Study Area.

Example 1

loam soil. 2-5% slopes

R = 80, K = 0.30, LS = 0.4, C = 0.45 or 0.15

a) conventional tillage, fall plowing, corn-soybeans

A = 80 x 0.3 x 0.4 x 0.45 = 4.3 tons/acre/yr

9.7 tonnes/ha/yr

Slight Erosion

b) O.B.A.T.A. tillage; spring cultivation, cover crops

A = 80 x 0.3 x 0.4 x 0.15 = 1.4 tons/acre/yr

3.2 tonnes/ha/yr

Negligible Erosion

difference = 6.5 tonnes/ha/yr

Example 2

loam soil, 9-15% slopes

R = 80, K = 0.30, LS = 2.0, C = 0.45 or 0.15

a) as in 1 a)

A = 22 tons/acre/yr

48 tonnes/ha/yr

Very Severe Erosion

b) as in 1 b)

A = 7.2 tons/acre/yr

16 tonnes/ha/yr

Moderately Severe Erosion

difference = 32 tonnes/ha/yr

Soil valued at $1.65/tonne

Annual losses/hectare	1 a) = $16.01;	1 b) = $5.28
	2 a) = $79.20;	2 b) = $26.40

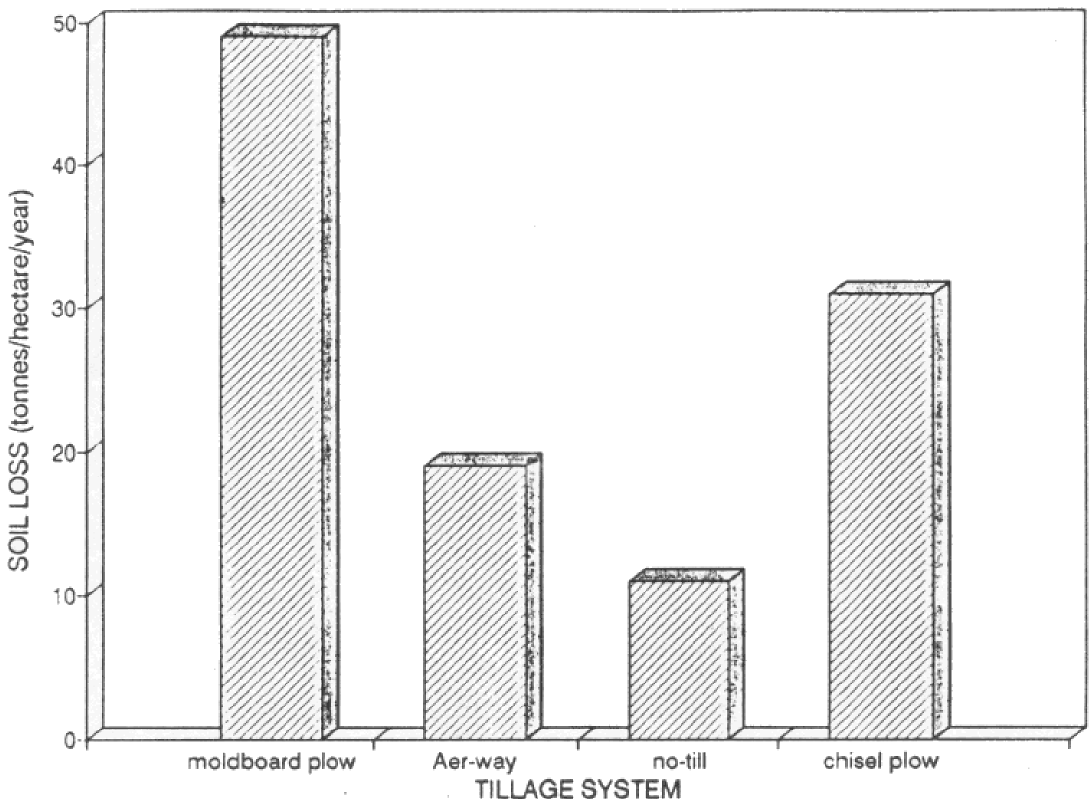

Figure 10. Annual Soil Loss on a 9-15% Slope for Four Tillage Systems.

runoff, which was in the severe range of erodibility. followed by the chisel plow, then the Aer-way®, and finally the no-till (Figure 10).

Ground cover was shown to have a pronounced influence on the occurrence of soil erosion. An estimation of ground cover was made in the spring (at the time of rainfall simulation experiments). and in the fall (after the last tillage operation was completed). The increased cover during the growing season was provided by the crop canopy. After harvest the ground cover results indicated the amount of surface residue. Figure 11 shows the percentage of ground cover from the months of May to April in the four tillage systems. Throughout the year, no-till had the greatest coverage. followed by the Aer-way®, then the chisel plow, and finally almost no cover with the moldboard plow.

6.2 CROP RESIDUE COVER

Estimation of percent residue cover was made at each site in November 1989. Field #1 belonging to John Van Dorp was fall Aer-wayed which left almost all of the crop residue on the soil surface (Table 28). Cover crops were also established but all had poor emergence. John's second field was planted with cover crops after wheat harvest. At this site the cover crops performed well and virtually eliminated any bare soil. The oilseed radish was killed by frost and the residue eventually broke down over the winter and left some exposed ground in the spring 1990.

Mint Klynstra's first field was Aer-wayed twice after soybean harvest then planted with winter wheat in October 1989. The wheat supplied a cover to the soil throughout the winter and spring of 1990. His field #2 had various cover crops on the O.B.A.T.A. treatments. Even the standard treatment received a winter rye cover crop.

With respect to Jim House's first field, the straw from the winter wheat was left on which contributed to residue cover. Two of the cover crops. buckwheat and oilseed radish. were fall-tilled but the red clover remained intact over the winter.

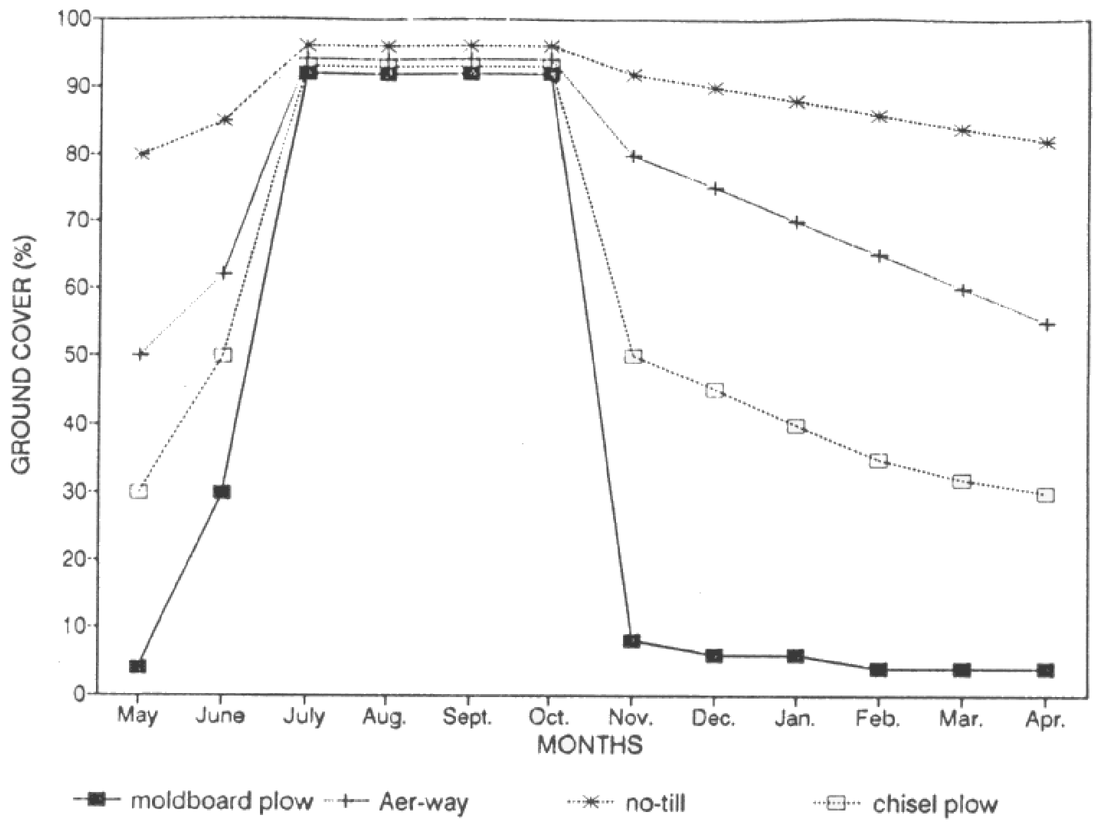

Figure 11. Percentage Ground Cover from the months of May to April in Four Tillage Systems.

Table 28. 1989, 1990, and 1991 Estimates for Crop Residue Cover.

Farmer	Year	Field #	Principal Crop	Treatment	Fall Tillage	Cover Crop	% Crop Residue
John Van Dorp	1989	1	corn	O.B.A.T.A.	Aer-way	yes	45-75
		2	winter wheat	O.B.A.T.A.	Aer-way^{s} subsoiler	yes	75-100
	1990	1	corn	O.B.A.T.A.	Aer-way®	yes	45-75
		2	corn	O.B.A.T.A.	Aer-way^{s}	yes	45-75
	1991	1	corn	O.B.A.T.A.	shredder + Aer-way®	no	72
		2	corn	O.B.A.T.A.	shredder + Aer-way	no	73
Mint Klynstra	1989	1	soybeans	Standard O.B.A.T.A.	Aer-way®	yes	45-75 45-75
		2	winter wheat	Standard O.B.A.T.A.	Aer-way®	yes	75-100 75-100
	1990	1	winter wheat	Standard O.B.A.T.A.	Aer-way®	no yes	45-75 75-100
		2	corn	Standard O.B.A.T.A.	moldboard Aer-way®	no	0-15 45-75
	1991	1	corn	Standard O.B.A.T.A.	so far no till	no "	72 "
		2	corn	Standard O.B.A.T.A.	so far no till	no "	66 "
Jim House	1989	1	winter wheat	Standard O.B.A.T.A.	soil saved soil saved, Aer-way®	no "	15-30 "
		2	corn	Standard O.B.A.T.A.	no till Aer-way®	no "	45-75 "
	1990	1	corn	Standard O.B.A.T.A.	no till	no yes	45-75 75-100
		2	soybeans	Standard O.B.A.T.A.	no till soil saved	no "	45-75 30-45

Note: 1989 were baseline estimates.

Table 28. 1989, 1990, and 1991 Estimates for Crop Residue Cover (concluded).

Farmer	Year	Field #	Principal Crop	Treatment	Fall Tillage	Cover Crop	% Crop Residue
Jim House	1991	1	corn/soy strip	Standard	chisel plow + disk (2x)	no	50
				O.B.A.T.A.	"	"	"
		2	corn/soy strip	Standard	no till	no	soy: 46
				O.B.A.T.A.	"	"	corn: 87
Joe Gerber	1989	1	corn	Standard	moldboard	no	0-15
				O.B.A.T.A.	no till "	"	30-45
	1990	1	corn	Standard	moldboard	no	0-15
				O.B.A.T.A.	"	"	"
Dave McIntosh	1990	1	corn	Standard	moldboard	no	0-15
				O.B.A.T.A.	"	"	"
		2	soybeans	Standard	moldboard	no	0-15
				O.B.A.T.A.		"	"
Arpad Pasztor	1989	1	corn	Standard	soil saved	no	15-30
				O.B.A.T.A.	no till	"	45-75
		2	soybeans	Standard	no till	yes	30-45
				O.B.A.T.A.			75-100
	1990	1	corn	Standard	soil saved	no	15-30
				O.B.A.T.A.	Aer-way'	"	45-75
		2	tomatoes	Standard	soil saved	yes	45-75
				O.B.A.T.A.	"	"	"
		3	winter wheat	Standard	soil saved	yes	45-75
				O.B.A.T.A.		"	"
	1991	1	corn	Standard	no till	no	60
				O.B.A.T.A.	"	"	"
Dean Glenney	1990	1	corn	Standard	moldboard	no	15-30
				O.B.A.T.A.		"	"
		2	corn	Standard	moldboard	no	15-30
				O.B.A.T.A.		"	"

Note: 1989 were baseline estimates.

Note: Arpad's field #1 in1989 was field #3 in 1990.

The whole field was soil saved (immediately after wheat harvest) which tended to eliminate much of the residue. then was soil saved again in late October to kill the two cover crops. His second field had quite a lot of surface residue as the standard plot was no till and the remaining two O.B.A.T.A plots were Aer-wayed once. The rye cover was a poor stand and therefore did not contribute much to the ground cover. Overall, there was more surface residue in his second field when compared with his first field.

The standard treatment of Arpad's first field was soil saved after corn harvest while the O.B.A.T.A. treatments received no tillage but were Aerwayed in the spring 1990. All treatments in his field #2 were established with no till winter wheat. The O.B.A.T.A. treatment which involved planting the soybeans into standing rye (then mulching the rye) still had considerable rye residue which aided in erosion protection.

With respect to Joe Gerber's field, the standard treatment was moldboard plowed in the fall while the O.B.A.T.A treatments were left untilled and were Aer-wayed in the spring 1990. No cover crops were established here. There was considerably less residue coverage in the standard versus the O.B.A.T.A plots (Table 28).

Unfortunately, in 1990 due to the late harvests and poor weather conditions (i.e. early snow falls) greater accuracy in the estimates could not be accomplished. Estimates could not be made until the snow had melted away enough so the field surface could be seen.

It was observed that in Mint Klynstra's first field, the percentage of crop residue cover was greater where cover crops were established (Aer-way® being the fall tillage) as opposed to no cover crop establishment. Likewise, in Jim House's first field, there was more residue cover on the soil surface where cover crops were established as opposed to none (no tillage).

In Mint Klynstra's field #2. the Aer-way® left considerably more trash on the soil surface as opposed to the moldboard plow which inverted most of it, as is the case in all the fields that were conventional plowed (McIntosh. Gerber. and Glenney). Those farmers that soilsaved (House and Pasztor) left a higher percentage of trash on the field compared with the moldboard plow.

In 1991 (as in previous years) use of the Aer-way® left almost all of the crop residue on the soil surface. John Van Dorp Aer-wayed his field and then shredded the remaining residue to aid in decomposition. After applying the residue spray, he noted that some weeks afterward, the crop residue was decomposing rapidly. Percent residue cover was similar in 1991 as in previous years when John aeration tilled only. The advantage of shredding is that the crop residue is reduced to smaller fragments increasing surface area thus allowing faster decomposition.

Mint Klynstra did not aeration till or plow his fields until late December 1991. Thus percent crop residue was estimated on no till only for both of his fields. Due to snow conditions, estimates could not be taken on his tilled fields in early January 1992. Crop residue estimates reveal a fairly high amount of crop residue left on the ground after combining (similar to estimates obtained when Mint Aer-wayed the fields in previous years). Mint did not establish cover crops in his research fields in 1991. Despite this, percent crop residue remained high when compared with other years.

Jim House chisel plowed and disked (twice) in his first field because he wanted to change the direction of crop rows for the coming year. About half of the crop residue was placed beneath the soil surface due to this tillage. Jim left his second field no till. Percent corn residue in his second field was quite high. Because Jim strip cropped his fields with corn and soybeans. estimates were taken separately for each crop. Percent crop residue for soybeans was about 46%, and for the corn it was about 87%. Jim did not establish a cover crop in either field which may have increased the cover estimated in both fields. Arpad Pasztor did not establish a cover crop. nor did he till his research field and it was estimated that his field had about 60% cover due to corn residue.

Residue cover levels of 30% or more offer good soil erosion protection. Most of the O.B.A.T.A farmers kept a fair amount of crop residue cover on their fields (over 50% on average). John Van Dorp. Mint Klynstra and Jim House had relatively high levels most of the time. The former two farmers used aeration tillage in the fall and the latter was a no till farmer. Estimating the residue cover in fields was important in identifying soil erosion problems and to control erosion.

7. ACCOMPLISHMENTS

Farmer progress in adapting to on-farm research techniques. as well as our progress (in communicating our needs) during the three years. has been remarkable. In 1989 the co-operating farmers were hesitant in undertaking some of the different steps. We were constantly being asked for guidance and our attendance in field operations. It was difficult at times to keep pace. By 1990, co-operators were well on their way to implementing activities on their own. Telephone calls were made when difficulties arose. For example. when bad weather interfered with certain operations, co-operators wanted to know what alternatives were available. In 1991. the program ran smoothly. The farmers were excited about the research and they were trying aspects of the program on other fields. They were trying other new ideas and their neighbours were showing increasing interest. Basically, we were able to take research concepts or ideas and turn them into workable on-farm systems in three years.

Findings throughout these three years have continued to demonstrate the complexities of researching new and innovative farming practices. By the second year of study. farmers were beginning to get a good idea for certain O.B.A.T.A. management options. For example. which cover crops to use (with respect to soil suitability, time management for planting/removal, degree of difficulty to manage etc.) As well. there was the aspect of reduced tillage. Use of the Aer-way® may or may not have fit into a farmers' tillage operation. Thus. depending on the farmer there were differing opinions about how useful it was to them. Time management was of the utmost importance and an integral part of the successful application of the O.B.A.T.A. system of farm management. But in certain situations, such as periods of unusual weather. farmers found they had little control.

Farmer's views and attitudes noted at the O.B.A.T.A. workshops continued to be positive toward the study and its objectives. As mentioned before. most farmers expected and accepted the extra management input that was required with this lower input or unconventional manner of farming. The establishment of cover crops certainly proved to be one aspect of the O.B.A.T.A. system that generated much interest. It was also the most work intensive and sensitive with respect to success rate.

Problems in the 1989 program included poor cover crop establishment when interseeding into corn. the late arrival of the Strohm aerator® subsoiler. and seedbed preparation with reduced tillage. One of the problems in the 1990 program was the poor establishment of cover crops on some of the fields. namely. when they were broadcast into standing corn. Another problem involved the use of the Aer-way® under certain field conditions. For example. if there was a large abundance of weeds. the Aer-way® was not the best implement to use. It did not sufficiently disturb the soil to bury or kill them. The Aer-way® was also not the best to use under wet soil conditions. Due to late harvest in 1990 for many farmers. the Aer-way® operation planned for after harvest was not completed. For many. the soils were too moist. and even the use of the Aer-way® (compared with the moldboard, for example) would have probably led to surface compaction.

There were several interesting observations up to this point involving some of the O.B.A.T.A. operations. particularly in the use of kelp and molasses as a seed treatment. Some success stories include Dave McIntosh who added talcum powder to his kelp and molasses mixture to stop the sticking problems that sometimes occurred. Dave claimed that the talcum worked very well. and he did not have sticking problems since he added it to his mixtures. In the late summer (second week August) 1989. John Van Dorp spread manure on his winter heat field. followed by kelp and molasses in the form of a residue spray. He noticed that crop residue breakdown was greatly enhanced with the kelp and molasses application. He repeated this operation in 1990 and 1991 following corn harvest on both of his research fields. and saw similar results. John is very happy with this. and will continue to do this type of operation.

There are a few interesting notes about the Aer-way®. Jim House, who had major problems in his soybean field in 1990 due to insect and geese infestations, initially predicted that 90% of the no till treatment would have modest yields. As it turned out, yields were greater than he expected. and better than the section that was aeration tilled (where he suspected to have better yields than the no till). Initially, Jim approved of the use of the Aer-way®. He felt it was good in that it does not move the soil around much, thus one of the benefits was that it did not disturb earthworms. It does not take much of power to pull the Aer-way®, therefore it would save farmers money in terms of fuel. equipment and operations. However, in 1990 Jim had a problem with slugs. and he attributed this to the use of the Aer-way®. This situation was peculiar to only Jim. The other farmers did not report such a problem. He felt that the extra trash left on the surface of the soil was an attractant for the pests.

Mint Klynstra used the Aer-way® simply to aid in loosening and thus aerating his soil. Dave McIntosh had used the Aer-way® as a part of his O.B.A.T.A. operations and approved of the results. He claimed it did not cause damage to the crops. for it was a less aggressive implement compared with the subsoiler (Strohm aerator®). The Aer-way® pokes holes into the ground, and does not disturb the surface soil too much. Dave had one concern about the Aer-way®, however. He had a small problem with volunteer corn in his soybean field in 1990 in the area that was aeration tilled. He states that conventional plowing would have buried the residue, thus placing the corn seed under the soil surface. The Aer-way® did not do this. It left the corn seeds near the soil surface and they remained viable and germinated. Fortunately, in Dave's case there was not a big enough problem to cause a yield decrease in his soybeans. Similar to this would be the situation where a field had a heavy infestation of weeds. One may not want to use the Aer-way®, for as mentioned. it is not an aggressive implement. Use of the soilsaver (such as what Jim House used in his field #2) is probably the better alternative.

Dave McIntosh subsoiled the middle of August 1990 in his soybean field. and he observed that the soybeans suffered from this operation. He stated the roots were lifted 5 to 8 cm and were disturbed too much by this operation which he described as being too aggressive for soybeans compared with the *Aer-way®*. He had no problems with the subsoiler in his corn field.

There have been several definite positive results over the past three years from this research. One of them was that through the use of the Aer-way® farmers had much less water runoff. phosphorus and/or soil losses. The establishment of cover crops also aided in giving protection against soil erosion, and as well. provided additional nutrients to the principal crops. They were also renown for providing better soil tilth.

Other interesting observations which were well noted occurred in both of Jim House's fields during the final year of the study. On 9 July 1991, corn and soybean heights were estimated for comparison between standard and O.B.A.T.A. treatment areas. A sample size of 30 plants was used.

In Jim's first field the estimated standard corn height was 133 cm compared with the estimated mean O.B.A.T.A. height of 152 cm. This was a 19 cm differential in favour of the O.B.A.T.A. treatment area. This field was not in tassel yet (only one tassel was found in the O.B.A.T.A. management section).

Considering the soybean crop. the mean standard height was 43 cm compared with the mean O.B.A.T.A. height of 50 cm. There was a 7 cm difference in favour of the O.B.A.T.A. section. There appeared to be a greater occurrence of lodging in the O.B.A.T.A. soybean section due to the greater mean height. At this time the field was in bloom. No other differences could be measured in this field.

In Jim's second field the estimated standard corn height was 156 cm compared with the estimated O.B.A.T.A. height of 154 cm. Here. there was a 2 cm differential in favour of the standard section. The estimated standard soybean height was 56 cm compared with 61 cm for the estimated O.B.A.T.A. height (a 5 cm difference in favour of O.B.A.T.A.).

General observations were that field #2 appeared to be more moist compared with field #1. There also appeared to be more weeds present in field #2.

Another interesting note was that corn tasselling appeared to differ with respect to treatment. On 9 July 1991 percent tasselling was estimated in field #2 (n=480). It was greater in the O.B.A.T.A. plots (37%) compared with the standard plots (12%). At this time. field #1 was not in tassel yet. Tasselling was observed on 17 July 1991 in field #1 (n=480). Again, a greater percentage were observed in the O.B.A.T.A. plots (80%) as compared with the standard plots (10%).

Pod counts were completed in Jim's first field in the middle of August 1991. A sample size of 16 was used. The mean estimate for the standard area was 28 pods/plant. The mean estimate for the O.B.A.T.A. treated area was 26 pods/plant. Field observations for corn indicated no obvious differences in the number of cobs per plant or size of cobs between treatments.

Thus, there were several biological differences in Jim's O.B.A.T.A. soybean and corn crops that were evident after the foliar sprays were applied. Jim was convinced that the foliar sprays applied were a main contributing factor to the interesting observations (increased height, % tasselling, etc.). Unfortunately, no obvious and measurable differences were noted in other fields in 1991.

One of the negative aspects observed from this research was the possible pest damage (eg. slugs or other) which may result from increased trash on the soil surface (i.e. use of the Aer-way®'.

Despite the challenges experienced during the three seasons. it was an excellent experimental and learning experience for the farmers. For the most part obstacles were overcome. The enthusiasm and innovative abilities demonstrated by the "average" farmers demonstrates the latest potential of on-farm research. The positive attitude exemplified by all the farmers does indeed look promising for the future practice of low input and for environmentally friendly farming techniques.

8. SUMMARY

Soil conditions on standard and O.B.A.T.A. management plots remained similar after the three years based on measurements of fertility. compaction and microbial biomass. The remarkable reductions are in management inputs: kinds and numbers of operations. power and fuel requirements and an increased level of protection against erosion. The O.B.A.T.A. plots appear to be clearly superior to moldboard plowed plots and are comparable to no-till plots or conservation tillage plots.

To date, no significant measurable changes in soil compaction were observed. The Dickey-john® penetrometer readings and bulk density measurements revealed no obvious differences in soil compaction between the treatments or between years. Only the pocket penetrometer ratings indicated greater compaction in the standard versus O.B.A.T.A. management plots, but in the compact and subsoil layers of the soil only.

Over the three year period no significant increases in soil microbial biomass measurements were detected in the O.B.A.T.A. plots when compared with the standard or conventional management plots. It was observed though. that those fields with the greatest biomass carbon counts had a history of intensive soil and crop management (i.e. use of manures. cover crops and kelp and sugar additions etc.) Much more time would be required to detect any measurable differences in biomass C. Special emphasis could be placed on studying whether changes in biomass C occur the following growing season after a certain crop was grown the previous year. It could take years of intensive soil management to actually see noticeable increases in biomass (Voroney. Univ. of Guelph). Microbial biomass measurement is a variable criteria to measure because it can change dramatically with soil conditions such as moisture. temperature changes. type of tillage etc.. Thus it is a difficult factor to measure and interpret.

It is well known that at least three to five years are needed to make a transition from one farming system to another. Experience in this project supports the above statement.

The first year (1989) was a period of learning. Most treatments were implemented even though the level of confidence. understanding. and expectation was perhaps less than comfortable. The second year (1990) was a turning point in that recommendations were understood and applied. but there remained a degree of skepticism about performance. Year three (1991) was really the first good test year. Farmers were confident about what they were doing. the practices were implemented well. the weather was fairly good except for some droughtiness. and enough time had elapsed for soil conditions to begin to adjust.

Although this report evaluates the O.B.A.T.A. versus standard practices over three years. major emphasis should be given to the final year. O.B.A.T.A. corn and soybean yields in 1991 were equal to or greater than those off standard plots (up to 6.0 % better). Winter wheat was not grown on any plots in 1991, however. in 1989 the O.B.A.T.A. plot winter wheat yields matched or exceeded standard plots (by up to 8.0% better). This may have been a response to foliar spraying as no other O.B.A.T.A. practices had been implemented at this time. In addition. O.B.A.T.A. plots provided fibre from cover crops - use for green manure, livestock feed. and soil protection. Cover crops also help to replenish and recycle nutrients and organic matter in the soil. There is no doubt that the use of cover cropping does lead to healthier soils. Although this type of management is more intensive it can result in a more efficient farming method capable of producing good yields and profits.

Conservation Management Systems research revealed no differences between standard plots and plots with added kelp and molasses and fertilizer solution. It was concluded that the use of kelp and molasses and 71B fertilizer solution as a seed or foliar treatment in an aeration tillage system did not significantly affect the growth or yield of soybeans.

No significant differences of soil micro-faunal populations could be detected between plots with added kelp and molasses and those standard management plots. It was unfortunate that this study did not extend the full three year period due to inherent problems with the research.

From the rainfall simulation experiments it was observed that the use of cover crops and aeration tillage (Aer-way®) systems were effective in reducing water runoff. soil or sediment and phosphorus losses. The use of cover crops and aeration tillage can reduce soil erosion by approximately one third that on conventional moldboard plowed fields. Further research should be continued on the use of cover crops for every effort should be made to produce nitrogen on-farm rather than to import nitrogen. The Aer-way® should become an authorized conservation tool. The O.B.A.T.A. system of crop management has proven to be a good conservation farming system.

In summary. it is important that this type of research be continued. There is no doubt that observations and results from on-farm research continue to act as extension aids in educating the farm community about new or old and innovative farming techniques.

9. RECOMMENDATIONS

The on-farm research has proven to be very effective in testing and demonstrating alternative conservation production practices. Considerable effort is required in the initial year of such an undertaking. Three C's to keep in mind in conducting this type of project are communication. consistency and continuity. Communication is extremely important at the outset. Researchers and farmers have very different perspectives so it is essential that a comfortable level of understanding is attained. The farmers are very innovative and enjoy the challenges once given the support and recognition. They can greatly help the research community to focus their efforts on practical needs. On the other hand. researchers can save farmers money and time by providing information tailored to site specific conditions. Consistency and continuity are more critical for research and statistical analysis than for regular farm management. Farmers often make decisions based on one year of results. Furthermore. once certain practices are identified as positive or negative the farmers are eager to expand the former and terminate or modify the latter. Careful attention to this area is therefore essential to maintain integrity of the experiments and to demonstrate whether results of one year represent a trend or a one-time occurrence.

Once procedures for a systems approach are developed and the implementation protocol is streamlined on about three farms. say after one season. it would be desirable to have an additional twelve or more farmers involved for a minimum of three years and preferably five years. Then. if a few withdraw from the program as can be expected. there would still be ten or more participants, thereby permitting better statistical results and a broader base for evaluation and extension purposes.

Longer term research is essential for studies of this nature. Both the farmers and researchers agree that the third year is really the first year of reliable data, considering the adjustment period needed for soils, weed control, co-operator, etc. The co-operating farmers were all very disappointed that the study could not be continued. They all felt that we were now in a position to proceed with really sound research. that soils were adjusting. that as a team we could now focus on refining techniques. assessing risk levels of alternatives and gaining an appreciation for vagaries of the weather.

An extension component should be added to projects of this type. Fortunately. Can-Ag Enterprises was able to obtain partial funding from SWEEP and Aer-way® to produce a video that can be potentially tailored to extension use.

The Aer-way® tool should be promoted as a conservation tillage tool. The reduced power requirements, preservation of surface trash, and the resulting infiltration channels for rainfall and liquid manure application all support its use. It is especially well suited to sloping terrain in that gravitational downslope soil movement induced by the implement is minimal.

Research funds should be made available for increased review of biological soil and crop products. Farmers with increased environmental awareness are turning to "natural" products in an attempt to increase yields. The performance of these products may be questionable but the farmer has few sources to obtain answers. The kelp and molasses study completed by CMS in association with the O.B.A.T.A. study revealed no differences in yield. Yet two of our sites produced noticeable yield increases with a kelp. sugar and fish emulsion foliar spray. The yield increases were not significant though (due to lack of data points). Examples such as these creates more questions which should be answered through more on-farm research.

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11. APPENDIX A

Soil Profile Descriptions For Each Field (Tables 29 to 35)

Soil Fertility Data for 1989. 1990 and 1991 (Tables 36 to 40)

Ammonium and Nitrate Data for Spring 1990 and 1991 (Table 41 and 42)

Mean Dickey-john Penetrometer Readings for Fall 1989 and 1991 (Table 43 to 47)

Mean Pocket Penetrometer Ratings for 1991 (Table 48) Fall 1991 Bulk Density Measurements (Table 49)

Microbial Biomass Data for 1989. 1990 and 1991 (Table 50) Crop Yield Data for 1989. 1990 and 1991 (Tables 51 to 55)

Table 29. Soil Profile Description for John Van Dorp's Two Research Fields.

Field #1

Classification: Orthic Gray Brown Luvisol
Materials: Glacial till, discontinuous fluvial veneer
Topography: Predominantly 5 to 9%

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 40	Dark grayish brown (10YR 4/2); silt loam; granular; very friable.
Bt	40 - 70	Dark brown (7.5YR 4/4); silt loam to clay loam; subangular blocky; friable to firm.
BC	70 - 100	Dark brown (7.5YR 4/4); loam; massive; friable.

Comments

Topsoil thickness varies from about 15 cm on hill crests to 40 cm in the lower positions. In places there is a 5 to 15 cm Ae horizon below the Ap. These soils are slightly compacted. The central valley. the side slopes. and the upper slope positions differ and should be treated as separate sub-units in any studies concerning crop yields or soil quality. There is a gradient of increasing topsoil thickness and increasing wetness from slope crest to valley bottom.

Field #2

Classification: Orthic Gray Brown Luvisol. Orthic Melanic Brunisol
Materials: Glacial till
Topography: Mainly 9 to 15% slopes. some places steeper

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 20	Dark grayish brown (10YR 4/2); silt loam; granular; very friable.
Bt	20 - 60	Dark brown (7.5YR 4/4); silt loam to clay loam; subangular blocky; firm.
Ck	60 - 100	Brown (10YR 5/3); loam massive; friable.

Comments

Topsoil thickness ranges from about 15 to 30 cm at the upper to the lower positions. respectively. An Ae horizon. 5 to 10 cm, occurs at some sites. The upper slope positions are expected to be somewhat drier than lower slope positions. hence. yield differences should be interpreted with this in mind.

Table 30. Soil Profile Descriptions For Mint Klynstra's Two Research Fields.

Field #1

Classification: Orthic Humic Gleysols and Eluviated Melanic Brunisols
Materials: Fluvial blanket overlying till
Topography: Slopes predominantly 2 to 5%. but steeper near the eastern end of the fields

Site 36

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 31	Dark grayish brown (10YR 4/2); silt loam; granular; very friable.
Bt	31 - 52	Yellowish brown (10YR 5/4); silt loam to loam; subangular blocky; friable.
Cca	52 - 100	Dark yellowish brown (10YR 4/4); silty clay loam; massive; friable.

Site 37

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 28	Dark grayish brown (10YR 4/2); loam; granular; friable.
Btj	28 - 50	Dark brown (7.5YR 4/4); loam; subangular blocky; friable.
Bc	50 - 100	Dark yellowish brown (10YR 4/4); loam; massive; friable.

Comments

Upper areas are generally moderately well drained where as level and lower areas are imperfectly drained and subsoils are mottled. Subsoil texture varies from silt loam to clay loam and consistence ranges from friable to firm. In placed the water table was within 1 metre at the time of the survey. The Cca horizon is usually below 100 cm.

Table 30. Soil Profile Descriptions for Mint Klynstra's Two Research Fields (concluded).

Field #2

Classification: Orthic Humic Gleysols and Eluviated Melanic Brunisols
Materials: Fluvial veneer/blanket over till
Topography: Main 2-5%. steeper slope near eastern end of field

Site 46

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 40	Very dark grayish brown (10YR 3/2); silt loam; granular; friable.
Btjgj	40 - 70	Yellowish brown (10YR 5/4); mottled; silt loam; subangular blocky; friable.
Bcg	70 - 100	Dark yellowish brown (10YR 4/4); mottled; loam; massive; friable.

Site 47

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 38	Very dark grayish brown (10YR 3/2); silt loam. granular; very friable.
Btj	38 - 60	Yellowish brown (10YR 5/4); silt loam; subangular blocky; friable.
Bcg	60 - 100	Dark yellowish brown (10YR 4/4); silt loam; massive; friable.

Comments

Sites on the lower level ground are mostly imperfectly drained with mottled subsoils. On the upland soils at the eastern end of the field, conditions are moderately well drained. Yield comparisons of entire strips should be valid as the sub-fields are perpendicular to the slopes. Comparisons of microplot yields should be made within the same units.

Table 31. Soil Profile Descriptions for Jim House's Two Research Fields.

Field #1

Classification: Orthic Gray Brown Luvisol
Materials: Glaciolacustrine
Topography: 2 to 5%

Site 97 (O.B.A.T.A.)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 38	Dark brown (10YR 3/3); clay to clay loam; fine subangular blocky friable to firm.
Ae	38 - 51	Dark yellowish brown (10YR 4/4); clay to clay loam; fine to medium angular blocky; firm.
Bt	51 - 100	Yellowish brown (10YR 5/4); silty clay; fine angular blocky; firm.

Site 98 (Std)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 31	Dark brown (10YR 3/3); clay to clay loam; fine angular blocky friable to firm.
Ae	31 - 45	Dark yellowish brown (10YR 4/4); clay; fine to medium angular blocky; firm.
Bt	45 - 98	Yellowish brown (10YR 5/4); silty clay; very fine angular blocky; firm.
Ck	98 - 100	Brown (10YR 5/3); silty clay; very fine angular blocky; friable to firm.

Comments

The two sites are very similar in terms of soils and topography.

Table 31. Soil Profile Descriptions for Jim House's Two Research Fields (concluded).

Field #2

Classification:	Brunisolic Gray Brown Luvisol
Materials:	Glaciolacustrine material
Topography:	2 to 5%

<u>Site 103 (O.B.A.T.A.)</u>

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 27	Dark brown (10YR 4/3);silt loam; granular; friable.
Ae	27 - 50	Light yellowish brown (10YR 6/4); sift loam; fine angular blocky; friable to firm.
Bt	50 - 75	Dark brown (7.5YR 4/4); silty clay; fine angular blocky; firm to friable.
Ck	75+	Brown (10YR 5/4); silty clay; medium subangular blocky; firm.

<u>Site 104 (Std)</u>

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 31	Dark brown (10YR 4/3); silt loam; fine subangular blocky; friable.
Ae	31 - 50	Yellowish brown (10YR 5/8); silt loam; fine angular blocky; friable to firm.
Btj	50 - 100	Yellowish brown (OYR 5/4); silt clay loam; fine angular blocky; friable.

<u>Comments</u>

Both sites are similar in topography and soils.

Table 32. Soil Profile Descriptions for Arpad Pasztor's Research Fields.

Field #1

Classification:. Gleyed Melanic Brunisol (may be Orthic Humic Gleysol)
Materials: Fluvial eolian sands
Topography: Nearly level. <2% slopes

Site 78 (O.B.A.T.A.).

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 30	Dark grayish brown (10YR 4/2); loamy fine sand; weak granular; very friable.
Bgj	30 - 52	Yellowish brown (10YR 5/4); fine sand; single grain; loose.
Cg	52 - 100	Brown (10YR 5/3) mottled; fine sand; single grain; loose.

Site 79 (Standard)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 28	Dark grayish brown (10YR 4/2); fine sand; weak fine granular; very friable.
Bgj	28 - 54	Dark brown (10YR 4/3) mottled; fine sand; single grain; loose.
Ahb	54 - 80	Black (10YR 2/1); fine sand; weak granular; very friable.
Cg	80 - 100	Light brownish gray (10YR 6/2) mottled; single grain; loose.

Comments

At the north end of the standard treatment there are soils with buried Ah horizons suggesting that this was a wetland filled in some time ago. A natural surface Ap has developed since. A shallow water table probably occurs here during much of the growing season. hence the potential for good yields in spite of the sandy soils.

Table 32. Soil Profile Descriptions for Arpad Pasztor's Research Fields (concluded).

Field #2

Classification: Orthic Melanic Brunisol. Gleyed in places
Materials: Fluvial eolian sands
Topography: Very gently undulating. 2 to 5% slopes

Site 88 (Standard)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 27	Dark grayish brown (10YR 4/2); fine sand; single grain; loose.
Bm	27 - 60	Yellowish brown (10YR 5/4); fine sand; single grain; loose.
C	60 - 100	Brown (10YR 5/3); fine sand; single grain; loose.

Site 89 (O.B.A.T.A.)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 18	Dark grayish brown (10YR 4/2); fine sand; single grain; loose.
Bm	18 - 52	Yellowish brown (10YR 5/5); fine sand; single grain; loose.
C	52 - 100	Yellowish brown (10YR 5/4); fine sand; single grain; loose.

Comments

The soils on both fields are very similar; however. the standard field has more pronounced topography so that upper and lower slope positions. and variations in yield are more pronounced.

Table 33. Soil Profile Descriptions for Dave McIntosh's Two Research Fields.

Field #1

Classification:	Eluviated Melanic Brunisol
Materials:	Discontinuous fluvial veneer over till
Topography:	Very gently undulating. 2 to 5% slopes and <2% slopes

Site 60

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 24	Very dark grayish brown (10YR 3/2); silt loam; granular; very friable.
Btj	24 - 60	Dark yellowish brown (10YR 4/4); silty clay loam; subangular blocky; friable to firm.
BC	60 - 85	Brown (10YR 5/3); silty clay loam; weak subangular blocky; firm.
Ck	85 - 100	Brown (10YR 5/3); silty clay loam; massive; firm.

Site 61

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 27	Very dark grayish brown (10YR 3/2); silt loam. granular; very friable.
Btj	27 - 85	Yellowish brown (10YR 5/4); silty clay loam; subangular blocky; friable.
Ck	85 - 100	Brown (10YR 5/3); silty clay loam; massive; friable.

Comments

The soybean O.B.A.T.A. field has very gently undulating topography whereas the standard field is nearly level. Field histories are somewhat different prior to 1989.

Table 33. Soil Profile Descriptions for Dave McIntosh's Two Research Fields (concluded).

Field #2

Classification: Eluviated Melanic Brunisol
Materials: Till. discontinuous fluvial veneer
Topography: Gently undulating, 2 to 5% slopes

<u>Site 68</u>

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 29	Dark grayish brown (10YR 4/2); silt loam; granular; very friable.
Bt	29 - 60	Dark yellowish brown (10YR 4/4); silt loam; subangular blocky; friable.
BC	60 - 80	Brown (10YR 5/3); silty clay loam; weak subangular blocky; firm.
Ck	80 - 100	Brown (10YR 5/3); silty clay loam; massive; firm.

<u>Site 69</u>

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 28	Dark grayish brown (10YR 4/2); silt loam; granular; very friable.
Btj	28 - 65	Dark brown (7.5YR 4/4); silty clay loam; subangular blocky; firm.
BC	65 - 80	Brown (10YR 5/3); silty clay loam; weak subangular blocky; firm.
Ck	80 - 100	Brown (10YR 5/3); silty clay loam; massive; firm.

<u>Comments</u>

The two fields are very similar in terms of soils and topography.

Table 34. Soil Profile Description for Joe Gerber's Research Field.

Field #1

Classification: Orthic Gray Brown Luvisol
Materials: Glacial till
Topography: Gently undulating. 2 to 5%

O.B.A.T.A. Treatment Site la

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 20	Dark grayish brown (10YR 4/2) silt loam; granular; friable.
Bg	20 - 55	Dark gray (10YR 4/1) with strong brown (7.5YR 4/6) mottles; clay; subangular blocky; firm.
Bcg	55 - 100	Grayish brown (10YR 5/2) mottled; clay; massive; friable. Standard Treatment

Site 6a

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 22	Dark grayish brown (10YR 4/2) loam; granular; friable.
Bm	22 - 60	Dark grayish brown (10YR 4/2); clay; subangular blocky; firm.
C	60 - 100	Dark grayish brown (10YR 4/2); clay; massive; firm.

Comments

Both fields are very similar. The O.B.A.T.A. site. above. represents a slightly depressed position. The standard site is typical of most of both fields.

Table 35. Soil Profile Descriptions for Dean Glenney's Two Research Fields.

Field #1

Classification: Brunisolic Gray Brown Luvisol
Materials: Glaciolacustrine material
Topography: 2 to 5%

Site #3 (standard)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 30	Dark grayish brown (10YR4/2) sandy loam; granular; very friable
Bm	30 - 36	Yellowish brown (10YR5/4); sand; loose
Ae	36 - 44	Yellowish brown (10YR5/6); sandy clay; fine angular; friable to firm
Bt	44 - 58	Yellowish brown (10YR5/4); sandy clay. medium subangular
Btj	58 - 89	Yellowish brown (10YR5/6); sandy clay - sand; loose
C	89 +	Light brownish gray (10YR6/2) clay; firm

Site #9 (O.B.A.T.A.)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 22	Dark brown (10YR3/3); clay loam; granular; friable
Ae	22 - 32	Yellowish brown (10YR5/4); silt clay loam. friable to firm
Bt	32 . 60	Brown (10YR5/3); clay angular blocky; firm
C	60 -	Brown (10YR5/3); clay fine angular blocky; firm

Table 35. Soil Profile Descriptions for Dean Glenney's Two Research Fields (concluded).

Field #2

Classification: Gleyed Brunisolic Gray Brown Luvisol
Materials: Glaciolacustrine material
Topography: 2 to 5%

Site #3 (O.B.A.T.A.)

HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 25	Brown - Dark brown (10YR4/3); sift loam; granular; friable
Ae	25 - 40	Dark grayish brown (10YR4/2); sift loam; fine angular blocky; friable to firm
Btqj	40 - 60	Brown - Dark brown (10YR4/3) with mottles; silty clay; subangular blocky. friable to firm
Bt	60 - 79	Yellowish brown (10YR5/4); clay; angular blocky; firm
C	79 +	Brown (10YR5/3); clay; angular blocky; firm

Site #8 (standard) HORIZON	DEPTH (cm)	DESCRIPTION
Ap	0 - 27	Dark grayish brown (10YR4/2); sandy loam; granular; friable
Ae	27 - 36	Brown (10YR4/3); sandy clay; fine angular blocky; friable to firm
Bt	36 - 73	Dark yellowish brown (10YR4/4) with some mottles; clay; medium subangular blocky; firm
C	73 +	Grayish brown (10YR5/2); with some mottles; clay; fine subangular blocky; firm

Table 36. Fall 1989. Spring/Fall 1990. and Spring/Fall 1991 Fertility Levels for Treatments at John Van Dorp's Two Fields.

Farmer	Field No.	Crop	Year	Position	Fertility (mg/kg)				pH	% O.M.
					P	K	Mg	Ca		
Van Dorp	1	corn	1989F*	upper slope	38	173	159	2156	5.9	3.7
				lower slope	23	119	272	2834	6.3	3.4
		corn	1990F	Aer-way only (upper slope)	41	158	206	1476	6.8	4.2
				Aer-way + disk (lower slope)	29	207	302	1920	7.1	5.0
		corn	1991S*	Aer-way only	31	98	504	1960	7.3	3.9
				oats-vetch	31	121	374	1370	6.5	3.0
			1991F	O.B.A.T.A.	32	121	121	1066	6.0	3.6
	2	winter wheat	1989F	top slope (red clover)	32	152	200	1939	6.2	3.4
				middle slope (hairy vetch)	36	141	216	2183	6.0	3.3
				bottom slope (oilseed radish)	43	224	193	1237	5.6	3.8
		corn	1990S	red clover	23	146	139	1634	6.9	-
				spring vetch	13	84	167	1386	6.4	-
				summer vetch	22	129	113	1220	5.8	-
				oilseed radish	34	147	113	1000	5.6	-
			1990F	top slope (red clover)	58	301	237	1510	6.9	4.9
				middle slope (vetch-oats)	39	155	196	1426	6.4	4.4
				bottom slope (hairy vetch)	59	273	142	1066	6.3	4.6
		corn	1991S	red clover	27	135	234	1313	5.7	3.1
				oats-vetch	24	153	279	1389	6.2	3.0
			1991F	O.B.A.T.A.	36	128	124	1166	6.1	3.7

* F= fall, S= spring.

Table 37. Fall 1989. Spring/Fall 1990. and Spring/Fall 1991 Fertility Levels for Treatments at Mint Klynstra's Two Fields.

Farmer	Field No.	Crop	Year	Position	Fertility (mg/kg)				pH	% O.M.
					P	K	Mg	Ca		
Klynstra	1	soybeans	1989F*	standard	18	117	354	2832	6.7	5.2
				O.B.A.T.A.	17	125	320	2659	7.0	5.3
		winter wheat	1990F	standard (Aer-way only)	36	207	318	2043	7.3	5.7
				vetch-rye	37	171	328	1927	7.0	5.8
				vetch-oats	25	187	342	2046	7.3	5.7
				oilseed radish	21	155	344	2231	7.3	5.4
		corn	1991S*	Aer-way only	28	137	535	2120	6.9	5.1
				rye-vetch	18	108	506	2200	7.0	4 8
				oats-vetch	14	91	501	1870	6.9	4.9
				oilseed radish	11	92	417	2110	7.2	4.7
			1991F	standard	21	90	184	1826	6.7	5.8
				O.B.AT.A	15	86	218	2100	6.8	5.6
	2	winter wheat	1989F	standard (rye)	26	251	356	2440	7.0	4.5
				red clover	20	168	341	2488	6.9	4.1
				oilseed radish	23	165	347	2690	7.0	4.4
				hairy vetch	18	170	326	2622	6.9	4.1
		corn	1990S	standard (rye)	18	157	240	1930	6.9	-
				summer vetch	17	164	239	2200	6.8	
				fall vetch	12	130	177	2010	6.7	-
				oilseed radish	28	175	223	1930	6.7	-
				red clover	15	143	186	2460	7.0	
			1990F	standard	39	330	264	1772	7.1	4.9
				O.B.AT.A	50	218	150	1207	6.7	4.3
		corn	1991S	standard	12	167	467	1600	6.7	4.7
				O.B.AT.A	28	198	518	2130	6.6	5.1
			1991F	standard	23	141	159	1579	6.6	4.7
				foliar spray	23	109	177	1620	6.5	4.2
				no foliar spray	19	121	165	1647	6.7	4.4

* F= fall, S= spring.

Table 38. Fall 1989. Spring/Fall 1990. and Spring/Fall 1991 Fertility Levels for Treatments at Jim House's Two Fields.

Farmer	Field No.	Crop	Year	Position	Fertility (mg/kg)				pH	% O.M.
					P	K	Mg	Ca		
House	1	corn	1989F	standard	19	108	137	2287	6.8	4.4
				O.B.A.T.A.	26	114	168	1619	6.2	2.2
				O.B.A.T.A. (rye)	15	124	238	2473	7.2	2.6
		corn	1990S	standard	15	180	126	2156	6.3	-
				red clover	15	121	158	2443	6.9	-
				oilseed radish	15	104	145	2830	7.1	-
			1990F	standard	19	120	182	2639	7.5	3.9
				oilseed radish	21	147	233	2699	7.4	4.2
				winter rye	27	145	213	2624	7.4	4.3
				annual ryegrass	23	151	266	2311	6.8	4.7
				oats	22	172	292	2762	7.1	4.2
		corn-soy	1991S	standard	18	125	466	4158	6.9	2.9
				cover crop	15	130	385	2965	6.9	3.4
				no cover crop	19	113	316	1970	6.0	3.4
			1991F	standard	22	128	161	2459	6.5	3.3
				O.B.A.T.A.	17	101	119	1898	6.8	3.3
	2	winter wheat	1989F	standard	22	140	172	2789	6.6	3.1
				red clover	24	374	146	6900	6.7	3.2
				buckwheat	20	169	144	4037	6.6	3.2
				oilseed radish	23	149	229	3589	6.8	3.6
		soybeans	1990F	standard	25	165	190	2038	7.3	3.5
				O.B.A.T.A.	23	158	211	1911	7.3	3.8
		corn-soy	1991S	standard	13	98	370	2150	7.0	3.0
				O.B.A.T.A.	27	121	366	2416	7.2	2.5
			1991F	standard	15	75	117	1472	6.6	3.3
				O.B.A.T.A.	16	84	106	1620	6.9	2.8

Table 39. Fall 1989 and 1990 Fertility Levels for Treatments at Joe Gerber and Dave McIntosh's Sites.

Farmer	Field No.	Crop	Year	Position	Fertility (mg/kg)				pH	% O.M.
					P	K	Mg	Ca		
Gerber*	1	corn	1989	standard	4	101	400	4744	6.9	3.9
				O.B.A.T.A.	6	134	378	3910	6.5	5.8
		corn	1990	standard	6	122	343	2116	7.4	4.3
				O.B.A.T.A.	5	127	385	2641	7.1	4.7
	2	corn	1989	standard	6	119	389	5761	7.0	4.1
				O.B.A.T.A.	6	150	405	5061	6.5	5.1
McIntosh*	1	corn	1989	standard	15	138	310	2527	7.1	3.2
				O.B.A.T.A.	15	123	278	2933	6.8	3.3
		corn	1990	standard	20	133	252	2238	7.0	4.9
				O.B.A.T.A.	13	123	192	1837	7.2	3.9
	2	soybeans	1989	standard	18	136	307	3527	7.0	4.2
				O.B.A.T.A.	14	148	290	3142	6.9	3.7
		soybeans	1990	standard	15	105	193	1893	7.5	4.1
				O.B.A.T.A.	19	122	188	2678	7.5	3.6

* Research fields not available for 1990 and/or 1991.

Table 40. Fall 1989. 1990. and Spring/Fall 1991 Fertility Levels for Treatments at Arpad Pasztor and Dean Glenney's Sites.

Farmer	Field No.	Crop	Year	Position	Fertility (mg/kg)				pH	% O.M.
					P	K	Mg	Ca		
Pasztor*	1	corn	1989F	standard	30	123	90	1391	7.3	2.7
				O.B.A.T.A.	36	154	93	899	6.5	3.5
		corn	1990F	standard	32	129	113	1018	6.8	4.1
				O.B.A.T.A.	63	170	92	630	6.0	4.9
	2	soybeans	1989F	standard	63	148	105	1156	7.1	1.5
				O.B.A.T.A.	52	144	108	870	6.8	1.5
				O.B.A.T.A. (rye)	57	152	86	890	6.8	1.2
	1 (3)**	corn	1991S	standard	41	102	217	1077	7.1	1.6
				O.B.A.T.A.	38	106	171	560	6.8	1.2
			1991F	standard	43	72	77	1370	7.4	1.6
				O.B.A.T.A.	27	64	64	680	7.1	1.8
Glenney*	1	corn	1990F	standard	7	102	152	1001	6.2	4.2
				O.B.A.T.A.	7	63	122	917	6.3	4.1
	2	corn		standard	29	133	150	915	6.3	4.0
				O.B.A.T.A.	26	159	179	1068	6.7	4.1

* Some research fields not available for

** 1991.Field #1 in 1991 was field #3 in 1990.

Table 41. Spring 1990 Ammonium and Nitrate Levels.

Farmer	Field No.	Crop	Treatment	% Soil Moisture				NH_3-N (mg/kg)				NO_3-N (mg/kg)			
				0-15cm	15-30cm	30-45cm	45-60cm	0-15cm	15-30cm	30-45cm	45-60cm	0-15cm	15-30cm	30-45cm	45-60cm
1 (Van	2	corn	red clover	19.2	19.4	17.7	17.9	3.01	0.83	0.83	0.61	20.29	14.73	14.33	8.81
			spring vetch	18.4	17.1	15.2	16.6	0.48	0.33	0.53	1.10	22.61	16.85	14.90	8.41
			summer	23.1	22.5	22.9	20.2	0.94	1.10	1.07	0.90	26.88	20.09	10.00	4.33
			oilseed	20.3	19.1	18.2	21.2	0.69	1.05	0.68	1.16	24.62	24.73	13.93	8.78
2 (Klynstra)	2	corn	standard	-	-	-	-	2.10		1.41		4.87		2.38	
			summer	-	-	-	-	2.21		2.27		8.69		4.41	
			fall vetch	-	-	-	-	4.01		3.49		4.96		2.77	
			oilseed	-	-	-	-	1.88		2.14		11.45		4.70	
			red clover	-	-	-	-	2.05		1.79		6.31		4.43	
3 (House)	1	corn	standard	20.6	20.4	26.6	25.1	5.86	2.87	1.23	1.56	3.62	7.03	5.55	3.26
			red clover	15.5	23.9	23.8	12.3	4.03	2.49	1.48	2.48	6.39	11.56	10.56	3.06
			oilseed	27.1	22.7	22.7	22.6	2.18	2.29	1.83	1.55	6.72	4.67	3.55	1.23

Table 42. Spring 1991 Ammonium and Nitrate Levels.

Farmer	Field No.	Crop	Treatment	% Soil Moisture		NH_3-N (mg/kg)		NO_3-N (mg/kg)	
				0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1 (Van Dorp)	1	corn	Aer-way only	21.9	20.3	3.44	3.26	12.04	9.30
			oats-vetch mix	19.4	19.0	2.50	2.60	11.49	10.96
	2	corn	red clover	22.6	20.9	5.26	2.83	19.66	14.67
			oats-vetch mix	22.4	22.6	2.74	2.75	15.02	11.17
2 (Klynstra)	1	corn	Aer-way only	28.6	26.4	1.13	1.99	29.42	46.09
			rye-vetch mix	27.1	25.1	1.84	1.82	19.05	14.83
			oats-vetch mix	27.2	26.0	2.03	3.99	26.64	18.66
			oilseed radish	27.7	25.4	0.30	0.29	27.05	16.27
	2	corn	standard	28.7	25.0	0.78	0.65	37.02	30.58
			O.B.AT.A.	28.8	25.8	8.22	0.94	43.45	33.84
3 (House)	1	corn/soy	standard	16.1	19.1	3.84	3.14	4.29	4.64
			with cover crop	18.2	17.5	4.94	5.70	2.69	2.56
			no cover crop	16.6	17.1	13.07	14.74	35.12	27.84
	2	corn/soy	standard	19.3	20.7	4.84	3.31	27.72	14.45
			O.B.A.T.A.	18.9	17.9	6.00	4.51	14.78	15.12
4 (Pasztor)	1	corn	standard	7.6	6.1	4.68	7.48	8.31	4.69
			O.B.A.T.A.	6.4	6.0	5.22	4.56	10.27	7.58

Table 43. Mean Dickey-john® Penetrometer Readings (kg/cm^2) for Fall 1989 and 1991 in John Van Dorp's Two Research Fields.

Field	Depth (cm)	O.B.A.T.A.				
		2 Readings per Site @ 12 Sites			Sample Pit Site	
		1989	1991* corn	1991 alfalfa	1989	1991
		n=24	n=12	n=12	n=6	n=6
1	0-8	110	213	325	130	188
	8-16	190	304	394	130	288
	16-24	250	379	400	250	375
	24-32	280	400	400	290	400
	32-40	320	400	400	290	400
	40-48	380	400	400	320	400
		n=24	n=24	-	n=6	n=6
2	0-8	80	216	-	110	213
	8-16	120	327	-	160	338
	16-24	190	388	-	200	396
	24-32	225	399	-	250	400
	32-40	290	400	-	300	400
	40-48	340	400	-	320	400

* Half the readings were taken in the corn area, the other half in the alfalfa area.

Table 44. Mean Dickey-john® Penetrometer Readings (kg/cm^2) for Fall 1989 and 1991 for Mint Klynstra's Two Research Fields.

Field	Depth (cm)	Standard				O.B.A.T.A.			
		Overall		Observation pit		Overall		Observation Pit	
		1989	1991	1989	1991	1989	1991	1989	1991
		n=14		n=6		n=14		n=6	
1	0-8	10	159	0	129	3	161	0	171
	8-16	154	250	158	213	156	261	142	258
	16-24	206	332	200	292	223	338	217	338
	24-32	264	373	258	346	280	375	271	367
	32-40	293	379	292	350	327	386	325	371
	40-48	329	384	358	363	363	393	350	383
		n=28*	n=14	n=6		-	n=14	n=6	
2	0-8	100	154	117	167	-	146	100	142
	8-16	143	250	750	250	-	259	150	250
	16-24	204	355	208	367	-	355	217	350
	24-32	247	395	258	396	-	391	258	383
	32-40	292	400	292	400	-	400	308	400
	40-48	366	400	367	400	-	400	375	400

* Means from both standard and O.B.A.T.A. areas.

Table 45. Mean Dickey-john® Penetrometer Readings (kg/cm^2) in Mint Klynstra's Fields #1 and 2 for 1991.

Field	Depth (cm)	Standard* (n=14)	O.B.A.T.A.* (n=14)	Moldboard* (field 1 n=6, field 2 n=8)
1	0-8	159	161	163
	8-16	250	261	254
	16-24	332	338	367
	24-32	373	375	396
	32-40	379	386	400
	40-48	384	393	400
2	0-8	154	146	163
	8-16	250	259	253
	16-24	355	355	331
	24-32	395	391	381
	32-40	400	400	400
	40-48	400	400	400

* Standard = Aer-way, no foliar spray O.B.A.T.A. = Aer-way, foliar spray
Moldboard = moldboard plow, no foliar spray

Table 46. Mean Dickey-john Penetrometer Readings (kg/cm^2) for Fall 1989 and 1991 in Jim House's Two Research Fields.

Field	Depth (cm)	Standard				O.B.A.T.A.			
		Overall		Sample Pit Site		Overall		Sample Pit Site	
		1989 n=12	1991 n=12	1989 n=6	1991 n=6	1989 n=24	1991 n=18	1989 n=6	1991 n=6
1	0-8	75	-	60	225	80	-	100	183
	8-16	170	279	180	329	180	250	250	283
	16-24	270	367	240	392	250	369	310	392
	24-32	340	396	280	400	310	396	330	396
	32-40	360	400	320	400	360	400	380	400
	40-48	370	400	350	400	390	400	400	400
2		n=6	n=12	n=6	n=6	n=18	n=18	n=6	n=6
	0-8	200	233	160	229	210	217	180	179
	8-16	260	325	250	325	300	331	250	321
	16-24	330	388	330	388	320	386	300	383
	24-32	380	400	380	400	350	399	330	400
	32-40	380	400	390	400	360	400	350	400
	40-48	400	400	400	400	380	400	390	400

* = no available data

Table 47. Mean Dickey-john® Penetrometer Readings (kg/cm^2) for Fall 1989 and 1991 in Arpad Pasztor's Research Field.

Depth (cm)	Standard				O.B.A.T.A.			
	Overall		Sample Pit Site		Overall		Sample Pit Site	
	1989 n=18	1991 n=18	1989 n=6	1991 n=6	1989 n=18	1991 n=18	1989 n=6	1991 n=6
0-8	120	146	130	63	140	154	120	88
8-16	230	254	240	179	280	321	200	221
16-24	390	350	380	333	460	400	350	383
24-32	500	371	480	400	520	400	450	400
32-40	530	371	470	400	500	388	380	400
40-48	520	346	470	383	470	371	380	333

Table 48. Mean Values for Pocket Penetrometer Ratings (kg/cm^2) in 1991.

Farmer	Field	Treatment	Soil Layer		
			Topsoil (depth. cm)	Compact (depth. cm)	Subsoil (depth. cm)
Van Dorp	1	O.B.A.T.A.	2.21* (0-18)	3.29 (18-28)	3.79 (28+)
	2	O.B.A.T.A.	1.54 (0-18)	4.08 (18-28)	3.67 (28+)
Klynstra	1	Standard	0.88 (0-18)	3.04 (18-28)	2.71 (28+)
		O.B.A.T.A.	0.96 (0-17)	2.92 (17-29)	2.50 (29+)
	2	Standard	1.21 (0-17)	3.04 (17-28)	2.83 (28+)
		O.B.A.T.A.	0.96 (0-16)	3.42 (16-27)	2.67 (27+)
House	1	Standard	2.54 (0-15)	4.42 (15-28)	4.46 (28+)
		O.B.A.T.A.	2.13 (0-18)	4.17 (18-33)	3.92 (33+)
	2	Standard	2.25 (0-16)	3.92 (16-29)	4.50 (29+)
		O.B.A.T.A.	2.21 (0-18)	4.38 (18-31)	4.5 (31+)
Pasztor	1	Standard	0.79 (0-18)	3.00 (18-32)	3.17 (32+)
		O.B.A.T.A.	0.75 (0-16)	2.38 (16-30)	2.67 (30+)

* For all means n=6.

Table 49. Fall 1989 and 1991 Bulk Density Measurements.

Farmer	Field No.	Tmt	Soil Layer	Rep No.	Wt Wet Soil		Wt Dry Soil		Wt Water	% Moisture	B.D. (g/cm^3)		Mean B.D.	
					1989	1991	1989	1991	1991	1991	1989	_1991	1989	1991
Van Dorp	1	OBA	A	1	-	176.4	141.5	146.1	30.3	20.7	1.43	1.47	1.44	1.44
				2	-	168.5	143.1	138.8	29.7	21.4	1.44	1.40		
			AB	1	-	187.9	143.6	158.0	29.9	18.9	1.45	1.59	1.48	1.53
				2	-	173.5	149.7	145.1	28.4	19.6	1.51	1.46		
			B	1	-	187.0	156.7	166.4	20.6	12.4	1.58	1.68	1.58	1.64
				2	-	182.4	156.8	157.4	25.0	15.9	1.58	1.59		
	2	OBA	A	1	-	164.6	144.9	130.7	33.9	25.9	1.46	1.32	1.47	1.38
				2	-	176.2	145.6	142.9	33.3	23.3	1.47	1.44		
			AB	1	-	180.4	143.2	149.1	31.3	20.9	1.44	1.50	1.54	1.53
				2	-	184.0	161.7	153.6	30.4	19.8	1.63	1.55		
			B	1	-	191.0	155.2	164.1	26.9	16.4	1.56	1.65	1.55	1.67
				2	-	194.9	151.9	166.4	28.5	17.1	1.53	1.68		
Klynstra	1	STD	A	1	-	164.6	131.0	130.6	34.0	26.0	1.32	1.32	1.32	1.34
				2	-	169.1	-	134.9	34.2	25.4	-	1.36		
			AB	1	-	177.8	142.8	144.8	33.0	22.8	1.44	1.46	1.44	1.47
				2	-	179.5	-	147.3	32.2	21.9	-	1.48		
			B	1	-	202.0	170.0	172.3	29.7	17.2	1.71	1.74	1.71	1.73
				2	-	198.4	-	169.9	28.5	16.8	-	1.71		
		OBA	A	1	-	159.1	136.9	123.5	35.6	28.8	1.38	1.24	1.38	1.23
				2	-	151.1	-	119.6	31.5	26.3	-	1.21		
			AB	1	-	184.0	147.4	150.0	34.0	22.7	1.49	1.51	1.49	1.50
				2	-	182.8	-	148.1	34.7	23.4	-	1.49		
			B	1	-	191.4	166.6	161.2	30.2	18.7	1.68	1.63	1.68	1.66
				2	-	197.0	-	166.7	30.3	18.2	-	1.68		

Note: All weights in grams (g).

Table 49. Fall 1989 and 1991 Bulk Density Measurements (continued).

Farmer	Field No.	Tmt	Soil Layer	Rep No.	Wt. Wet Soil		Wt Dry Soil		Wt Water	% Moisture	B.D. (g/cm^3)		Mean B.D.	
					1989	1991	1989	1991	1991	1991	1989	1991	1989	1991
Klynstra	2	STD	A	1	-	155.6	124.6	124.1	31.5	25.4	1.26	1.25	1.26	1.27
				2	-	161.8	-	127.1	34.7	27.3	-	1.28		
			AB	1	-	176.9	140.5	140.2	36.7	26.2	1.42	1.41	1.42	1.43
				2	-	180.9	-	143.8	37.1	25.8	-	1.45		
			B	1	-	182.5	146.5	146.1	36.4	24.9	1.48	1.47	1.48	1.53
				2	-	194.0	-	158.3	35.7	22.6	-	1.59		
		OBA	A	1	-	175.1	125.5	137.4	37.7	27.4	1.27	1.39	1.27	1.38
				2	-	172.2	-	134.7	37.3	27.7	-	1.36		
			AB	1	-	188.2	137.5	151.3	36.9	24.4	1.39	1.53	1.39	1.53
				2	-	185.5	-	151.7	33.8	22.3	-	1.53		
			B	1	-	194.9	146.1	158.9	36.0	22.7	1.47	1.60	1.47	1.60
				2	-	194.1	-	159.1	35.0	21.9	-	1.60		
House	1	STD	A	1	-	174.4	-	158.3	16.1	10.2	-	1.60	-	1.57
				2	-	171.4	-	151.4	20.0	13.2	-	1.53		
			AB	1	-	181.7	153.6	162.8	18.9	11.6	1.55	1.64	1.55	1.64
				2	-	183.5	-	162.7	20.8	12.8	-	1.64		
			B	1	-	186.0	158.4	164.5	21.5	13.1	1.60	1.66	1.60	1.66
				2	-	179.4	-	164.8	14.6	10.0	-	1.66		
		OBA	A	1	-	181.2	-	146.0	35.2	24.1	-	1.47	-	1.53
				2	-	182.2	-	158.1	24.1	15.2	-	1.59		
			AB	1	-	183.0	155.5	150.7	32.2	21.4	1.57	1.52	1.57	1.53
				2	-	185.2	-	152.1	33.1	21.8	-	1.53		
			B	1	-	194.7	149.5	164.9	29.8	18.1	1.51	1.66	1.51	1.62
				2	-	186.3	-	155.6	30.7	19.7	-	1.57		

Note: All weights in grams (g).

Table 49. Fall 1989 and 1991 Bulk Density Measurements (concluded).

Farmer	Field No.	Tmt	Soil Layer	Rep No.	Wt Wet Soil		Wt Dry Soil		Wt Water	% Moisture	B.D. (g/cm^3)		Mean B.D.	
				_	1989	1991	1989	_1991	1991	1991	1989	1991	1989	1991
House	2	STD	A	1	-	173.5	128.3	142.5	31.0	21.8	1.29	1.44	1.29	1.51
				2	-	188.8	-	156.8	32.0	20.4	-	1.58		
			AB	1	-	185.2	142.9	153.7	31.5	20.5	1.44	1.55	1.44	1.44
				2	-	189.9	-	132.3	57.6	43.6	-	1.33		
			B	1	-	186.3	135.8	165.5	20.8	12.6	1.37	1.67	1.37	1.65
				2	-	182.5	-	160.6	21.9	13.6	-	1.62		
		OBA	A	1	-	177.2	144.2	142.8	34.4	24.1	1.45	1.44	1.45	1.47
				2	-	176.1	-	147.8	28.3	19.1	-	1.49		
			AB	1	-	168.4	144.3	142.0	26.4	18.6	1.45	1.43	1.45	1.37
				2	-	165.8	-	130.3	35.5	27.2	-	1.31		
			B	1	-	176.8	144.1	154.6	22.2	14.4	1.45	1.56	1.45	1.60
				2	-	186.7	-	161.5	25.5	15.8	-	1.63		
Pasztor	3(1)*	STD	A	1	-	147.7	-	136.6	11.1	8.1	-	1.38	-	1.37
				2	-	144.8	-	133.7	11.1	8.3	-	1.35		
			AB	1	-	170.7	-	155.8	14.9	9.6	-	1.57	-	1.56
				2	-	168.6	-	154.2	14.4	9.3	-	1.55		
			B	1	-	163.5	-	145.7	17.8	12.2	-	1.47	-	1.48
				2	-	162.8	-	147.0	15.8	10.7	-	1.48		
		OBA	A	1	-	148.5	-	138.4	10.1	7.3	-	1.40	-	1.41
				2	-	147.9	-	139.8	8.1	5.8	-	1.41		
			AB	1	-	166.4	-	154.5	11.9	7.7	-	1.56	-	1.57
				2	-	167.1	-	155.6	11.5	7.4	-	1.57		
			B	1	-	169.6	-	152.9	16.7	10.9	-	1.54	-	1.51
				2	-	163.7	-	147.5	16.2	10.9	-	1.47		

* Pasztor's field #1 (1991) was field #3 in 1990. Note: All weights in grams (g).

Table 50. Microbial biomass analyses for 1989, 1990. and 1991 from the standard and O.B.A.T.A. management treatments at two soil depths.

Farmer	Field	Crop	Year	Rep.	Biomass carbon (µg/g) 0-10 cm std.	0-10 cm oba.	10-20 cm std.	10-20 cm oba.
J. House	1	winter wheat	1989	1	272	30	206	150
				2	184	184	142	103
				3	363	218	171	102
				mean	273	144	173	118
		corn	1990	1	293	234	149	69
				2	119	79	63	40
				3	234	113	70	98
				mean	215	142	94	69
		corn/ soybean	1991	1	189	185	182	197
				2	165	164	166	160
				3	165	190	179	187
				mean	173	179	175	181
	2	corn	1989	1	302	189	278	60
				2	251	136	67	153
				3	207	210	186	165
				mean	253	178	177	126
		soybean	1990	1	158	62	83	52
				2	115	47	64	187
				3	142	117	83	47
				mean	138	75	77	95
		corn/ soybean	1991	1	206	166	189	167
				2	195	160	191	149
				3	196	162	165	142
				mean	199	163	182	153
M. Klynstra	2	winter wheat	1989	1	219	383	238	285
				2	364	394	307	382
				3	316	339	340	291
				mean	299	372	295	319
		corn	1990	1	246	240	132	189
				2	271	228	189	183
				3	167	183	48	60
				mean	228	217	123	144
		corn	1991	1	186	196	206	203
				2	196	187	211	216
				3	197	190	218	205
				mean	193	191	212	208
	1	corn	1991	-	-	177	-	200
J. Van Dorp	1	corn	1991	-	-	189	-	192
	2	corn	1991	-	-	195	-	169

Note: Soil samples taken mid. June 1989, 15-19 June 1990, and 19 June 1991.

Table 50. Microbial biomass analyses for 1989. 1990. and 1991 from the standard and O.B.A.T.A. management treatments at two soil depths (concluded).

Farmer	Field	Crop	Year	Rep.	Biomass carbon (µg/g) 0-10 cm std.	0-10 cm oba.	10-20 cm std.	10-20 cm oba.
D. McIntosh	1	corn	1989	1	132	132	95	87
				2	143	116	111	79
				3	136	113	124	160
				mean	137	120	110	108
		corn	1990	1	287	-	165	138
				2	312	194	336	201
				3	142	173	232	93
				mean	247	184	244	144
A. Pasztor	1	corn	1989	1	206	135	101	60
				2	139	69	109	70
				3	190	117	149	80
				mean	178	107	119	70
		corn	1990	1	146	137	158	64
				2	79	95	50	59
				3	187	180	190	167
				mean	137	137	133	97
	2	soybean	1989	1	253	84	117	84
				2	181	114	104	102
				3	195	179	131	123
				mean	209	125	117	103
		tomato	1990	1	184	81	60	82
				2	145	100	81	35
				3	150	111	110	71
				mean	160	97	84	63
J. Gerber	1	corn	1989	1	227	424	391	499
				2	435	651	477	426
				3	310	276	279	330
				mean	324	450	382	418
		corn	1990	1	366	276	270	215
				2	357	339	312	288
				3	314	258	287	298
				mean	346	291	289	267

Note: Soil samples were obtained mid. June 1989 and 15-19 June 1990.

Table 51. Fall 1989 and 1990 Crop Yields for Treatments at Dave McIntosh and Joe Gerber. and Dean Glenney's Research Fields.

Farmer	Field No.	Crop	Year	Treatment	Yield (dry bu/ac)
D. McIntosh	1	corn	1989	standard	141.8
				O.B.A.T.A. (less subsoiling)	142.8
		corn	1990	standard	no data
				O.B.A.T.A. (no kelp/molasses seed	
				O.B.A.T.A. (kelp/molasses seed	
				O.B.A.T.A. (with subsoiling)	
	2	soybean	1989	standard	37.4
				O.B.A.T.A. (no kelp/molasses seed	37.0
				O.B.A.T.A. (kelp only with seed)	39.9
				O.B.A.T.A. (kelp/molasses with seed)	41.4
		soybean	1990	standard	no data
				O.B.A.T.A. (no seed treatment)	'
				O.B.A.T.A. (kelp only seed treatment)	
				O.B.A.T.A. (kelp/molasses seed	'
J.Gerber	1	corn	1989	standard	78.9
				O.B.A.T.A.	47.9
				O.B.A.T.A. (less subsoiling)	58.7
			1990	standard	137.8
				O.B.A.T.A. (no seed treatment)	119.8
				O.B.A.T.A. (seed treatment)	123.3
D. Glenney	1	corn	1990	standard	111.6
				no till into fall disked corn stalks	110.6
				no disk	96.9
				no till into oilseed radish	102.7
	2	corn	1990	standard (disked twice in spring)	126.2
				standard (plowed. disked twice)	139.5
				O.B.A.T.A. (subsoiler)	120.0

Note: No data available for D. McIntosh in 1990 due to untimely fall harvest.

Table 52. Fall 1989. 1990. and 1991 Crop Yields for Treatments at John Van Dorp's Two Research Fields.

Farmer	Field No.	Crop	Year	Treatment	Yield (dry bu/ac)
Van Corp	1	corn	1989	standard (30 lb N planter, 30 lb N sidedress)	128.9
				no N (either planter or sidedress)	115.0
				no N with planter - 30 lb sidedress	122.4
				- 60 lb sidedress (June)	129.5
				- 90 lb sidedress (June)	129.0
				30 lb N with planter - no sidedress	122.0
				30 lb N with planter - 30 lb sidedress	127.2
				- 60 lb sidedress (June)	129.5
				- 90 lb sidedress (June)	133.8
		corn	1990	Aer-way only	114.0
				Aer-way plus disk	100.0
		corn	1991	Aer-way only	104.0
				Aer-way plus disk (lx)	102.5
				Aer-way plus disk (2x)	104.0
	2	winter	1989	no spring cover crop (Augusta)	55.0
				spring planted hairy vetch (Augusta)	51.0
				spring planted red clover (Harus)	42.0
		corn	1990	spring planted red clover	110.0
				spring planted hairy vetch	130.0
				summer planted hairy vetch 0 kg/ha N	108.0
				67 kg/ha N	107.0
				135 kg/ha N	96.9
				oilseed radish	145.0
		corn	1991	1990 red clover	108.0
				1990 spring planted hairy vetch	112.0
				1990 summer planted hairy vetch	120.0
				1990 oilseed radish	115.0

Note: the nitrogen amounts are actual N.

Table 53. Fall 1989, 1990. and 1991 Crop Yields for Treatments at Mint Klynstra's Two Research Fields.

Farmer	Field No.	Crop	Year	Treatment	Yield (dry bu/ac)
Klynstra	1	soybean	1989	standard = double seeding rate (128 lb/ac) no seed or foliar treatments - Aer-wayed	59.7
				standard = regular 20' planter rate (55 lb/ac) no seed or foliar treatments - Aer-wayed	45.0
				O.B.A.T.A., plowed = planter (55 lb/ac) seed and foliar treatments	39.9
				O.B.A.T.A., plowed = drilled (87 lb/ac) seed and foliar treatments	41.9
				O.B.A.T.A., Aer-wayed = drilled (87 lb/ac) seed and foliar treatments - Aer-wayed	51.8
				O.B.A.T.A., Aer-wayed = planter (55 lb/ac) seed and foliar treatments - Aer-wayed	42.4
				O.B.A.T.A.. Aer-wayed = planter (55 lb/ac) seed and foliar treatments - Aer-wayed	48.3
				O.B.A.T.A., Aer-wayed = planter (128 lb/ac) seed and foliar treatments - Aer-wayed	46.5
		winter wheat	1990	field average	67.0
		corn	1991	standard = hairy vetch - rye (Aer-way', no foliar spray)	144.0
				oilseed radish (foliar spray)	155.5
				hairy vetch - oats (foliar spray)	149.4
				moldboard plow (foliar spray)	159.3
	2	winter wheat	1989	standard (Augusta)	51.0
				underseeded with hairy vetch (Augusta)	54.0
		corn	1990	1989 winter rye (Standard) 1989 buckwheat	79.6 108.9
				'89 fall planted hairy vetch (no seed '89 fall planted hairy vetch (seed treatment)	94.3 101.8
				'89 oilseed radish, '90 oats (no seed '89 oilseed radish, '90 oats (treated seed)	109.0 109.5
				1989 rye (treated seed)	84.7
				1989 red clover	95.3
		corn	1991	standard (Aer-way, no foliar spray)	129.2
				Aer-way, foliar spray	136.4
				moldboard plow, foliar spray	142.4

Table 54. Fall 1989. 1990. and 1991 Crop Yields for Treatments at Jim House's Two Research Fields.

Farmer	Field No.	Crop	Year	Treatment	Yield (dry bu/ac)
House	1	winter	1989	standard*	52.4
				O.B.A.T.A.	59.0
		corn	1990	standard	139.5
				red clover	139.7
				oilseed radish 28% N NH_3	 137.7 138.7
				buckwheat	138.7
		corn/soy	1991	corn:standard O.B.A.T.A.	159.6 174.7
				soybean:standard foliar spray no foliar spray	49.8 51.6 50.2
	2	corn	1989	standard (no till)	155.3
				O.B.A.T.A.	146.7
		soybean	1990	standard (no till)	36.9
				O.B.A.T.A.	32.7
		corn-soy	1991	corn:standard (no till) O.B.A.T.A.	220.8 248.2
				soybean:standard O.B.A.T.A.	38.8 39.6

* Hand samples.

Table 55. Fall 1989. 1990. and 1991 Crop Yields for Treatments in Arpad Pasztor's Research Fields.

Farmer	Field No.	Crop	Year	Treatment	Yield (dry bu/ac)
Pasztor	1	corn	1989	standard	131.0
				O.B.A.T.A.	110.0
		corn	1990	standard	100.3
				O.B.A.T.A.	90.2
	2	soybean	1989	standard	31.0
				standard*	41.5
				O.B.A.T.A.	27.9
				O.B.A.T.A.*	32.4
				O.B.A.T.A. (soybean into standing	14.2
				O.B.A.T.A. (soybean into standing	36.0
	1	corn	1991	standard	116.0
				O.B.A.T.A.	116.0

* Hand samples (2 m^2) taken from equally populated areas.

12. APPENDIX B

Three Year Summary Tables of Farmer Records

(John Van Dorp. Mint Klynstra. Jim House and Arpad Pasztor):

Management Operations and Machinery Used

(Tables 56. 57. 62. 63. 68. 69. 74)

Principal and Cover Crops Used

(Tables 58. 64. 70. 75)

Fertilizer and O.B.A.T.A. Spray Operations

(Tables 59. 60. 65. 66. 71. 72. 76. 77)

Herbicide Applications

(Tables 61. 67. 73. 78)

Table 56. John Van Dorp - Operations and Machinery Used in Field #1 for 1989, 1990 and 1991.

FIELD	YEAR	CROP	OPERATIONS		MACHINERY
			STANDARD	O.B.A.T.A.	
1	1989	corn	same as O.B.A.T.A.	Nov. 88 - residue spray	White 2-110(L), 2700 gal tanker
				- Aer-way once	White 2-110, 11'8" pull type Aer-way
				April - weed control	White 2-110(D), 19' disk
				May - culti-packing pass	White 2-110(D), 16' cultipacker
				- Aer-way + planter + N	White 2-85(D), 12' pull type + planter
				- herbicide spraying	White 2-85(S), 43' sprayer
				June - sidedress N	White 2-85(S), coulters
				- foliar spray	White 2-85(S), 100' passes with mister
				Sept. - cover crop seeding	aerial seeded with Hy-Boy (60' spread)
				Oct. - combine	J.D. 7700 + White 2-110: unload on go
				- residue spray	White 2-110(L), 2700 gal tanker
				- Aer-way once over	White 2-110, 11'8" pull type
	1990	corn	same as O.B.A.T.A.	April - residue incorporation	White 2-110, 19' disk harrow
				- Aer-way + planter	White 2-85, 12' pull type Aer-way + planter
				May - herbicide spraying	White 2-85, 43' 500 gal sprayer
				June - sidedress N	White 2-85, 12' 300 gal sprayer
				- foliar spray	White 2-85, automatic mister 20 A/App.
				Oct. - combine	J.D. 7700
				- residue spray + fertilizer	White 2-110, 43' 500 gal sprayer
				Nov. - Aer-way once	White 2-110, 15' pull type
	1991	corn	same as O.B.A.T.A.	April/May - disk once or twice	White 2-110, 19' disk harrow
				May - Aer-way + planter	White 2-85, 7x20" row planter N.C. Kinze
				June - sidedress N	White 2-85, 12' spray boom
				- foliar spray	White 2-85, fogger 200' width
				Oct. - combine	J.D. 7720 12' header
				- shred crop residue	White 2-110, 12' shredder
				- crop residue spray	White 2-85, 43' boom 500 gal tanker
				- Aer-way once	White 2-110, 12' pull type

Table 57. John Van Dorp - Operations and Machinery Used in Field #2 in 1989, 1990 and 1991.

FIELD	YEAR	CROP	OPERATIONS		MACHINERY
			STANDARD	O.B.A.T.A.	
2	1989	winter wheat	same as O.B.A.T.A.	Oct. 88 - combine	J.D. 7700
				- residue spray	White 2-85, 43' boom 500 gal sprayer
				- plowing	White 2-110(L), 4x18' plow
				- culti-packing (1 pass)	White 2-110(D), cultipacker
				- seeding wheat	J.D. 710, seed drill (9' width)
				April - seeding cover crop	3 wheel electric seeder (30' wide)
				May - applying N	White 2-85, 43' boom 500 gal sprayer
				- drilling cover crop	J.D. 710, seed drill (9' width)
				- foliar feeding	White 2-85, foliar sprayer (50')
				Aug. - combine	J.D. 7700 (16' header)
				- residue spray + fert.	White 2-110(L), 2700 gal tanker
				Aer-way	White 2-85, 12' pull type Aer-way'
				- seed cover crops	J.D. 710, seed drill
	1990	corn	same as O.B.A.T.A.	May - residue incorporation	White 2-110, 19' disk harrow
				- Aer-way + planter	White 2-85, 12' pull type + planter
				- herbicide spraying	White 2-85, 43' 500 gal sprayer
				June - sidedress N	White 2-85, 12' 300 gal applicator
				- foliar spray	White 2-85. automatic mister 20 A/App.
				Aug. - cover crop seeding	Aerial seeded with Hy-boy: 60' spreader
				Oct. - combine	J.D. 7720
				- residue spray	White 2-85, 43' 500 gal sprayer
				- Aer-way	White 2-110, 15' pull type
	1991	corn	same as O.B.A.T.A.	April/May - disk once or twice	White 2-110, 19' disk harrow
				May - Aer-way + planter	White 2-85, 7x20" row planter N.C. Klnze
				June - sidedress N	White 2-85, 12' spray boom
				- foliar spray	White 2-85, fogger 200' width
				Oct. - combine	J.D. 7720 12' header
				- shred crop residue	White 2-110, 12' shredder
				- crop residue spray	White 2-85, 43' boom 500 gal tanker
				- Aer-way once	White 2-110, 12' pull type

Year	Tractor(s)	Horsepower	Wheeldrive
1989	J.D. 710 (nonloaded tires)	40	2WD
	White 2-85 (nonloaded tires)	90	2WD duals (D)
	White 2-110 (nonloaded tires)	115	2WD duals (D)
	White 2-110 (loaded tires = L)	115	2WD single (S)
1990	White 2-85 (no fluid ballast)	90	2WD
	White 2-110 (no fluid ballast)	115	2WD
1991	White 2-85	90	2WD
	White 2-110	115	2WD
	Combine J.D. 7720	140	2WD

MACHINERY USED FOR FIELD #2 IS THE SAME AS THAT USED FOR FIELD #1 FROM 1989 TO 1991.

Table 58. John Van Dorp - Principal and Cover Crop Inputs for 1989, 1990 and 1991.

YEAR	FIELD	PRINCIPAL CROP	COVER CROP	SEEDING RATE	AREA SEEDED	COST	COMMENTS
1989	1	corn (Pioneer 3790)	rye (Hyland) hairy vetch rye-vetch mix	84 kg/ha (75 lb/ac) 28 kg/ha (25 lb/ac) vetch: 8-9 kg/ha (15-20 lb/ac) rye: 34 kg/ha (30 lb/ac)	7.3 ha (18 ac) 7.3 ha 7.3 ha		- cover crops broadcast into standing corn 7-10 Sept with Highboy - all had a very thin fall stand, seeding may have been a few weeks too late, also there was a lack of significant rainfall in September which hindered plant emergence - 20 inch corn rows blocked out a considerable amount of sunlight, and left a large amount of residue on the ground after harvest
	2	w. wheat (Haus) 2.5 bu/ac	red clover* (Harus) hairy vetch* (Augusta) hairy vetch** (drilled, broadcast) oilseed radish**	18 lb/ac 14 lb/ac 14 lb/ac 18 lb/ac	3.2 ha (8 ac) 3.2 ha (8 ac) 3 ac (drilled) 2 ac (broad.) 3 ac	 $112.50 (total) 112.50 (total) 55.00 (total)	- hairy vetch broadcast 10 Aug. - hairy vetch and oilseed radish drilled 22 Aug. - both cover crops received manure - all performed well and virtually eliminated any bare areas - oilseed radish developed good roots (30 cm by 5 cm), it was easily killed by frost - the residue broke down easily over the winter which left some exposed ground in the spring - most vigorous growth from the spring planted hairy vetch
1990	1	corn (Pioneer 3790)	hairy vetch vetch-oats mix	34 kg/ha (30 lb/ac) vetch: 28 kg/ha (25 lbs/ac) oats: 49 kg/ha (44 lb/ac)	4.0 ha (10ac) 4.0 ha (10ac)		cover crops failed to achieve good establishment and survive, due to restricted light conditions, competitions from grasses
	2	corn (Pioneer 3790 + replant Pioneer 3921)	red clover hairy vetch oats-vetch mix	16 kg/ha (14 lb/ac) 34 kg/ha (30 lb/ac) oats: 49 kg/ha (44 lb/ac) vetch: 28 kg/ha (25 lbs/ac)	1.2 ha (3 ac) 2.8 + 1.4 ha (2 strips) 2.4 ha (6ac)		all cover crops broadcast into standing corn 20-21 Aug. with Highboy red clover did not establish well at all, hairy vetch alone did not fair well, vetch-oats mixture had spotty catch but did not establish poor cover crops possibly due to effects of narrow corn rows, residual effects of herbicides, competition with weeds (ie. grasses)
1991	1	corn (Pioneer 3790) 28,000 pop.	none	- - - - - -	- - - - - -	- - - - - -	- - - - - -
	2	corn (Pioneer 3790)	none	- - - - - -	- - - - - -	- - - - - -	- - - - - -

* Spring planted cover crop. ** Summer planted cover crop, after wheat harvest

Table 59. John Van Dorp - Fertilizer and O.B.A.T.A. Spray Inputs for 1989 and 1990.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	RATES			APPL. RATE
				KELP	MOLASSES	FERTILIZER	
1989	1	corn	seed	10.0 oz/ac	0.5 gal/ac	(9-18-9) 3.0 gal/ac	5.0 gal/ac
			with nitrogen	5.0 oz/planter	1.0 gal/ac	30 lbs planter 30 lbs sidedress	20.0 gal/ac
			foliar	8.0 oz/ac	0.5 gal/ac	(9-18-9) 2.0 gal/ac	3.0 gal/ac
			residue	10.0 oz/ac	3.0 gal/ac	(hog manure) 1500 gal/ac	1500 gal/ac
	2	w. wheat	corn residue spray (fall 1988)	10.0 oz/ac	1.0 gal/ac	water	20.0 gal/ac
			seed	none	none	none	--
			with nitrogen	8.0 oz/ac	1.0 gal/ac	60 lbs U.A.N. + 4% sulfur	20.0 gal/ac
			foliar	8.0 oz/ac	0.5 gal/ac	(9-18-9) 2.0 gal/ac	
			residue	10.0 oz/ac	3 gal/ac	(hog manure) 1500 gal/ac	1500 gal/ac
1990	1	corn	seed	10.0 oz/ac	1.0 gal/ac	(9-18-9) 2.0 gal/ac	
			foliar	8.0 oz/ac	1.0 gal/ac	(9-18-9) 2.0 gal/ac	
			residue	12.0 oz/ac	2.0 gal/ac	(hog manure) 3000 gal/ac	
	2	corn	seed	10.0 oz/ac	1.0 gal/ac	(9-18-9) 2.0 gal/ac	
			foliar	8.0 oz/ac	1.0 gal/ac	(9-18-9) 2.0 gal/ac	
			residue	12.0 oz/ac	2.0 gal/ac	(hog manure) 3000 gal/ac	

Table 60. John Van Dorp - Fertilizer and O.B.A.T.A. Spray Inputs for 1991.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	RATES			APPL. RATE
				KELP	MOLASSES	FERTILIZER	
1991	1	corn	seed	6.0 oz/ac	1 qt/ac corn sugar	(9-18-9) 2.0 gal/ac (fish emulsion) 3.0 gal/ac 10 ton manure	
			with nitrogen	0.0 oz/ac	1.0 qt/ac corn sugar	(U.A.N. 28-0-0-2) 20.0 gal/ac (liq. calcium) 1.0 gal/ac	
			foliar ..	5.0 oz/ac	1.0 qt/ac corn sugar	(ammonia) 1 pt/ac (fish emulsion) 0.5 gal/ac (liq. calcium) 0.25 gal/ac	
			residue	5.0 oz/ac	0.5 gal/ac corn sugar	(28-0-0-2) 5.0 gal/ac (liq. calcium) 2.0 gal/ac	
	2	corn	seed	6.0 oz/ac	1 qt/ac corn sugar	(9-18-9) 2.0 gal/ac (fish emulsion) 3.0 gal/ac 10 ton manure	
			with nitrogen	0.0 oz/ac	1.0 qt/ac corn sugar	(U.A.N. 28-0-0-2) 20.0 gal/ac (liq. calcium) 1.0 gal/ac	
			foliar	5.0 oz/ac	1.0 qt/ac corn sugar	(ammonia) 1.0 pt/ac (fish emulsion) 0.5 gal/ac (liq. calcium) 1.0 gal/ac	
			residue	5.0 oz/ac	0.5 gal/ac corn sugar	(28-0-0-2) 5.0 gal/ac (liq. calcium) 2.0 gal/ac	

Table 61. John Van Dorp - Herbicide Inputs for 1989, 1990 and 1991.

YEAR	FIELD	CROP	CHEMICALS		CONTROL	RATE/ ACRE or HECTARE	COST/ LITRE
			Type	Name			
1989	1	corn	atrazine cyanazine dicamba	Attrex Bladex Banvel	grasses ann. grasses broadleaves	1 lb/ac 1 lb/ac 0.5 L/ac	
	2	w. wheat	none	none	----		
1990	1	corn	atrazine cyanazine dicamba	 Bladex Banvel	grasses ann. grass broadleaves	3.5 kg/ha (3 lb/ac) 3.5 kg/ha (3 lb/ac) 0.5 L/ha	
	2	corn	atrazine dicamba	 Banvel		2 kg/ha (2 lbs/ac) applied 2x (replant) 0.25 L/ha	
1991	1	corn	 2,4-D Amine	Dual" Banvel	grasses broadleaves	0.5 L/ac + 0.5 L/ac Landoil 0.25 L/ac + 0.25 L/ac Landoil" 0.25 L/ac (no Landoil")	
	2	corn		Dual Banvel RoundUp	grasses broadleaves	0.5 L/ac + 0.5 L/ac Landoil" 0.25 L/ac + 0.25 L/ac Landoil" 0.6 L/ac	

Table 62. Mint Klynstra - Operations and Machinery for Field #1 in 1989, 1990 and 1991.

<table>
<tr><th rowspan="2">FIELD</th><th rowspan="2">YEAR</th><th rowspan="2">CROP</th><th colspan="2">OPERATIONS</th><th rowspan="2">MACHINERY</th></tr>
<tr><th>STANDARD</th><th>O.B.A.T.A.</th></tr>
<tr><td rowspan="3">1</td><td>1989</td><td>soybean</td><td>May - cultivate 2x
- appl. herbicide
- planted
June - appl. herbicide
Oct. - combined
- Aer-wayed 2x
- planted winter wheat</td><td>May - cultivate 2x
- appl. herbicide
- Aer-wayed 2x
- planted with seed tmt
June - appl. herbicide
- foliar spray
Oct. - combined
- Aer-way 2x
- residue spray
- planted with seed tmt</td><td></td></tr>
<tr><td>1990</td><td>winter wheat</td><td>April - N fertilizer applied
May - foliar sprayed
August - combined
- manure appl.
- residue spray
- planted cover crops
- moldboard plowed</td><td>April - N fertilizer applied
May - foliar sprayed
August - combined
- manure appl.
- residue spray
- planted cover crops
- Aer-wayed 2x</td><td>J.D. 3130, Vicon spreader
Balthes sprayer
M.F. 750(15' header)
White 105, N.H. 350 bu. spreader
Balthes sprayer (36')
J.D. 3130, J.D. 8200 21 run drill
White 105, 5 furrow plow
White 105, pull type 11'</td></tr>
<tr><td>1991</td><td>corn</td><td>April - applied herbicide
- applied CaN + sugar
May - Aer-wayed 1x entire field
- planting + seed treatment
- applied herbicides
June - foliar spray
- cultivation lx
Oct. - combined
Dec. - moldboard plowed 35' wide strip perimeter, 30 row down mid field</td><td>April - applied herbicide
- applied CaN + sugar
May - Aer-wayed lx
- planted + seed tmt
- applied herbicides
June - foliar spray
- cultivation lx
Oct - combined
Dec. - Aer-wayed 30 rows each on either side of the middle plowed area</td><td>J.D. 3130
J.D. 3130
White 105 (17')
M. F.750 (40')
White 105</td></tr>
</table>

Table 63. Mint Klynstra - Operations and Machinery for Field #2 in 1989, 1990 and 1991.

FIELD	YEAR	CROP	OPERATIONS		MACHINERY
			STANDARD	O.B.A.T.A.	
2	1989	winter wheat	w.w. was very advanced when program was initiated	May - foliar spray - plant cover crops	
			Aug. - disked - subsoiled - residue spray on all cover crop, not rye	Aug. - add. cover crops planted - subsoiled - residue spray on all cover crops, not rye	
	1990	corn	May - applied herbicide - Aer-wayed entire field (2x) - planted corn	May - applied herbicide - Aer-wayed field (2x) - planted corn	Balthes sprayer (23 nozzle, 36') White 105,11' Aer-way J.D. 3130, 4x36' row JD. 7000
			June - sprayed for weeds - interrow cultivation	June - sprayed for weeds - interrow cultivation	Balthes sprayer J.D. 3130, 4 row cultivator
			July - foliar spray	July - foliar spray - covercrop underseeding	Balthes spr., TX12 cone jet nozzles Balthes, Vicon fert. spreader
			Nov. - combine	Nov. - combine	M.F. 750 (4 row header)
			Dec. - appl. manure - moldboard plow field	Dec. - appl. manure - Aer-wayed 3 ac strip	Vicon fertilizer spreader Aer-way
	1991	corn	April - applied CaN + sugar - applied herbicide - cultivated 2x	April - applied CaN + sugar - applied herbicide - Aer-way lx, cult lx	
			May - planted + seed tmt - applied herbicides	May - planted + seed tmt - applied herbicides	J.D. 3130
			June - foliar spray - cultivation lx Oct. - combined Dec. - moldboard plowed	June - foliar spray - cultivation lx Oct. - combined Dec. - Aer-wayed (28 strips)	Hy-Boy (12 rows 35') White 105, (17') M.F. 750 (40') White 105

Year	Machinery	Horsepower	Wheeldrive
1989	J.D. 3130	80	2WD
	White 105	105	4WD
1990	Balthes Sprayer	35	2WD
	J.D. Loader	55	4WD
	J.D. 3130	80	2WD
	White 105	105	4WD
	Hy-Boy		
1991	Hy-Boy		
	J.D. 3130	80	2WD
	White 105	105	4W0
	Combine - M.F. 750		

MACHINERY USED FOR FIELD #2 IS THE SAME AS 'HAT USED FOR FIELD #1 FROM 1989 TO 1991.

Table 64. Mint Klynstra - Principal and Cover Crop Inputs in 1989, 1990 and 1991.

YEAR	FIELD	PRINCIPAL CROP	SEEDING RATE	COST	COVER CROP	SEEDING RATE	AREA SEEDED	COST FOR SEED	COMMENTS
1989	1	soybean	----	----	none	----	----	----	----
	2	w. wheat (Harus)	----	----	red clover* hairy vetch* oilseed radish** hairy vetch** winter rye** buckwheat**	8-10 lb/ac 25 lb/ac 15-18 lb/ac	5.0 ac 1.0 ac 5.0 ac 4.0 ac 4.0 ac 1.0 ac	$112.50 99.00 112.50 66.50	- summer planted cover crops seeded 22-23 Aug. after harvest - all cover crops performed well, hairy vetch climbed up the wheat and hindered combining - buckwheat appears sensitive to early frosts (killed in early October), therefore does not produce good erosion cover
1990	1	w. wheat (Harus)	----	----	rye-vetch mix oats-vetch mix oilseed radish	67 kg/ha (60 lb/ac)-18 kg/ha (16 lb/ac) 38 kg/ha (34 lb/ac)-18 kg/ha (16 lb/ac) 21 kg/ha (18 lbs/ac)	1.0 ha (2.5 ac) 1.0 ha (2.4 ac) 1.0 ha (2.4 ac)	0.70/lb	- oilseed radish seeded 23 Aug., remaining cover crops seeded 30 Aug. - all germinated well, but did not have good establishment, possible competition with weeds
	2	corn (Pioneer 3845)	27,200 seeds/ac	$28.28/ac	oats	95 kg/ha (2.5 bu/ac)	2.5 ha		- broadcast into corn 22 July using Highboy, establishment was poor, restricted light conditions
1991	1	corn	----	----	none	----	----	----	----
	2	corn	----	----	none	----	----	----	----

* Spring planted cover crop. ** Summer planted cover crop.

Table 65. Mint Klynstra - Fertilizer and O.B.A.T.A. Spray Inputs for 1989 and 1990

.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	RATES			COST	OTHER FERTILIZER	COST/ ACRE
				KELP	MOLASSES	FERTILIZER			
1989	1	soybean	seed	10 oz/ac	1 qt/ac		$34.80/tmt		
			foliar				57.85/tmt		
			residue	10 oz/ac	4 qt/ac		71.20/tmt		
	2	w. wheat	seed	yes					
			foliar						
			residue	yes					
1990	1	w. wheat	seed	yes		9-18-9			
			foliar	none	none	none	----	manure 12 ton/ac	
			residue	10 oz/ac	3.0 qts/ac				
	2	corn	seed	7.0 oz/ac	2.0 L/ac	(71B) 2 gal/ac (liq. organic matter) 6.0 oz/ac (humate) 0.2 L/ac (wetting agent) 2 oz/ac (NaSe) 4 g (GAFC) 50 g	$18.22/ac* (appl. to 10 ac) 182.20 (total for tmt)	51 lb special blend MAP @ 0.2168/lb ($11.06/ac) CaN @ 3 lb/ac (0.42¢/ac) bulk spread (incl. spread fee): 46-0-0 @ 140 lb/ac (64 lb act N) 0-0-60 @ 100 lb/ac (60 lb act. N) 150 lb urea (46%) 75 lb act. N	$11.48/ac` 19.19/ac* 6.68/ac*
			foliar	5.0 oz/ac	1 L/ac	(71B) 2 gal/ac (10-8-8) (H_2O2) 8 oz/ac (vinegar) 8.0 oz/ac (Zn chelate) 16.0 oz/ac (wetting agent) 1.0 oz/ac	$14.90/ac* 173.50 (total for tmt)		
			residue						

* Note: $70.65/ac is the total fertilizer costs for 1990 in field #2.

Table 66. Mint Klynstra - Fertilizers and O.B.A.T.A. Spray Inputs for 1991.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	RATES			APPL. RATE	COST/ ACRE
				KELP	MOLASSES	FERTILIZER		
1991	1	corn	seed	6.0 oz/ac	1.0 qt/ac	(10-34-0) 3.0 gal/ac (fish emulsion) 1 qt/ac (Z-Hume) 2.0 qts/ac		
			foliar	5.0 oz/ac	----	(9-18-9) 2.0 gal/ac (Z-hume) 0.6 L/ac (H_2O_2) 0.7 oz/ac (Vitamin B„) n/a	----	$10.54
			residue	none	none	none	----	----
	2	corn	seed	none	1.0 qt/ac	(10-34-0) 3.0 gal/ac (fish emulsion) 1.0 qt/ac (Z-Hume) 2.0 qts/ac		
			foliar	5.0 oz/ac	----	(9-18-9) 2.0 gal/ac (Z-hume) 0.6 L/ac (H_2O_2) 0.7 oz/ac (Vitamin B,$_2$) n/a	----	$10.54
			residue	none	none	none	--	----

Table 67. Mint Klynstra - Herbicide Inputs for 1989, 1990 and 1991.

YEAR	FIELD	CROP	CHEMICALS		RATE/ACRE	AREA APPLIED	COST
			Type	Name			
1989	1	soybean					
	2	w. wheat					
1990	1	w. wheat	none	none			
	2	corn	atrazine + oil	Banvel Roundup	0.25 L/ac 1 lb/ac 1.3 L/ac	4 ha (10 ac) 4 ha (10 ac) 0.75 ac	$4.25/ac 4.50/ac 18.25/ac 27.00/ac
1991	1	corn	atrazine atrazine + oil	Roundup	1 L/ac 1 L/ac	perimeter of field applied to plowed strip only	
	2	corn	atrazine	Roundup Banvel	1 L/ac 1 L/ac 0.25 L/ac		

Table 68. Jim House - Operations and Machinery for Field #1 in 1989, 1990 and 1991.

FIELD	YEAR	CROP	OPERATIONS STANDARD	 O.B.A.T.A.	MACHINERY
1	1989	w. wheat	Oct. 88 - planted wheat	Oct. 88 - planted wheat	Ford 6600, Great Plains N.T.
			March - N application	March - N application	spreader truck, drill spread N to R.C.
			May - applied N	May - applied N	Ford 6600, small spreader N
			- applied herbicide	- applied herbicide	Ford 6600, sprayer
				- foliar spray	Ford 6600, sprayer
			July - combined	July - combined	White 7300
			August - Rotomower	Aug. - subsoiled	Ford TW20
			clipped	- residue spray	Ford TW20, sprayer
				- soil saved	Ford TW20
				- Aer-way'	Ford 6600, pull type
				- drill	Ford 6600, Tye Drill (10' width)
				- Rotomower clipped r.c.	Ford TW20
			Oct - Great Plains N.T.	Oct. - soil saved	Ford TW20
			- soil saved		
	1990	corn	May - cultivation	May - cultivation	Ford TW20, 'S'tine cultivator (25')
			- planting	- planting	Ford 6600, 4 row + tiller
			- sprayed herbicides	- sprayed herbicides (2x)	Ford 6600, sprayer (40' boom)
			June - cultivation	June - cultivation	Ford TW20, 'S'tine cultivator
			- sprayed Partner'		Ford 6600, sprayer (40' boom)
			July - applied NH_3	July - applied NH_3	Ford TW20, 5 tine applicator
				- applied 28% N	Ford TW20, 5 tine applicator
				- foliar spray	Ford 6600, sprayer
			Oct - combined	Oct. - combined	White 7300 (4 row C.H.)
	1991	corn/soy	May - planted corn	May - planted corn	J.D. 2955, 3 row rototiller planter
		strip	- planted soybeans	- planted soybeans	J.D. 2955, 8 row JD planter, 1 coulter
			- applied herbicide	- applied herbicide	J.D. 2955, sprayer
			June - applied NH_3	June - foliar sprayed	J.D. 2955, sprayer with 40' boom
			- applied herbicide	- applied NH_3	J.D. 2955, 2 tine applicator
				- applied herbicide	J.D. 2955, sprayer
			Oct. - combined	Oct. - combined	White 7300, 3 row C.H., 11' soybean
			- soil saved*	- soil saved*	Ford TW20, 9 skank
			- disked*	- disked*	Ford TW20, light 12' disk

* only done to allow for new direction in crop rows for 1992.

Table 69. Jim House - Operations and Machinery for Field #2 in 1989, 1990 and 1991.

FIELD	YEAR	CROP	OPERATIONS		MACHINERY
			STANDARD	O.B.A.T.A.	
2	1989	corn	May - planted corn - applied herbicide June - row cultivation - applied NH_3 - sprayed herbicide Oct. - combined	Oct. 88 - Aer-wayed May - planted corn - applied herbicide June - row cultivation - applied NH_3 - sprayed herbicide July - foliar sprayed Oct. - combined - Aer-wayed	Ford TW20, pull type Aer-way Ford 6600, Rototill planter Ford 6600, sprayer Ford 6600, cultivator Ford TW20, N applicator Ford 6600, small sprayer Ford 6600, foliar sprayer White 7300 Ford TW20, pull type Aer-way
	1990	soybean	May - cultivation - planted soybeans - applied herbicide June - applied herbicide Oct - combined	May - cultivation - planted soybeans - applied herbicide June - replant (bird damage) - applied herbicide July - foliar spray Oct. - combined Nov. - combined replant area - soil saved damaged area	Ford TW20, 'S'tine cultivator (25') Ford 6600,8 row no till Ford 6600, sprayer Ford 6600, 8 row no till Ford 6600, sprayer Ford 6600, sprayer White 7300 (13' head) White 7300 (13' head) Ford TW20
	1991	corn/soy strip	May - planted corn - planted soybeans - applied herbicide June - applied NH_3 - applied herbicide Sept. - combined soy Oct - combined corn	May - cultivated once - planted corn - planted soybeans - applied herbicide June - foliar sprayed - applied NH_3 - applied herbicide Sept - combined soy Oct. - combined corn	Ford TW20, 'S'tine cultivator J.D. 2955, 3 row rototiller planter J.D. 2955, 8 row J.D. planter 1 coulter J.D. 2955. sprayer J.D. 2955, foliar sprayer (40' boom) J.D. 2955, 2 tine applicator J.D. 2955, sprayer White 7300 (11' soybeans) White 7300 (3 row C.H.)

Year	Tractor(s)	Horsepower	Wheeldrive	Misc. Costs (1989)	
1989	Ford 6600	70	2WD	Custom spreader (Fingal)	$4.50/ac
	Ford TW20	135	2WD	Cargill sprayer	5.50/ac
	Combine White 7300		2WD	small spreader	9.00/tonne
				N.T. Drill	10.00/day
1990	Ford 6600	70	2WD	Aer-way'	5.00/day
	Ford TW20	135	2WD		
	Combine White 7300		2WD		
1991	J.D. 2955	85	Front wheel assist		
	Ford TW20	135	2WD		
	Combine White 7300 (3 row)		2WD		

MACHINERY USED FOR FIELD #2 IS THE SAME AS THAT USED FOR FIELD #1 FROM 1989 TO 1991.

Table 70. Jim House - Principal and Cover Crop Inputs for 1989, 1990 and 1991.

YEAR	FIELD	PRINCIPAL CROP	SEEDING RATE	COST FOR SEED	COVER CROP	SEEDING RATE	AREA SEEDED	COST FOR SEED	COVER CROP COMMENTS
1989	1	w. wheat (Harris)	130 lb/ac	$5.00/bu	red clover (Double cut)	10 lb/ac	2.5 ac	$1.50/lb	poor emergence rate for oilseed radish (30% germination), buckwheat had 90% germination and was killed early by a light frost
					buckwheat*	75 lb/ac	5 ac	$199.84 (total)	both these cover crops were soil saved in the fall (7 Oct), red clover had 75% germination and remained intact over the winter
					oilseed radish*	15-18 lb/ac	5 ac	$55.00 (total)	
	2	corn (Pioneer 3772)	29,700/ac	$89.50/ 75,000	rye	75 lb/ac	3 ac	$19.00 (total)	rye was planted 21 July and developed into a poor stand, thus it did not add much to residue cover
1990	1	corn (Pioneer 3757)	29,000/ac	--	annual ryegrass	39 kg/ha (35 lb/ac)	3800 m^2	75¢/lb	seeded 23 Aug., emergence was good, establishment was good, with adequate ground coverage
					oats	84 kg/ha (75 lb/ac)	3800 m^2		
					winter rye	84 kg/ha (75 lb/ac)	3800 m^2		
	2	soybean (T8508)	70 lb/ac	--	none	- - -	- - -	- - -	- - -
1991	1	corn/soy (Pioneer 3757E/ N.K 1990)	corn: 60,000/ac	$87.50/ 90,000	none	- - -	- - -	- - -	- - -
	2	corn/soy (Pioneer 3757E/ N.K 1990)	soybean: 75 lb/ac	$17.50/ 25 kg	none	- - -	- - -	- - -	- - -

* Fall-planted cover crops

In 1991 Jim House seeded cover crops in another field.

500 buckwheat seed	0.28¢	$140.00
300 hairy vetch seed	$1.50	$450.00
		$590.00 total

Table 71. Jim House - Fertilizer and O.B.A.T.A. Spray Inputs for 1989 and 1990.

YEAR	FIELD	CROP	O.B.AT.A. TREATMENT	SPRAY RATES			COST	STANDARD FERTILIZER	APPLICATION RATE	COST
				KELP	MOLASSES	FERTILIZER				
1989	1	w. wheat	seed	none	none	none		urea (45% N)	120 lb/ac*	$290.00/tonne
			foliar	3.5 L	10.0 L	60.0 L	$248.45 (total)			
			residue	10.0 oz/ac	2 qt/ac					
	2	corn	seed	none	none	none	----	7-26-28	125 lb/ac	$254.00/tonne
			foliar					NH_3 (82% N)	180 lb/ac	$310.00/tonne
			residue	none	none	none				
1990	1	corn	seed	none	none	none		8-32-16** active Zn	175 lb/ac 1.5 lb/ac	
			foliar	7.0 oz/ac	1.0 gal/ac	2.0 gal/ac (3-18-9)	$412.80 (total) 80.00 (sprayer)	28% N NH_3	150 lb/ac 150 lb/ac	
			residue	none	none	none				
	2	soybean	seed	none	none	none		none		
			foliar	7.0 oz/ac	1.0 gal/ac	2.0 gal/ac (3-18-9)				
			residue	none	none	none				

* 80 lbs applied in March, 40 lbs applied in May.

** O.B.A.T.A. treatment only.

Table 72. Jim House - Fertilizer and O.B.A.T.A. Spray Inputs for 1991.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	SPRAY RATES			COST	STANDARD FERTILIZER	APPLICATION RATE	COST
				KELP	MOLASSES	FERTILIZER				
1991	1	corn/soy strip	seed	none	none	none	----	8-32-16*** active Zn	150 lb/ac 1.5 lb/ac	$268.00/tonne
			foliar	10 oz/ac (Agrikelp)	0.5 gal (corn sugar)	0.5 gal (liq. fish) 0.9 L (ammonia) 1 gal (CaN)	$14.23/tmt $10.00 (sprayer rental)	28% N*** (45 lb N) NH_3*** (82% N)	10.0 gal/ac 140 gal/ac	185.00/tonne 330.00/tonne
			residue	none	none	none	----			
	2	corn/soy strip	seed	none	none	none		8-32-16*** active Zn	150 lb/ac 1.5 lb/ac	$268.00/tonne
			foliar	10 oz/ac (Agrikelp)	0.5 gal (corn sugar)	0.5 gal (liq. fish) 0.9 L (ammonia) 1 gal (CaN)	$14.23/tmt $10.00 (sprayer rental)	28% N*** NH_3***	10.0 gal/ac 140 gal/ac	185.00/tonne 330.00/tonne
			residue	none	none	none	----			
			TOTAL COST FOR BOTH FIELDS	$10.00	$3.55	$14.90	$48.46			

*** Application to corn only.

Table 73. Jim House - Herbicide Inputs for 1989, 1990 and 1991.

YEAR	FIELD	CROP	CHEMICALS		PURPOSE	TIME	APPL. RATE	COST/ LITRE
			Type	Name				
1989	1	w. wheat	2,4-D	Ester600	broadleaf	May	0.4 L/ac	$5.60
	2	corn		Partner Dual	broadleaf grass	June May	0.4 L/ac 0.7 L/ac	$17.80 17.65
1990	1	corn	 atrazine atrazine + oil 	Dual Partner	nightshade vol. wheat broadleaf	May June	0.75 L/ac 1.0 L/ac 1.0 L/ac 0.4 L/ac	- - - -
	2	soybean	Lorox bentazon	Dual Basagran	grass broadleaf	May June	0.75 L/ac 1.0 L/ac	- -
1991	1	corn/soy	2,4-D Dual bentazon	MCPA Dual Basagran Roundup	burn down grass broadleaf spot spray	May June	0.75 L/ac 0.75 L/ac 1.1 L/ac 1.25 L/ac (spot sprayed)	$4.85 18.50 18.10 12.50
	2	corn/soy	2,4-D Dual bentazon	MCPA Dual Basagran Roundup	burn down grass broadleaf spot spray	May June	0.75 L/ac 0.75 L/ac 1.1 L/ac 1.25 L/ac (spot sprayed)	$4.85 18.50 18.10 12.50

Note: no difference in herbicide application between O.B.A.T.A. or standard management treatments.

Table 74. Arpad Pasztor - Operations and Machinery in 1989, 1990 and 1991.

YEAR	FIELD	CROP	OPERATIONS		MACHINERY
			STANDARD	O.B.A.T.A.	
1989	1	corn			
	2	soybean			
1990	1	corn	April - soilsaved - disked May - planted June - sprayed herbicide July - N sidedress - cultivated Nov. - combined	April - soilsaved - disked May - planted June - sprayed herbicide July - N sidedress - cultivated Nov. - combined	Int. 1586, 9 shank soilsaver Int 1586, J.D. disk 20' + packer Int 656, 6 row IH planter Int 656, Hardi sprayer 45' boom M.F. 285, 7 row applicator M.F. 285, 6 row 'S'tine cultivator J.D. 7720
	2	tomato	----	----	----
	3	w. wheat	March - spread fertilizer	March - spread fertilizer	Int. 656, 4 ton spreader
			May - spread fertilizer - sprayed herbicide(2x)	May - spread fertilizer - sprayed herbicide(2x)	Int 656, 4 ton spreader M.F. 285, Hardi sprayer
			Aug. - harvest	Aug. - harvest	J.D. 7720
1991	1	corn	April - disk + packer - plant	April - disk + packer - plant	Int. 1586, J.D. disk 20' + packers Int. 656, 4 row planter
			May - spray herbicides	May - spray herbicides	Int. 656, Hardi sprayer (50' boom)
			June - N sidedress - spray herbicides	June - N sidedress - spray herbicides - foliar spray	Int 1586, 7 tooth 28% applicator Int. 656, Hardi sprayer (cutworms)
			Nov. - combine	Nov. - combine	7720 4 row corn head

Year	Machinery	Horsepower	Wheeldrive
1989			
1990	Int. 656	65	2WD
	M.F. 285	80	2WD
	Int 1586	160	2WD
1991	Int. 656	60	2WD
	Int. 1586	160	2WD
	7720		

Table 75. Arpad Pasztor - Principal and Cover Crop Inputs for 1989, 1990 and 1991.

YEAR	FIELD	CROP	COVER CROPS	SEEDING RATE	AREA SEEDED	COST	COMMENTS
1989	1	corn	none				
	2	soybean	rye oilseed radish	80-100 lb/ac 18-20 lb/ac	0.5 ha 1.2 ha		rye had good establishment, provided good erosion protection, excellent control over weed growth, and good soil moisture retention
1990	1	corn (Hyland 2334)	none	----	----	----	----
	2	tomato (8245)	winter rye	125 kg/ha (112 lb/ac)	2.0 ha		rye lightly spread and disked in on 21 Oct over entire field used to aid in building humus levels in the soil
	3	w. wheat (Harus)	oats	approx. 100 kg/ha (2-3 bu/ac)	3.0 ha		soil saved into entire field on 1 Sept wanted to keep spring 1991 tillage to a minimum; establishment was good
1991	1	corn (Hyland 2490) 30,000/ac	none	----	----	----	----

Table 76. Arpad Pasztor - Fertilizer and O.B.A.T.A. Spray Inputs for 1989 and 1990.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	SPRAY RATES			FERTILIZER
				KELP	MOLASSES	FERTILIZER	
1989	1	corn	seed	none	none	none	
			with nitrogen	none	none	none	
			foliar	8.0 oz/ac	1.0 qt/ac	(9-18-9) 2.0 gal/ac	
			residue	none	none	none	
	2	soybean	seed	none	none	none	
			foliar				
			residue	none	none	none	
1990	1	corn	seed	none	none	none	as a preplant 297 lb of 11-0-40
			foliar	8.0 oz/ac	1.0 gal/ac	(9-18-9) 2.0 gal/ac	on with planter 200 lb of 13-11-16, 0.7 lb Zn 26 lb N
			residue	none	none	none	in June 28%N (200 lb actual N)
	2	tomato	seed	none	none	none	as a preplant 641 lb potash (6-0-47)
			foliar	none	none	none	on with planter 130 lb of 18-13-6
			residue	none	none	none	in June 100 lb of ammonium nitrate
	3	w. wheat	seed	none	none	none	200 lb of 6-24-24
			foliar	none	none	none	50 lb actual ammonium nitrate
			residue	none	none	none	170 lb of 25-0-6

Table 77. Arpad Pasztor - Fertilizer and O.B.A.T.A. Spray Inputs for 1991.

YEAR	FIELD	CROP	O.B.A.T.A. TREATMENT	SPRAY RATES			APPL RATE	COST/ TMT	FERT.	RATE
				KELP	MOLASSES	FERTILIZER				
1991	1	corn	seed	none	none	none	----	----	dry: 14-0-32	200 lb/ac
									liq.: 6-25-6	3 gal/ac
			with nitrogen	none	none	none	----	----	28% N side.	100 lb/ac
			foliar	24 oz (total) 8 oz/ac	(corn sugar) 1.0 gal	(liq. fish) 1.0 gal 1.8 L ammonia 3.0 gal Ca	this went on approx. 3 ac	$33.95	none	none
			residue	none	none	none	----	----	none	none

Table 78. Arpad Pasztor - Herbicide Inputs for 1989, 1990 and 1991.

YEAR	FIELD	CROP	CHEMICALS		RATE/ ACRE or HECTARE	COST/ LITRE
			Type	Name		
1989	1	corn				
	2	soybeans				
1990	1	corn		Marksman	3.7 L/ha (1.5 L/ac)	
			atrazine		3.7 L/ha (1.5 L/ac)	
	2	tomatoes	metribuzin	Sencor	1.2 L/ha (0.5 L/ac)	
			methyl isothiocyanate	Vorlex	33.7 L/ha (3 gal/ac)	
			diphenamid	Enide	1.1 kg/ha (1 lb/ac)	
	3	w. wheat	2,4-D		2.2 kg/ha (2 lbs/ac)	
			propiconazole	Tilt	1.2 L/ha (0.5 L/ac)	
1991	1	corn		Marksman	1.5 L/ac	
				Dual	0.5 L/ac	