Sustainable Agriculture Research and Education Program

1. Final Report

2. Date of Report: April 1, 1992

3. Project Title: Alternative Cropping Systems For Low-Input Agriculture in the Northeast

4. Project Status: NA

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6. Major Participants: No change

7. Cooperators: No change

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Organization	SARE	Non-Federal Match	Other Federal Match
Cornell University	$202,075	$436,588	
Rodale Research Institute	66,225	59,470	
Pennsylvania State Univ.	42,700	79,888	
USDA-ARS			$20,500

11. Abstracts: No change

12. Objectives: No change

LNE88-09

13. **Project Results**

A. Findings. Objectives 1A and 1B.

Field experiments were conducted in NY and PA to meet these objectives. The NY experiment emphasized crops and cultural practices appropriate to dairy farms in contrast to the PA study which focused on cropping systems for beef and cash-grain enterprises that are typical of south/central PA. Results and findings from the experiments conducted in each state are discussed below.

New York

An experiment comparing cropping systems has been in place since 1989 at two sites in the state. The Musgrave Research Farm has level, high-lime soils with a fairly long growing season (2400 GDD) and is characteristic of the better agricultural land in the state. The Mt. Pleasant Research Farm is located on more acid soils with rolling topography and a much shorter growing season (2050 GDD). It is typical of farmland on the more marginal soils of the Southern Tier of New York and Northern Pennsylvania. The experiment compared two corn-based rotations and eight continuous corn system using management practices that varied in tillage, manure application, and the use of interseeded cover crops. In NY, weed management in corn was targeted as a critical factor for successful sustainable systems. Consequently, three levels of weed control were imposed on all cropping systems. Tables 1 and 2 provide a brief description of the cropping systems and weed control treatments. Orthogonal contrasts were used to compare cropping systems and weed control treatments (Table 3). Major findings from three years of the field experiment are presented below. The reader must remain aware that all conclusions presented are qualified due to the premature termination of the experiment. Additional years might have revised the presented conclusions.

<u>Effects of Cropping System and Weed Control on Corn Silage Yields</u>.

1. Corn silage yields were always higher when corn was grown in rotation, compared to continuous corn (Table 4). Continuous corn on the marginal soil resource (Mt. Pleasant) was much more vulnerable to yield reduction than continuous corn on the more productive soil (Musgrave). This confirms the importance of using crop rotations, particularly on less productive soils.

2. Tillage (conventional vs. ridge) did not effect corn silage yields on the better soil (Musgrave) but yields were lower with ridge tillage at Mt. Pleasant in two years out of three (Table 5). Reductions in tillage can greatly reduce the potential for soil erosion but ridge tillage is probably not well suited to soils with fragipans and other physical limitations.

3. In the first year of manure application under conventional tillage, silage yields in this system were lower than corn fertilized with inorganic N. In subsequent years corn fertilized with manure yielded as well as (Musgrave) or better than (Mt. Pleasant) corn fertilized with inorganic N (Table 6). Other experiments (Rodale Farming Systems Trial 1981-1985) have also documented corn yield reductions in systems changing from an inorganic to organic N source.

4. At the Musgrave Farm, when manure was applied under ridge tillage, there was no reduction in corn silage yields in the first year (Table 6). An in-depth study[1] at this site concluded that nitrogen was limiting under conventional tillage with manure, but nitrogen from manure application was more available under ridge tillage. This has important implications for farmers changing from inorganic to organic nitrogen sources for corn production. It suggests that ridge tillage may reduce or eliminate yield reductions associated with insufficient nitrogen in the transitional phase.

5. At Mt. Pleasant manure applications to corn in the second and third years of the experiment substantially increased yields, compared to corn grown with inorganic N fertilizer (Table 6). On these poorer soils, manure appeared to substitute, at least in part, for the beneficial effects of crop rotation which were so apparent at this site.

6. At Mt. Pleasant corn silage yields were higher under interseeded corn, compared to corn monoculture in 1989, but in subsequent years there was no yield advantage with interseedings (Table 7). We had hypothesized that interseeded forage species such as ryegrass and redclover in continuous corn might provide some of the same benefits as crop rotation. However, a consistent advantage from the interseedings was not observed, possibly due to the short duration of the experiment.

7. At the Musgrave Farm, interseeding had no effect on silage yields in 1989, but in 1990 and 1991 yields were lower with interseeding, compared to monoculture corn (Table 8). The yield decrease was most pronounced under ridge tillage with ryegrass. Other research in NY with interseedings in corn, conducted primarily under conventional tillage, has not shown yield reductions. Additional work is needed to identify the reason for the yield reduction at this site.

8. Relying on cultivation alone, compared to weed control practices which used herbicide alone or herbicide with cultivation, reduced silage yields in two years out of three at Mt. Pleasant and one year out of three at the Musgrave Farm (Table 8). However, even when corn yields were lower, the reductions were not large. Silage yields with band herbicide plus cultivation were not different, compared to broadcast herbicide alone. These results demonstrate that cultivation may substitute, at least in part, for chemical weed control. Banding herbicide over the corn row reduced herbicide use by 60-65%. Since herbicides represent a large portion of the purchased inputs for corn production, this reduction can represent a substantial reduction in inputs.

<u>Effects of Weed Control and Cropping System on Weed Infestation.</u>

1. Weed cover was highest under cultivation alone and lowest with broadcast herbicide alone (Table 9). At the Mt. Pleasant Farm weed levels with each weed control practice were relatively stable over the three years, but treatments which utilized cultivation had very heavy weed infestation, ranging from 28 to 75% cover in mid-season. It was surprising that these weed levels did not result in more drastic yield reductions. It was also surprising that weed levels remained constant over time, given the large weed seed

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[1]This portion of the research was conducted by W. Cox and D. Mataruka.

production each year. Weed levels were much lower at the Musgrave site (2-35% cover) but weed cover in 1991 jumped dramatically compared to previous years. The reason for this is unknown.

2. The effects of continuous vs. rotational corn on weed cover were inconsistent over years and sites (Table 10).

3. Weed cover was much higher under ridge than conventional tillage at Mt. Pleasant in two out of three years, but conventional tillage corn had more weeds at Mt. Pleasant in 1990 and was higher every year at the Musgrave Farm (Table 11). Reduced tillage systems frequently require more inputs to control weeds to offset the reduction in tillage. Ridge tillage, with a vigorous cultivation to reform the ridge, allowed reductions in both tillage and herbicide on the more productive soils at the Musgrave Farm. However, weed problems under ridge tillage were more severe on the marginal soils at Mt. Pleasant.

4. Manure application did not increase weed cover in conventional or ridge tillage at either site (Table 12). Farmers often express concern that manure is a source of weed introduction and/or multiplication. Results from this experiment indicate that manure application does not increase weed levels in cropped fields.

5. Weed cover in monoculture and interseeded corn was the same under conventional tillage at Mt. Pleasant but weed cover in these systems under ridge tillage varied over years (Table 13). Weed cover was less with interseeded ridge tillage corn in 1989, but greater in 1991. Weed cover was always higher under ridge tillage corn interseeded with ryegrass, compared to red clover at this site. Interseedings had no effect on weed cover under either tillage system at the Musgrave Farm except in 1991 when interseeded conventional tillage corn had more weed cover than monoculture corn. Although some of the increase in weed cover may be attributable to the different herbicide program used in the interseeded treatments, these results indicate that interseedings cannot be relied on to reduce weed pressure.

<u>Effects of Cropping Systems on Corn Rootworm Damage</u>[2].

1. The number of lodged plants was used as an indicator of rootworm damage in 1990 when rootworm infestation at the Mt. Pleasant site was very heavy. First-year corn following alfalfa in 1990 had very few lodged plants compared to second-year and continuous corn (Table 4). In 1990 ridge tillage and manure application significantly reduced the number of lodged plants compared to conventional tillage and inorganic N fertilizer (Tables 5 and 6). In continuous corn, the use of ridge tillage with manure greatly reduced lodging at Mt. Pleasant and probably accounts for at least some of the increase in silage yields in this treatment. A more detailed study in 1991 did not find differences in rootworm emergence or root damage ratings among manure and tillage systems at Mt. Pleasant. Manure application, however, reduced root damage ratings at the Musgrave Farm in 1991.

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[2]This portion of the research was conducted by R. Zobel, P. Davis and N. Brenes.

These results are potentially very significant. The effect of crop rotation on corn rootworm has been well documented, but this research suggests that ridge tillage and manure reduce the impact of root worm damage in continuous corn. As a result of these initial results, an expanded research program to study the effects of manure and tillage on corn rootworm has been funded by the Northeast Region IPM Program.

Effect of Cropping System on Corn Root Growth and Development[3]

1. Roots studies at the Mt. Pleasant site support the results of the corn root worm study. In 1990 the conventional till with fertilizer not only had more lodging, but it had significantly more nuclear roots (nodal or prop roots) than the other three treatments. We speculate that this was probably due to regrowth after root worm damage - this treatment had continued nuclear root initiation throughout the season while the other three treatments ceased nuclear root development shortly after anthesis. Continuation of this experiment would have allowed confirmation of this.

2. In 1991 insecticide was applied to the Mt. Pleasant plots, eliminating much of the differential corn root worm activity. Both conventional till and ridge till with fertilizer had significantly fewer nuclear roots than the manure applications, and 30% and 12% fewer nuclear roots than 1990. On the other hand, the manure applications had the same number of nuclear roots in both years. This suggests that in 1990 manure applications suppressed corn root worm feeding, while ridge tillage suppressed the symptoms (lodging).

3. In 1990 and 1991 at Aurora, herbicide applications resulted in increases in nuclear root numbers in fertilizer but not manure treatments. Manure may act to protect roots from herbicide by de-activating the chemicals or modifying the environment.

4. At both sites in both years, manure treatments and ridge till increased root length density in the top foot of soil. This was a synergistic effect with ridge-till + manure having significantly greater surface roots than any other treatment. The flip side of this story is that conventional with fertilizer had the greatest root length density at two feet deep and deeper - possibly resulting in greater drought tolerance. Total root length density for the whole rooting profile was not significantly different between treatments but did differ both between years and locations.

5. The above findings have been confirmed at Rodale where, because of the longer duration of the experiment, the difference between conventional practices and green or animal manure are much greater in terms of root length density and nuclear root numbers.

Effect of Cropping System on Soil Hydraulic Properties[4].

1. Soil infiltration capacity and soil pore size distribution are affected both by cropping

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[3]This portion of the research was conducted by R. Zobel and N. Bushamuka.

[4]This portion of the research was conducted by H. van Es, B. Brorens, and S. Verheyden.

system and time. Soil under conventional moldboard tillage is loosened prior to planting, while soil under ridge tillage remains virtually unchanged. Conventionally tilled soil subsequently re-compacts due to the planting operation (in-row) and wetting-drying cycles (in-row and between-row). Planting may considerably reduce soil infiltration capacity and percentage of large pores if it occurs on wet soil (1990). In a very dry spring (1991), loosened soil does not re-compact because of lower soil wetness at planting and the absence of wetting/drying cycles. In fact, when soils become very dry, soil infiltration is increased by the development of soil cracks.

2. Soil infiltration capacities and percentage of large pores are higher for ridge tillage in the row position and lower in the in-between row position compared to conventional tillage. This is attributed to the fact that ridges do not get compacted by tire traffic and are better drained at the time of planting, thereby reducing compaction from the planter. The between-row areas under ridge tillage, however, receive repeated traffic without soil loosening, thereby creating a compacted, slowly permeable soil. This problem tends to become more serious because reduced soil permeability and soil shaping increases soil wetness in the between-row areas, thereby increasing the susceptibility to further compaction. Soil loosening under conventional tillage reduces carryover traffic effects from one season to the next. In a dry year (1991), differences in soil hydraulic properties under ridge and conventional tillage are much less pronounced for the reasons described under 1.

3. Manure application resulted in a consistently higher infiltration capacity and percentage of large pores in the in-row position under ridge tillage. Under conventional tillage, manure application did not affect these hydraulic properties in the between-row position, and had a negative effect in the in-row position. The latter can be attributed to wetter soil conditions at planting. In general, infiltration capacity and percentage of large pores in the row position followed the sequence ridge+manure > ridge-manure > conv-manure > conv+manure. In the between-row position, this follows conv > ridge, independent of manure application. It appears that manure application improves soil structure _if_ the soil is not recompacted under wet conditions. Again, in a dry year (1991), these differences are small.

Effect of Cropping System on Soil Compaction

1. Soil strength (penetration resistance) varies greatly during the growing season, primarily due to soil drying and wetting (dryer soils are harder). Soils at the Musgrave Farm were above the critical strength levels for root growth (2Mpa) for most of the dry 1991 growing season at depths greater than 20 cm.

2. Soil in the row position under ridge tillage has higher soil strengths between 20-32 cm depths compared to soil under conventional tillage. At 28 cm depth, maximum strength under ridge tillage was 5 Mpa compared to 2.5 Mpa for conventional tillage. A direct cause for greater compaction at this depth under ridge tillage was not identified and may be the result of wetter traffic zones during planting and harvest. Manure application did not significantly affect soil strength in the surface layer during a dry year (1991).

Effect of Cropping System on Soil Nitrate Levels.

1. Cropping system had little effect on soil nitrate levels in the spring and fall at the Musgrave Farm (Table 14) but some differences were observed at Mt. Pleasant (Table 15). Nitrate levels were highest in April 1990 under alfalfa and conventional tillage corn interseeded with red clover. The limited sampling, however, prevents conclusive statements.

Effect of Cropping System on Ground Cover.

1. There was no consistent pattern in ground cover between rotational and continuous corn at the Musgrave Farm but at Mt. Pleasant interseeded cover crops in continuous corn provided a substantial ground cover advantage compared to rotational corn (Tables 16 & 17). Winter rye seeded after silage harvest in rotational corn established successfully in two out of three years at the Musgrave site with its longer growing season. This practice was not successful at Mt. Pleasant where the very short period of seasonable weather after silage harvest greatly limited rye establishment and growth.

2. In contrast, interseeded cover crops in continuous corn were considerably more successful at Mt. Pleasant than the Musgrave Farm (Tables 16 and 17). As a consequence there were large differences at Mt. Pleasant in ground cover under continuous corn, dependent on the presence or absence of an interseeding (Table 17). Interseeded ryegrass provided more cover than redclover at Mt. Pleasant, but there was no consistent species advantage at the Musgrave Farm (Tables 16 & 17). These results indicate that in areas with a short growing season, interseeding cover crops at cultivation is likely to be more successful than seeding after silage harvest.

Pennsylvania

The Farming Systems Trial (FST) at the Rodale Institute Research Center was initiated in 1981 to examine the process of converting a conventionally managed cropping system to an organically managed system (Liebhardt et al., 1989). Three distinct rotational cropping systems are being evaluated: 1) an animal-based (Low Input Animal or LIP-A); 2) a cash grain-forage legume-based (Low Input Cash Grain or LIP-CG); and 3) a cash grain/fertilizer N-based (Conventional Cash Grain or CONV) system (figures 1a and 1b). These systems differ in terms of the crops grown, weed control strategies, N-P-K inputs (amounts and type), the use of cover crops, and the amount of time that the land is occupied by living crop plants. The primary feature common to all three systems is the use of conventional tillage, i.e. moldboard plow, disk, harrow, and cultipack.

A major objective of this study has been to test the hypothesis that organic/low input cropping practices create a more favorable soil environment for plants than do conventional cropping methods by reducing physiological stresses and increasing biological efficiency. If this is true, the low input systems should produce crops of similar or greater growth and yield compared to conventional systems, while using less resources and/or conserving more of the available nutrients (Peters et al., 1992).

The approach taken to substantiate this hypothesis has been to compare the overall performance of each cropping system with regards to plant growth and yield, and to document changes in soil physical and chemical properties. Data collected includes whole plant biomass, plant tissue analysis, plant population, phenology, grain yields, impact of weeds, soil nitrate-nitrogen, elemental analysis of soil, soil bulk density, and water infiltration rates. In addition, collaborators from several other agricultural institutions have helped attain the research objectives by studying specific components of the biological system. Some of these components being researched include: 1) N-cycling dynamics with an N-15 isotope tracer; 2) soil aggregate stability; 3) potentially mineralizable soil N; 4) microbial respiration; 5) presence and infection rate of VA-mycorrhizae in corn and soybean roots; 6) root length density of corn; and 7) presence of nitrate-N in leachate leaving the crop rooting zone.

While the LISA funding period for this study was from 1989 to 1991, results from the years just prior to this time are important because they more clearly reveal long term trends among the three cropping systems under investigation. The results from 1981 to 1985 will be omitted because it has been assumed that during this period the plant/animal/soil system in the low input rotations was undergoing a major "transition" or adjustment upon elimination of fertilizer N and pesticides in 1981. Results reported will begin from 1986, at which time the low input systems had established a degree of stability.

The major findings of this study since 1986 are as follows (#1-13 from Peters et al., 1989; Peters et al., 1992; Peters et al., 1991; Peters and Janke, 1992):

1) Average LIP-A and LIP-CG corn yields were, respectively, 102% and 98% of the CONV corn yields from 1986 to 1990 (Table 18).
2. In 1991, LIP-A and CONV corn yields were equal, but LIP-CG corn yields were only 72% of the others because of a crop rotation change in this system. The LIP-CG system requires an excellent legume green manure crop just prior to corn to achieve equivalent yields with the other systems (Table 18).
3) In a dry year (1988), the corn in both low input systems outyielded the CONV corn treatment that had grown corn the previous year (1987) (Table 18).
4) With the exception of the CONV corn in 1986 and the LIP-A and LIP-CG corn in 1990 and 1991, ear leaf nitrogen concentration at corn silking always equalled or exceeded the sufficiency level of 2.75% reported in the literature (Table 19).
5) Soil nitrate-nitrogen levels, measured in all corn treatments throughout each growing season, were usually the highest in the LIP-A system. Nitrate-N levels in the LIP-CG and CONV were similar except in 1991 when the levels were lower in LIP-CG (Figures 2a-2f).
6) Average LIP-A and CONV soybean yields from 1986 to 1991 were equal. Until 1990, LIP-CG soybeans were intercropped (or relay cropped) with either wheat or barley, and as a result, the yields were 85% of those in the other systems. This was partly compensated by having an additional yield of small grain in this system (Table 20).
7) In 1991, LIP-CG soybeans were grown alone (i.e. not intercropped with a small grain), and yields were equal to CONV soybeans (Table 20).
8) Although weed levels were consistently greater in the two low input systems compared to the CONV, these higher weed levels adversely affected corn yield in only two of fourteen treatments, and in two of eight soybean treatments, from 1986 to 1991 (Tables 21 and 22).

9) Water infiltration rates, recorded in 1990 and 1991 in the corn treatments, were more rapid in the low input systems than the CONV. These results suggest that a heavy rain falling on conventionally managed land would likely lead to more water runoff and erosion (Figures 3a and 3b).

10) The CONV system returned to the soil the greatest quantity of aboveground plant biomass from 1981 to 1990, yet the low input systems had higher organic matter levels at the end of this period. Residues incorporated in the low input systems had higher concentrations of nitrogen relative to carbon than did the residues in the conventional system (Figure 4).

11) Compared to 1981 levels, the total soil nitrogen levels in 1991 indicate a slight increase of N in LIP-A, no change in LIP-CG, and a slight decrease in CONV (Figure 5).

12) Soil exchangeable potassium levels gradually dropped in all systems from 1981 to 1988 (less in the LIP-A system) (Table 23) resulting in low corn tissue K levels in 1988 (data not shown). Potassium fertilizer was added in 1989 to all treatments and corn tissue K levels have increased slightly, yet soil K levels continue to decline in all systems (Table 24).

13) Soil phosphorus levels have been high in all cropping systems since 1981, but by 1991 soil P levels were lower in the CONV than in the other systems (Tables 23 and 24).

14) N-15 tracer studies have determined that the primary contribution of fertilizer N inputs is to the aboveground plant biomass, while the red clover (present only in the low input systems) mainly contributes N to the soil. Therefore, while nitrogen from an organic source (e.g. red clover) is more slowly available to plants, the legumes are more effective than fertilizer for building up a reservoir of soil N for the benefit of future crops (Harris et al., 1989; Harris et al., 1990).

15) Soil incubation studies in 1988 determined that more nitrogen is mineralized (i.e. converted to plant-available ammonium- or nitrate-N) over a 200 day period in the low input soil than in the conventional soil (Harris et al., 1990).

16) In 1990, the LIP-A soil had the highest levels of microbial respiration (an indicator of soil biological activity), while the CONV soil had the lowest respiration levels (Wander et al., 1992).

17) In 1990, the LIP-A soil had the highest percentage of stable soil aggregates while the CONV soil had the lowest percentage. Soil aggregation is essential for healthy root development, adequate water holding capacity, and sufficient soil oxygen for promoting a vigorous and diverse community of soil organisms (Wander et al., 1992).

18) The low input soils have higher populations and greater diversity of vesicular-arbuscular mycorrhizal (VAM) fungi than do the conventional soils. VAM fungi have been shown to improve the growth of corn, soybeans, and small grains by protecting the host plant from pathogenic fungi, alleviating water stress, increasing symbiotic N fixation, and enhancing plant uptake of phosphorus (Douds et al., 1992)

19) The low input cropping systems produce more extensive horizontal and vertical corn root networks than does the CONV system, and they produce these roots earlier in the season. This extra corn root length provides resistance to drought and erosion, and it may lead to more efficient nutrient uptake in dry years (Pallant, 1992).

20) Preliminary results from gravity flow lysimeters (devices designed to capture any solute leaving the plant rooting zone) indicate that, while the LIP-A system from October, 1990 to October, 1991 leached the greatest amount of nitrate-N, the levels were relatively low for all three systems (Paul et al., 1992).

A fundamental question being asked of these cropping systems is how effectively do the crops make use of the available resources. Does a particular set of cultural practices create an environment that enhances the availability of nutrients? Does this set of cultural practices also prevent the loss of nutrients? These questions then lead into the broader question of sustainability. Are the cropping systems represented in this trial improving the soil environment, maintaining it, or actually degrading it? While it may never be possible to answer these questions completely, the results stated above at least suggest that the low input systems in this trial are producing equal crop yields and creating a slightly improved soil environment compared to the conventionally managed system.

These low input systems encompass much more than simply reducing the amount of purchased inputs. They emphasize more efficient use of the available, on-farm resources. For example, beef manure is immediately plowed under after spreading it to avoid some of the gaseous losses of N. Also, the manure is only incorporated before a high N-demanding crop (i.e. corn) to make better use of the inorganic N present and to avoid leaching losses. Growing cover crops during the late fall and early spring captures a greater amount of sunlight (and hence fixation of carbon by plants) than does a more conventional system that does not include cover crops. Maintaining a living ground cover almost year-around not only reduces erosion, but it improves soil structure which increases nutrient availability and allows for easier and more effective cultivation.

A low input cropping system that avoids large subsidies of fertilizers and pesticides must employ a more diverse crop rotation to reduce weed and pest outbreaks. Some of these crops may have a lower monetary value than the crops in a simpler rotation. The low input rotation must also include soil-building crops, which have a long term rather than an immediate economic return. Therefore, tradeoffs exist between systems that favor either short term profits or long term stability. The 1989 and 1991 economic returns of the cropping systems in this trial indicate that the low input systems are competitive with the conventional (Dunbar, 1991; also see Musser in this report). Therefore, this experiment has demonstrated that field crop systems that utilize animal and/or green manures judiciously, have well-planned and diverse crop rotations, timely field operations, and nearly continuous live plant cover, can be successful while avoiding synthetic fertilizer N and pesticides and can maintain or even improve the natural resource base.

<u>Overall Statistical observations</u>:

1. A detailed analysis of the Rodale experiment and a three year analysis of the New York experimental sites suggest that manure applications affect crop responses in a dramatic and unsuspected manner. Our observations suggest that the manure treatments are much more stable in terms of yield (either silage of grain) across years. We cannot at this point make any general conclusions about this response.

2. Within field spatial variability is much more significant than previously understood. This is especially critical at the Rodale experimental site where previously unanalyzed soil

One Ph.D. thesis has been completed under this project and publication in a scientific journal will follow. (Daniel Mataruka under the direction of W. Cox; thesis title: Growth, Yield and Quality of Maize Forage Under Conventional and Sustainable Cropping Systems). Three M.S. theses are in progress and will be completed within three to twelve months (D. Schlather under the direction of J. Mt. Pleasant; thesis title: Incidence of Weed Seed In Dairy Cow Manure: Potential For Dissemination; 2) N. Bushamuka, under the direction of R. Zobel; Root system development under conventional and sustainable practices; and 3) N. Brenes, under the direction of R. Zobel; thesis subject is influence of tillage and manure on corn rootworm damage). We anticipate at least three journal publications will be forthcoming from these M.S. theses.

The original design of the project required four years of field research in order to compare four-year rotations with continuous corn systems. Termination of the project after three years severely limits the conclusions and subsequent publication of results from the study at this point. Other funding has been secured that will allow the project to continue for a fourth and final year in 1992. At that time we expect to summarize results of this project in both extension and research publications.

E. Producer Involvement (contacts/outreach) during period of report
Number of farmers/ranchers in attendance at:*

1584 Workshops** 950 Conferences 2181 Field Days
___ Other events (specify)

* Numbers are estimates since at most events we don't have separate numbers for farm and non-farm audiences.

** Growers' meetings are grouped here.

14. Potential Contributions and Practical Applications:

A. A number of findings in this project have substantial potential to reduce chemical inputs in cropping systems and limit the negative impact of crop production on the environment.

1. Band application of herbicide combined with cultivation reduces herbicide use in corn by 60-65% with little if any, effect on yield. Since most field corn in the Northeast is treated with herbicide, the reduction in pesticide use would be substantial.

2. The use of ridge tillage on fields in which the primary N source has changed from inorganic N fertilizer to animal manure may reduce or eliminate corn yield reductions frequently observed in this transitional phase.

3. Continuous corn systems can be made more sustainable and productive through the use of appropriate management practices. Manure application improves soil physical properties and the use of interseeded cover crops provides substantial protection against soil erosion.

characteristics suggest far more spatial variability and far less solid conclusions about the differences between conventional and low input treatment yields. Only with further research will we be able to decipher this problem.

<u>References Cited</u>:

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B. New hypotheses

1. Ridge tillage and manure application may play a significant role in controlling corn rootworm. Understanding how rootworms move in soils and identify feeding sites enhances our understanding of plant/insect relationships and permits development of cropping systems and practices that reduce the use of insecticides.

15. Areas Needing Additional Study:

1. Role of manure and tillage on rootworm infestation and damage in corn.

2. Effects of ridge tillage on N availability when organic N sources are used to meet corn needs.

3. Long-term effects of reduced levels of weed control on weed seed population and weed infestation.

APPENDIX

Extension Activities

New York

1988. Oral Presentations.

Grain Crops Field Day. Aurora Research Farm, June 21. (55) Corn Tillage Systems and Weed Control Methods. W. Cox; Low-Input Crop Production: Cornell's Research Plans. J. Mt. Pleasant.

Seed and Fertilizer Dealer Meetings. Five locations across New York State. October 10-14. (310) Fertilizer Replacement Value of Animal Manures and Sod Crops for Corn Production. S. Klausner.

New York State Pest Control Conference. Ithaca. November 10. (35) Evaluation of some weed control methods under different corn tillage systems. W. Cox.

1989.

Oral Presentations.

Farmers Meetings in Chenango and Broome Counties. January (45) Fertilizer Replacement Value of Animal Manures and Sod Crops for Corn Production. S. Klausner.

Farmers Meetings in Seneca and Otsego Counties. January. (35) Tillage, Herbicide and Cultivation Effects on Weed Infestation and Corn Yields. W. Cox.

Corn Congress. January 16. Batavia. (230) Tillage, Herbicide and Cultivation Effects on Weed Infestation and Corn Yields. W. Cox.

Cayuga County Corn Day. Auburn. January 24. (45) LISA Project for Field Crops in New York. J. Mt. Pleasant.

Transitions Conference. Geneva. February 15. (280) The Role of Rotations in Crop Production. J. Mt. Pleasant.

International Dairy Manure Management Symposium. Syracuse. February 22. (250) Managing the Land Application of Dairy Manure: Agronomic Considerations. S. Klausner.

Early Inservice Education. Mt. Pleasant Research Farm. July 12. (10) Low-Input Sustainable Agriculture. J. Mt. Pleasant.

Oneida County Farmers Tour. Aurora Research Farm. July 19. (10). Low-Input Sustainable Agriculture. J. Mt. Pleasant.

Empire State Soil Fertility Association Summer Tour. Aurora Research Farm. July 20. Low-Input

Sustainable Agriculture. J. Mt. Pleasant.

Northeast State Soil and Water Conservation Districts Annual Meeting. Niagara Falls. Aug. 8 (60) Low-Input Sustainable Agriculture in New York. W. Cox.

Aurora Farm Field Day. Aurora Research Farm. Aug. 18. (100) Low-Input Sustainable Agriculture. J. Mt. Pleasant; Soil and Water Management. H. van Es.

Western New York Crop Management Association/Cooperative Extension Field Crops Tour. Aug. 22-24. (50) In-Season Testing for Efficient Nitrogen Use. S. Klausner; Using Winter Rye to Retain Free Nutrients and Control Erosion in Corn. B. Tillapaugh and C. DeGolyer.

Campus Experience for County Volunteers. Cornell University. Sept. 22. (8) Low-Input Sustainable Agriculture. J. Mt. Pleasant

Field Crop Dealers Meetings. Five locations across New York State. Oct. 2-6. (264) LISA: Low-Input Research and Extension for Field Crops. J. Mt. Pleasant.

Production Agriculture Training School. Cornell University. Nov. 8. (20) New Developments in the Water Quality Arena. H. van Es; Soil Test for Nitrogen. S. Klausner; Principles of Low-Input Agriculture. J. Mt. Pleasant.

<u>Written Materials</u>

Ag News Service

1. Developing a Fertilizer Program. S. Klausner
2. Sustainable Agriculture Aims For Increased Profitability and Greater Environmental Protection. J. Mt. Pleasant.

<u>1990.</u>

<u>Oral Presentations.</u>

Empire State Soil Fertility Association Winter Meeting. Auburn. Jan. 10-11. (140) Fertilizer Response Studies Including A Soil Test for N. S. Klausner; Cornell's Research and Extension Efforts in Field Crops Under the LISA Program. J. Mt. Pleasant.

Empire State Potato Club, Inc. Rochester. Jan. 10. (45) Land Stewardship: Consequences of Soil Compaction, Drainage, Erosion, and Chemical Application. H. van Es.

Finger Lakes Corn Congress. Phelps. Jan. 15. (70) Soil Test N Update. S. Klausner; Corn Response to Fertilizer. S. Klausner

Western New York Corn Congress. Batavia. Jan. 16. (250) Soil Test N Update. S. Klausner; Corn Crop Response to Fertilizer. S. Klausner.

New York State Forage and Grasslands Council Annual Meeting. Dryden. Jan. 17. (100) LISA

Research and Extension Efforts in Field Crops. J. Mt. Pleasant.

Agway Crops Training Program. Tully. Jan. 24. (25) Considerations for Cultivation as Supplemental Weed Control. J. Mt. Pleasant.

Aurora Farm Field Day. Aurora Research Farm. July 13. (125) Banded Herbicides and Cultivation of Corn. J. Mt. Pleasant; Low-Input Sustainable Agriculture: Cover Crops. T. Scott; Low-Input Sustainable Agriculture: Soil and Water Conservation Management. H. van Es.

Western NY Field Crop Management Tour. Aug. 30. (110) In-Season Nitrogen Testing For Corn. S. Klausner; Integrating Cultivation and Band Herbicides For Corn, J. Mt. Pleasant; Cover Crops and Intercrops in Corn. J. Mt. Pleasant.

Drive Yourself Tour: Dairy and Field Crops Program in Cortland, Chemung, Tioga and Tompkins Counties. Mt. Pleasant Research Farm. Sept. 4. (45). Low-Input Sustainable Agriculture. J. Mt. Pleasant.

Twilight Meeting. Dairy and Field Crops Program in Tompkins and Cortland Counties. Fouts Farm. Sept. 11. (6) Cultivation, Band Herbicide and Interseeding in Corn. J. Mt. Pleasant.

New York State College of Agriculture and Life Sciences Advisory Council Meeting. Geneva. Oct. 11. (40) Research and Extension Efforts in Low-Input Sustainable Agriculture. J. Mt. Pleasant.

Agway, Inc. Crop Specialist Training Session. Tully. Nov. 1. (12) Cultivation and Other Weed Control Options. J. Mt. Pleasant.

Production Agriculture Training School. Cornell University. Nov. 12-15. (20-35) Soil Test Nitrogen. S. Klausner; Fertilizer Research Update. S. Klausner; Cultivation and Band Application of Herbicides in Corn. J. Mt. Pleasant; Cover Crops and Interseeding in Corn. J. Mt. Pleasant; Soil Physical Properties and Tillage. H. van Es.

Written Materials.

Ag News Service

1. Cultivation Can Still Pay Off. J. Mt. Pleasant
2. Cover Crops Provide Many Benefits. J. Mt. Pleasant

1991.

Oral Presentations.

Corn/Soybean Production Meeting. Auburn. Feb. 8. (80) Interseeding and Cultivation of Corn. J. Mt. Pleasant.

Transitions Conference. Cobleskill. March 2. (120) Soil Fertility Management to Reduce Inputs and Protect the Environment. T. Scott; Cultivation: An Option for Weed Control in Corn. J.

Frisch.

Musgrave Research Farm Field Tour. Aurora. July 12. (150) Cultivation Demonstration for Corn Weed. C. Mohler and J. Frisch; Nitrogen Dynamics of Interseedings in Corn. R. Burt; Sustainable Agriculture Systems. J. Mt. Pleasant and R. Zobel.

Written Materials

Ag News Service

1. On-Farm Research: Why Bother? J. Mt. Pleasant.

What's Cropping Up? A Newsletter for New York Field Crops and Soils.

Cultivation: It Has A Place In Corn Management. J. Mt. Pleasant. Vol. 1, #3.

Using Organic Nitrogen To Reduce Fertilizer Input. S. Klausner. Vol. 1, #3.

Rye Cover Crop Provides Many Benefits. J. Mt. Pleasant. Vol. 1, #5.

Video

Sustainable Agriculture Practices for Field Crop Production in the Northeast. 12 min. Project Coordinator: J. Mt. Pleasant.

Pennsylvania

1988.

Rodale Research Center Annual Field Days. Kutztown. July. (350).

1989.

NOFA New England Annual Meeting. Williamstown, Mass. July 15. (50) Transition to Organic Farming. S. Peters.

Rodale Research Center Annual Field Days. Kutztown. July 25-26. (400) Farming Systems Trial - Nine Years of Results. S. Peters.

Staff Seminar - USDA/ARS, Beltsville, MD. Sept. 25. (15) Cropping Systems Research at the Rodale Research Center. R. Janke.

Seminar, Dept. Plant and Soil Science, University of Delaware, Newark, DE. Oct. 31. (45) Long-Term, Low-Input Cropping Systems Research. R. Janke.

Seminar, Depts. Entomology, Plant Pathology and Plant and Soil Sciences. University of Massachusetts, Amherst, MA. Nov. 14. (50) Sustainable Cropping Systems Research. R. Janke.

Seminar, Dept. Agronomy, Cornell University, Ithaca, NY. Dec. 5. (45) Long-Term Cropping Systems research at the Rodale Research Center: An Update.

Richmond County. Low-Input Sustainable Ag Production Meeting. Warsaw, VA. Dec. 6. (30) Low-Input Sustainable Weed Control. S. Peters.

<u>1990.</u>

Low-Input Farming Workshop, Rodale Institute and University of MD. Queenstown, MD. Jan. 4. (100) Low-Input Weed Control Practices. S. Peters; Changing to Low-Input Farming - Management Considerations and Research Results. S. Peters.

Sustainable Ag Workshop. Napolean Ohio. Jan. 11. (104) Developing A Regenerative Cropping System. R. Janke.

Transitions - Toward a More Sustainable Agriculture In New England, New Hampshire/Vermont Soil and Water Conservation Society. Fairlee, Vermont. Jan. 13. (350) Reducing Inputs and Making the Transition. S. Peters.

Low Input Farming Workshop, Rodale Institute, Chesapeake Bay Foundation, and Lancaster County (PA) Cooperative Extension. New Holland, PA. Feb. 1. (120) Low Input Weed Control Practices. S. Peters; Changing to Low Input Farming - Management Decisions and Research Results. S. Peters.

Priorities In Sustainable Agriculture Research, Guelph Agricultural Alternatives, REAP-Canada. Guelph, Ontario. Feb. 3. (300) Cropping Systems at the Rodale Research Center. R. Janke.

Low Input Farming Workshop, Penn. St. Cooperative Extension - Potter, McKean, Cameron, and Elk Counties. Port Allegany, PA. Feb. 13. (50) Changing to Low Input Farming - Management Consideration sand Research Results. S. Peters.

Agway Annual Research Symposium, Agway, Syracuse, NY. March 6-7. (50) Cropping Systems Research at the Rodale Research Center. R. Janke.

Ohio State University Cooperative Extension In-Service Training. Columbus, OH. March 23-24. (60) Conversion from Conventional to Low-Input Farming. R. Janke; Integrating On-Farm Research with On-Station Research. R. Janke.

Field Crops Expo '90, Wolfville, Nova Scotia. July 17. (100) Sustainable Cropping Systems: Furthering 'Better Balance' in the Farming Community. R. Janke.

Rodale Research Center Annual Field Days. Kutztown, PA. July 24-25. (300) Farming Systems Trial - Ten Years of Results. S. Peters.

Farmer Field Day, Bennett Farm, Napoleon, OH. Aug. 1. (100) Presentation on legume establishment and soybean relay cropping. R. Janke.

Farmer Field Day, Fogg Farm, Leslie, MI. Aug. 3. (90) Presentation of agronomy research at

Rodale Research Center. R. Janke.

Farmer Field Day, Epply Farm, Wabash, IN. Aug. 8. (85) Presentation of agronomy research at Rodale Research Center. R. Janke.

SCS Field Day, Defiance, OH. Aug. 14. Presentation of agronomy research at Rodale Research Center. R. Janke.

1991.

Take Charge Workshop, Rodale Institute and Brandywine Conservancy. Chadds Ford, PA. Jan. 9. (60) Considerations in Reducing Inputs. S. Peters.

Take Charge Workshop, Rodale Institute, Practical Farmers of Iowa, Iowa State University Cooperative Extension. Des Moines, IA. Jan. 11. Use of Legume Cover Crops in Sustainable Farming Systems. R. Janke.

Agriculture Production Meeting, Agri-Basics Soil Service. New Holland, PA. Jan. 22. (60) Harrisburg, PA. Jan. 23. (35) Low Input Techniques for Pennsylvania Farmers. S. Peters.

Take Charge Workshop, Rodale Institute, Chesapeake Bay Foundation, Franklin County (PA) Cooperative Extension. Chambersburg, PA. Feb. 20. Solving Your Weed Problems. R. Janke.

Farming for Profit and Stewardship, 5th Annual Virginia Sustainable Agriculture Conference, Virginia Tech, Virginia State Cooperative Extension, and other groups. Charlottesville, VA. Feb. 21. Lysimeters, Compost, and Perennial Silage Crops: Update on Long-term Cropping Systems Research. R. Janke.

Sustainable Agriculture in the Chesepeake Bay Region, Maryland Cooperative Extension, Institute for Alternative Agriculture, Chesapeake Bay Foundation, and other groups. Timonium, MD. Feb. 28. Farming Systems' Conversion Trial. R. Janke.

Take Charge Workshop, Rodale Institute and Michael Fields Agricultural Institute. East Troy, WI. March 14. (75) Mixing Tillage Practices for Better Crop Performance. S. Peters.

Twilight Farm Field Day, Rodale Institute Research Center. April 29. (25) Alternative Crops and Cultural Practices for Pennsylvania Farmers. S. Peters.

Organic and Sustainable Agriculture Farm Tours and Workshop, Central Pennsylvania Energy Center. Milton, PA. June 28. An Update on Research at the Rodale Institute Research Center. R. Janke.

Rodale Institute Research Center Annual Field Days. Kutztown, PA. July 30-31. (400) Farming Systems Trial - Eleven Years of Results. S. Peters.

Farmer Field Day. Fogg Farm, Leslie, MI. Sept. 12. Update of Research at the Rodale Institute Research Center. R. Janke.

Kansas Sustainable Agricultural Conferences, Kansas Rural Center. Ioala, KS. Nov. 21; Marysville, KS. Nov. 22. Making a Transition Toward Sustainable Agriculture; and Non-chemical Weed Control. R. Janke.

Table 1. Cropping Systems Compared in NY Field Experiments, 1989-1991.

Cropping System

Rotational Systems

1. Corn-Corn-Alf-Alf
   a. C-C-A-A
   b. C-C-A-A
   c. C-C-A-A
   d. C-C-A-A

2. Corn + rye cover - Oats+Alf-Alf-Alf
   a. C+RC-O+A-A-A
   b. C+RC-0+A-A-A
   c. C+RC-0+A-A-A
   d. C+RC-0+A-A-A

Continuous Corn

3. Conventional tillage, inorganic fertilizer
4. Conventional tillage, manure
5. Ridge tillage, inorganic fertilizer
6. Ridge tillage, manure
7. Conventional tillage, interseeded red clover
8. Conventional tillage, interseeded ryegrass
9. Ridge tillage, interseeded redclover
10. Ridge tillage, interseeded ryegrass

Table 2. Weed control treatments used for corn in NY field experiments. 1998-1991.

Weed Control Practice

1. Cultivation only
2. Band herbicide* plus cultivation
3. Broadcast herbicide only

* Herbicide applied at recommended rate in 10-inch band over the corn row.

Table 3. Cropping system and weed control contrasts used to compare treatment means.

Contrast	Description	Cropping Systems Compared*
C1	Continuous corn vs Rotational corn	3,4,5,6,7,8,9,10 vs 1a, 1b, 2a
C2	1st yr. corn vs 2nd yr. corn	1a, 2a vs 1b
C3	Corn w/ rye cover vs Corn w/out cover	1a vs 2a
C4	Conv. till vs Ridge till	3,4,7,8 vs 5,6,9,10
C5	Ridge interseeded vs Ridge monoculture	9,10 vs 5,6
C6	Conv. interseed. vs conv. monoculture	7,8 vs 3,4
C7	Ridge w/ manure vs Ridge w/ inorganic N	6 vs 5
C8	Conv. w/ manure vs Conv. w/ inorganic N	3 vs 4
C9	Conv. + red clover vs Conv. + ryegrass	7 vs 8
C10	Ridge + red clover vs Ridge + rye grass	9 vs 10
Contrast	**Description**	**Weed Control Treatment's Compared**
CA	Cultivation only vs Herbicide	1 vs 2,3
CB	Band herbicide + cultiv. vs Broadcast herb.	2 vs 3

* Cropping systems and weed control treatments are described in Tables 2 and 3.

Table 4. Corn silage yields and number of lodged plants under continuous and rotational corn. Mt. Pleasant and Musgrave Research Farms, 1990-1991.

	Mt. Pleasant		Musgrave	
	1990	1991	1990	1991
----Silage T/A 65%----				
Continuous Corn	8.9	8.5	18.9	13.6
Rotational Corn	11.8	10.8	20.6	15.1
F test p	.0001	.0001	.0006	.0039
1st Yr. Corn after Alf	14.3	12.1	21.2	16.0
2nd Yr. Corn after Alf	6.7	8.2	19.2	13.2
F test p	.0001	.0001	.0068	.0032
----Lodged Plants/A-----				
Continuous Corn	8970	322	603	39
Rotational Corn	5218	1923	478	303
F test p	.0001	.0001	NS	NS
1st Yr. Corn After Alf	203	2710	407	0
2nd Yr. Corn After Alf	15246	348	620	910
F test p	.0001	.0001	NS	.0022

Table 5. Corn silage yields and number of lodged plants under conventional and ridge tillage. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
— Silage T/A 65% —						
Conv. Till	10.5	9.6	9.2	19.8	19.0	13.7
Ridge Till	8.2	8.5	7.7	20.5	18.5	13.4
F test p	.0001	NS	.0003	NS	NS	NS
— Lodged Plants/A —						
Conv. Till	-	14676	465	-	702	10
Ridge Till	-	3263	179	-	503	68
F test p		.0001	NS		NS	NS

Table 6. Corn silage yields and number of lodged plants under conventional and ridge tillage with manure or inorganic N fertilizer. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
--- Silage T/A 65% ---						
Conv. Till, Manure	8.4	12.3	11.8	17.5	17.8	15.3
Conv. Till, IF	10.8	7.6	7.7	20.9	19.8	13.6
F test p	.0001	.0001	.0001	.0030	.0293	NS
Ridge Till, Manure	5.0	10.7	9.9	19.5	20.3	15.8
Ridge Till, IF	7.3	7.5	6.0	20.2	18.9	14.1
F test p	.0001	.0010	.0001	NS	NS	NS
--- Lodged Plants/A ---						
Conv. Till, Manure	-	9394	426	-	1045	19
Conv. Till, IF	-	17642	1123	-	503	19
F test p		.0001	NS		.0252	NS
Ridge Till, Manure	-	624	116	-	736	0
Ridge Till, IF	-	6026	407	-	639	19
F test p		.0001	NS		NS	NS

Table 7. Corn silage yields in monoculture and interseeded corn under conventional and ridge tillage. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
— Silage T/A 65% —						
Conv. Till, Mono. *	9.6	9.9	9.8	19.2	18.8	14.4
Conv. Till, Inter.	11.4	8.5	8.7	20.0	19.1	12.9
F test p	.0001	.0326	NS	NS	NS	.0463
Conv. Till, Inter. RC	11.4	8.5	8.5	20.8	19.3	13.0
Conv. Till, Inter. RG	11.5	8.6	8.9	19.3	18.9	12.9
F test p	NS	NS	NS	NS	NS	NS
Ridge Till, Mono.	6.2	9.1	8.0	19.9	19.6	15.0
Ridge Till, Inter.	10.3	8.0	7.4	20.3	17.4	11.9
F test p	.0001	NS	NS	NS	.0015	.0001
Ridge Till, Inter. RC	10.7	8.9	7.1	20.4	18.4	13.2
Ridge Till, Inter. RG	9.9	7.1	7.6	20.2	16.4	10.5
F test p	NS	.0432	NS	NS	.0344	.0117

* Mono. = monoculture; Inter. = interseeded at cultivation; RC = red clover; RG = ryegrass.

Table 8. Corn silage yields with mechanical and/or chemical weed control.* Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
--- Silage T/A 65% ---						
Mechanical only *	8.8	9.1	9.5	19.2	19.3	14.6
Mech. + Chem., or Chem. only	9.6	10.0	8.8	20.2	19.2	13.7
F test p	.0129	.0004	.0010	.0001	NS	.0001
Mech. + Chem.	10.0	9.5	8.7	20.4	19.3	13.3
Chem. only	9.3	10.4	9.0	19.9	19.1	14.0
F test p	NS	.0024	NS	NS	NS	.0044

* Mechanical only = cultivation alone; Mech. + Chem. = band herbicide plus cultivation; chem. only = broadcast herbicide alone.

Table 9. Midseason weed cover in corn using mechanical and/or chemical weed control. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
--- % Weed Cover ---						
Mech. only *	75	64	45	10	10	33
Mech. + Chem. or Chem. only	20	17	23	4	3	24
F test p	.0001	.0001	.0001	.0001	.0001	
Mech. + Chem.	36	28	34	4	2	35
Chemical only	4	5	12	3	4	13
F test p	.0001	.0001	.0001	.1155	.0013	.0001

* Mech. only = cultivation alone; Mech. + Chem. = band herbicide plus cultivation; Chem. only = broadcast herbicide alone.

Table 10. Midseason weed cover in continuous and rotational corn. Mt. Pleasant and Musgrave Research Farms, 1990 - 1991.

	Mt. Pleasant		Musgrave	
	1990	1991	1990	1991
---- % Weed Cover ----				
Continuous Corn	32	36	3	25
Rotational Corn	32	16	12	33
F test p	NS	.0001	.0001	.0301
1st Yr. After Alf	31	13	15	22
2nd Yr. After Alf	33	21	7	55
F test p	NS	NS	.0003	.0001

Table 11. Midseason weed cover in corn under conventional and ridge tillage. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
	— % Weed Cover—					
Conv. Till	32	37	25	7	5	36
Ridge Till	45	28	47	4	2	14
F test p	.0001	.0118	.0001	.0039	.0220	.0001

Table 12. Midseason weed cover in corn under conventional and ridge tillage with manure or inorganic N Fertilizer. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
	--- % Weed Cover ---					
Conv. Till, Manure	34	38	29	8	3	27
Conv. Till, IF*	31	35	19	6	6	25
F test p	NS	NS	NS	NS	NS	NS
Ridge Till, Manure	47	29	38	2	2	9
Ridge Till, IF	66	20	44	4	2	11
F test p	.0027	NS	NS	NS	NS	NS

* IF = Inorganic N fertilizer.

Table 13. Midseason weed cover in monoculture or interseeded corn under conventional and ridge tillage. Mt. Pleasant and Musgrave Research Farms, 1989 - 1991.

	Mt. Pleasant			Musgrave		
	1989	1990	1991	1989	1990	1991
--- % Weed Cover ---						
Conv. Till, Mono.	33	37	24	7	5	26
Conv. Till, Inter.	31	37	27	8	5	45
F test p	NS	NS	NS	NS	NS	.0013
Conv. Till, Inter. RC	32	31	24	7	4	43
Conv. Till, Inter. RG	31	43	29	8	5	48
F test p	NS	NS	NS	NS	NS	NS
Ridge Till, Mono.	57	25	41	3	2	10
Ridge Till, Inter.	33	31	52	5	2	18
F test p	.0001	NS	.0122	NS	NS	NS
Ridge Till, Inter. RC	26	24	42	5	2	15
Ridge Till, Inter. RG	40	39	63	6	2	20
F test p	.0215	.0310	.0011	NS	NS	NS

Table 14. Inorganic soil nitrate levels at two depths under rotational and continuous corn cropping system. Musgrave Research Farm, NY 1989-1990.

Cropping System	Musgrave					
	Nov. '89		April '90		Nov. '90	
	0-9"	9-18"	0-9"	9-18"	0-9"	9-18"
Rotational Systems	-------------------------lbs/A Inorganic N-------------------------					
C-C-A-A						
<u>C</u>-C-A-A	-				14	11
C-<u>C</u>-A-A	-				15	13
C-C-<u>A</u>-A	-				16	8
C-C-A-<u>A</u>	20	7	17	9	15	6
C-0+A-A-A						
<u>C</u>-0+A-A-A	23	12	15	12	15	13
C-<u>0+A</u>-A-A					16	11
C-0+A-<u>A</u>-A					16	7
C-0+A-A-<u>A</u>	25	12	19	11	12	6
Continuous Corn						
Conv. Till, IF	21	10	14	4	15	11
Conv. Till, M	25	11	16	10	14	9
Ridge Till, IF	20	14	14	12	16	11
Ridge Till, M	28	14	15	12	16	11
Conv. Till, Inter. RC	17	9	12	7	16	10
Conv. Till, Inter. RG	22	13	15	10	14	7
Ridge Till, Inter. RC	-	-	-	-	19	15
Ridge Till, Inter. RG	-	-	-	-	16	15
	NS	NS	NS	NS	NS	5

Table 15. Inorganic soil nitrate levels at two depths under rotational and continuous corn cropping systems. Mt. Pleasant Research Farm, NY, 1989-1990.

Cropping System / Rotational Crops	Mt. Pleasant Nov. 1989 0-9"	Mt. Pleasant Nov. 1989 9-18"	Mt. Pleasant April 1990 0-9"	Mt. Pleasant April 1990 9-18"
	----------lbs/A Inorganic N----------			
C-C-A-A				
C̲-C-A-A	-		-	
C-C̲-A-A	-		-	
C-C-A̲-A	-		-	
C-C-A-A̲	10	6	27	12
C-0+A-A-A				
C̲-0+A-A-A	20	16	12	10
C-0̲+̲A̲-A-A	-		-	
C-0+A-A̲-A	-		-	
C-0+A-A-A̲	16	6	25	13
Continuous Corn				
Conv. Till. IF	18	11	11	9
Conv. Till, M	12	7	13	9
Ridge Till, IF	17	13	17	12
Ridge Till, M	13	10	17	13
Conv. Till, Inter. RC	14	14	22	10
Conv. Till, Inter. RG	10	7	16	8
Ridge Till, Inter. RC	-	-	-	
Ridge Till, Inter. RG	-	-	-	
LSD .05	7	5	5	3

Table 16. Ground cover in rotational and continuous corn systems. Musgrave Research Farm, NY, 1990-1991.

Cropping System*	Spring 1990 Total Cover**	Spring 1990 Cover Crop	Fall 1990 Total Cover	Fall 1990 Cover Crop	Fall 1991 Total Cover	Fall 1991 Cover Crop
	------% Ground Cover------					
Rotational Corn	9	8	24	3	44	14
Continuous Corn	6	5	30	8	39	9
F test p	.0103	.0043	.0002	.0001	NS	.0002
Rotational Corn Systems						
1st Yr. Corn after Alf. + WR	23	23	26	8	56	43
1st Yr. Corn after Alf, no cover	2	0	24	0	24	0
F test p	.0001	.0001	NS	.0011	NS	.0001
Continuous Corn Systems						
Conv. Till, Mono.	10	0	22	0	30	0
Conv. Till, Interseed.	2	9	37	13	50	15
F test p	.0001	.0001	.0001	.0001	.0001	.0001
Conv. Till, Inter. RC	14	12	37	11	57	20
Conv. Till, Inter. RG	7	5	37	15	43	9
F test p	.0027	.0017	NS	NS	.0098	.0002
Ridge Till, Mono.	12	0	21	0	25	0
Ridge Till, Interseed.	1	11	41	18	53	22
F test p	.0001	.0001	.0001	.0001	.0001	.0001
Ridge Till, Inter RC	13	12	33	11	51	21
Ridge Till, Inter. RG	10	9	48	25	54	23
F test p	NS	NS	.0001	.0001	NS	NS

* WR = Winter rye seeded after silage harvest; Mono = corn monoculture; Interseed = cover crop seeded at cultivation; RC = red clover; RG = ryegrass.
** Total cover includes cover from corn trash, weeds and any seeded cover crop (WR, RC, or RG).

Table 17. Ground cover in rotational and continuous corn systems. Mt. Pleasant Research Farm, NY, 1990-1991.

	Spring 1990		Fall 1990	
	Total Cover	Cover Crop	Total Cover	Cover Crop
Cropping System*	---------% Ground Cover---------			
Rotational Corn	10	2	44	3
Continuous Corn	21	10	84	30
F test p	.0001	.0001	.0001	.0001
1st Yr. Corn after Alf. + WR	12	3	30	10
1st Yr. Corn after Alf, no cover	7	0	44	0
F test p	NS	NS	.0021	.0022
Conv. Till, Mono.	4	0	49	0
Conv. Till, Interseed.	29	24	116	64
F test p	.0001	.0001	.0001	.0001
Conv. Till, Inter. RC	24	17	107	61
Conv. Till, Inter. RG	38	32	125	68
F test p	.0001	.0001	.0001	.0241
Ridge Till, Mono.	18	0	58	0
Ridge Till, Interseed.	30	21	113	55
F test p	.0001	.0001	.0001	.0001
Ridge Till, Inter. RC	22	15	100	43
Ridge Till, Inter. RG	39	27	126	67
F test p	.0001	.0001	.0001	.0001

* WR = winter rye seeded after silage harvest; Mono = corn monoculture; Interseed. = cover crop seeded at cultivation; RC = red clover; RG = ryegrass.

Table 18. Corn grain yields (bu/a) under different cropping systems: 1986-1991. Rodale Institute Research Center.

Cropping System	Previous Crop	1986	1987	1988	1989	1990	1991
LIP-A	Hay	172a	--	110a	124ab	--	133a
LIP-CG	Green Manure	137b[1]	144a	109a	111c	149a	96b
CONV	Corn	166a[2]	130a	85b	116bc	--	137a[2]
CONV	Soybean	168a[2]	139a	104a	130a	158a	130a[2]

Note: Corn yields are adjusted to 15.5% moisture.

1 Short season (95 day) corn variety.

2 Both conventional corn treatments in 1986 and 1991 were preceded by a soybean crop.

Table 19. Corn ear leaf nitrogen (%) at silking under different cropping systems: 1986-1991. Rodale Institute Research Center.

Cropping System	Previous Crop	1986	1987	1988	1989	1990	1991
LIP-A	Hay	2.79a	--	2.86a	2.75a	--	2.62bc
LIP-A[1]	Soybean	2.80a	--	2.85a	--	2.25c	2.57c
LIP-CG	Green Manure	2.78a	2.83a	2.96a	2.72a	2.47b	2.15d
CONV	Corn	2.62b	2.80a	2.74a	2.86a	--	2.68ab
CONV	Soybean	2.52b	2.87a	2.79a	2.87a	2.82a	2.76a

[1] This corn was grown for silage.

Table 20. Soybean seed yield (bu/a) under different cropping systems and intercropped small grain yield (bu/a) in the Low Input Cash Grain (LIP-CG) system: 1986-1991. Rodale Institute Research Center.

Cropping System	1986	1987	1988	1989	1990	1991
LIP-A	--	44b	--	43a	47a	--
LIP-CG (soybean)	48a	44b	*[1]	33b	29c	50a
LIP-CG (sm.grain)[2]	29	32	61	*[3]	38	--
CONV	42b	53a	49a	46a	41b	50a

1 Not harvested due to drought.

2 Small grain was spring barley in 1986, 1988, 1989, 1990; winter wheat in 1987. A small grain was not planted in 1991.

3 Not harvested due to wet weather.

Table 21. Weed biomass in corn (dry weight - lb/a) under different cropping systems: 1986-1991. Rodale Institute Research Center.

Cropping System	Previous Crop	1986	1987	1988	1989	1990	1991
LIP-A	Hay	223b	--	900a[1]	1322a	--	1607a
LIP-A	Soybean	669a	--	799a	--	517a	1928a
LIP-CG	Gr.Manure	702a[1]	467a	449b	110c	657a	865b
CONV	Corn	143b	106b	250bc	487b	--	145c
CONV	Soybean	366b	61b	88c	252bc	9b	320c

[1] Significantly negative effect of weeds on corn grain yields.

Table 22. Weed biomass in soybeans (dry weight - lb/a) under different cropping systems: 1986-1991. Rodale Institute Research Center.

Cropping System	1986	1987	1988	1989	1990	1991
LIP-A	--	1492a[1]	--	*[2]	114b	--
LIP-CG	446a	361b	--	487a[1]	391a	756a
CONV	312a	115c	325a	162b	343a	83b

[1] Significantly negative effect of weeds on soybean seed yields.

[2] Weed biomass was not measured for this treatment but yields from plus/minu weed subplots indicated no adverse effect on yields when weeds were present.

Table 23. Soil chemical analysis (0-8"): 1981-1989. Rodale Institute Research Center.

Cropping system	pH	P(lb/a)	K	Ca	Mg	CEC	K	Mg	Ca	OM
			meq/100g				%			
1981										
LIP-A	6.54a	338a	0.49a	7.12a	1.54a	11.41b	4.3a	14.1a	63.3a	2.31a
LIP-CG	6.51a	295a	0.45a	7.09a	1.57a	11.36b	4.0ab	14.5a	63.8a	2.44a
CONV	6.17b	338a	0.50a	6.77b	1.48a	12.98a	3.9b	13.7a	52.8b	2.31a
1983										
LIP-A	6.38b	356b	0.45a	6.70ab	1.54b	10.99a	4.0a	14.5b	61.4b	2.17ab
LIP-CG	6.40b	438a	0.36b	6.64b	1.51b	10.99a	3.3b	14.2b	60.9b	2.23a
CONV	6.82a	418ab	0.41a	6.99a	1.99b	10.05a	4.0a	20.3a	69.8a	1.99b
1985										
LIP-A	6.29b	376a	0.42a	6.21b	1.46b	10.79a	3.8a	13.5b	57.4b	2.22a
LIP-CG	6.21c	382a	0.38a	6.09b	1.43b	10.83a	3.4a	13.1b	55.9b	2.26a
CONV	6.92a	395a	0.37a	6.76a	2.26a	9.47b	3.9a	23.9a	71.2a	2.06b
1987										
LIP-A	6.49b	366a	0.42a	6.38b	1.56b	10.71a	3.8a	14.6b	59.8b	2.15b
LIP-CG	6.47b	316b	0.32b	6.01c	1.41c	10.20b	3.1b	14.0b	59.1b	2.70b
CONV	7.18a	288b	0.31b	6.85a	2.47a	9.62c	3.2b	25.8a	70.8a	2.08b
1989										
LIP-A	6.37b	369a	0.30a	5.66b	1.18b	9.78a	3.0a	12.1b	57.7b	3.07ab
LIP-CG	6.36b	328b	0.23b	5.78b	1.15b	9.77a	2.3b	11.8b	58.8b	3.25a
CONV	6.83a	336b	0.22b	6.08a	1.90a	8.46b	2.5b	22.2a	71.9a	2.91b

Table 24. Soil chemical analysis (0-8") combining all rotational entry points in each cropping system. Rodale Institute Research Center 1991.

Cropping System	pH	(lb/a) P	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)	CEC (meq/100g)	%K	%Ca	%Mg	% Org. Matter	Total %C	Total %N
LIP-A	6.5b	334a	.28a	5.84a	1.14b	9.47a	3a	62b	12b	2.97a	2.14a	.312a
LIP-CG	6.5b	283ab	.18b	5.55a	1.04b	9.03a	2b	62b	12b	2.76a	2.23a	.298a
CONV	6.7a	246b	.17b	5.49a	1.48a	7.71b	2b	72a	19a	2.34b	1.90b	.283b

Note: Organic matter content measured by Walkley-Black wet combustion method; Total C and N measured by Carlo-Erba analyzer (dry combustion).

Table 25. Description of farms and soils used for the field scale trials, 1989-1991.

1. Vaill Farm, Cayuga County	400 acre cash crop farm. Honeoye silt loam moderately well drained with corn yieldpotential of 141 bu/A.
2. Shaul Farm, Schoharie County	1500 acre cash grain and vegetable farm. Barbour-Tioga fine silt loam, well drained with corn yield potential of 141 bu/A.
3. Gates Farm, Schuyler County	72 cow dairy with 655 acres cropped. Mardin channery silt, moderately well drained with corn yield potential of 112 bu/A.
4. DeGolyer Farm, Wyoming County	500 cow dairy with 600 acres cropped. Bath-Vallois gravelly loam, well drained with a corn yield potential of 124 bu/A.
5. Luenberger Farm, Oneida County	70 cow dairy with 350 acres cropped. Cazenovia silt loam, moderately well drained with a corn yield potential of 135 lb/A.
6. Cornell Hog Farm, Tompkins County	Rhinebeck silt clay loam, somewhat poorly drained with a corn yield potential of 105 bu/A.
7. Musgrave Research Farm, Cayuga County	Honeoye-Lima-Kendaia-Lyons category a silt loam with very mixed drainage and a corn yield potential of 135 bu/A.

Table 26. Effects of tillage, manure, weed control and cover crop management on ground cover, cover crop biomass and corn grain yields. Vaill Farm, Popular Ridge, NY, 1989-1991.

	% Cover			Biomass lbs/A DM		Grain Yields
Treatments*	July					bu/A 15%
1989	Oats	Weeds				
1. CT, B'cast herb., IF	-	2				164
2. CT, Band herb. + cult, M, Oats	13	6				137
3. RT, Band herb. + cult, M, Oats	14	4				131
4. CT, Band herb. + cult, M	-	4				159
LSD .05		NS				19
	July			November		
1990	SOR	CC	Weeds	SOR	CC	
1. CT, B'cast herb.	-	-	2			133
2. CT, Band herb. + cult.	-	-	2			132
3. CT, Band herb. + cult, SOR	14	-	6	672		125
4. CT, Band herb. + cult, CC	-	17	5		791	132
5. RT, Band herb. + cult.	-	-	3			141
6. RT, Band herb. + cult, SOR	14	-	2	735		135
7. RT, Band herb. + cult, CC	-	14	4		992	133
LSD .05			NS			NS
	October			November		
1991	RG	CC	Weeds		CC	
1. CT, B'cast herb.	-	-	1			91
2. CT, Band herb. + cult.	-	-	24			78
3. CT, Band herb. + cult, RG	11	-	21			82
4. CT, Band herb + cult, CC	-	17	15		368	80
5. RT, Band herb, + cult	-	-	11			80
6. RT, Band herb, + cult, RG	4	-	9			89
7. RT, Band herb. + cult, CC	-	16	7		475	87
LSD .05			15			NS

* CT = Conventional tillage; RT = Ridge tillage; IF = Inorganic fertilizer; M = manure; Cult = Cultivation; SOR = Sorghum seeded at cultivation; CC = Crimson clover seeded at cultivation; RG = Ryegrass seeded at cultivation.

Table 27. Effects of a rye grass cover crop on ground cover, cover crop biomass and corn grain yields. Shaul Farm, Fultonham, NY, 1989-1990.

	% Cover					lbs/A DM	Grain Yields
1989	RG	Weeds					
1. Band herb. + cultiv.	-	2					166
2. Band herb. + cult. + RG	32	1					168
LSD .05		NS					NS
	August		December **			December	
1990	RG	Weeds	RG	Weeds	TC**	RG	
1. Band herb. + cultiv.	-	1	-	1	1		181
2. Band herb. + cult. + RG	24	2	59	1	60	164	175
LSD .05		NS		NS	12		NS

* RG = Ryegrass seeded at cultivation.

** TC = Total cover.

Table 28. Effects of weed control and cover crop management on ground cover, cover crop biomass and grain yields. Gates Farm, Montour Falls, NY, 1989-1991.

	% Cover**							lbs/A DM		
Treatments*	August			November				April '90		Grain Yields
1989	RC/RG	WR	Weeds	RC/RG	WR	Weeds	TC	RC/RG	WR	bu/A 15%
1. B'cast herb.	-	-	7	-	-	8	8			47
2. Band herb. + cult. + RC/RG	15	-	20	30	-	14	44	87		42
3. Band herb. + cult. + WR	-	37	18	-	49	23	72		63	41
LSD .05			NS			10	12			NS
	August			December						
1990	RC/RG	WR	Weeds	RC/RG	WR	Weeds	TC			
1. B'cast herb.	-	-	12	-	-	14	14			106
2. Band herb. + cult. + RC/RG	12	-	26	22	-	29	51			101
3. Band herb. + cult. + WR	-	70	16	-	47	17	64			112
LSD .05			8			12	17			NS
	August									
1991	RC/RG	WR	Weeds							
1. B'cast herb.	-	-	6							49
2. Band herb. + cult. + RC/RG	5	-	18							49
3. Band herb. + cult. + WR	-	26	19							45
LSD .05			NS							NS

* RC/RG = Red clover + ryegrass seeded at cultivation; WR = Winter rye seeded at cultivation.

** TC = Total cover.

Table 29. Effect of cover crop management on ground cover, cover crop biomass, and corn silage yields. DeGolyer Farm, Castile, NY, 1989-1991.

	% Cover						lbs/A DM	Silage Yields
Treatments*	July						April '90	T/A 65%
1989	WR	Weeds					WR	
1. B'cast herb. + cult.	-	2					-	14.3
2. B'cast herb. + cult. + WR (1.5 bu)	24	1					452	14.4
3. B'cast herb. + cult. + WR (2.0 bu)	29	4					402	14.5
4. B'cast herb. + cult. + WR after harvest	-	-					365	15.3
LSD .05		NS					NS	NS
	July		December**			April '91	April '91	
1990	WR	Weeds	WR	CT	TC	WR	WR	
1. B'cast herb.	-	1	-	-	-	-	-	19.0
2. B'cast herb. + cult. + WR (1.5 bu)	40	1	-	-	-	-	-	19.6
3. B'cast herb. + cult. + WR (2.0 bu)	47	0	-	-	-	-	-	20.6
4. B'cast herb. + cult. + WR after harvest	-	1	32	4	36	65	498	20.3
LSD .05		NS						NS
1991	July		December				December	
	WR	Weeds	WR	Weeds	CT	TC	WR	
1. B'cast herb.	-	2	-	1	11	12	-	17.5
2. B'cast herb. + cult. + WR (1.5 bu)	19	1	34	1	14	49	388	16.7
3. B'cast herb. + cult + WR (2.0 bu)	29	1	45	1	11	57	576	17.9
4. B'cast herb. + cult. + WR after harvest	-	2	68	1	8	76	342	16.2
LSD .05	NS	NS		NS	NS	19	NS	NS

* WR = Winter rye seeded at cultivation or after harvest.

** CT = Corn trash; TC = Total cover.

Table 30. Effects of weed control and cover crop management on ground cover, cover crop biomass and corn grain yields, Luenberger Farm, Oriskany Falls, NY, 1989-1991.

	—————% Cover					——————	Grain Yields
Treatments*							bu/A 15%
1989							
1. Broadcast herb.							53
2. Band herb. + cult. + RC/RG							63
LSD .05							NS
	August		October**				
1990	RC/RG	Weeds	RC/RG	Weeds	CT**	TC	
1. Broadcast herb.	-	17	-	10	73	83	113
2. Band herb. + cult. + RC/RG	21	26	32	20	82	134	118
LSD .05		NS		7	6	11	NS
1991							
1. Broadcast herb.		41					123
2. Band herb. + cult. + RC/RG	36	23					126
		15					NS

* RC/RG = Red clover and ryegrass seeded at cultivation.

** CT = Corn trash; TC = Total cover

Table 31. Effects of weed control and cover crop management on ground cover an dcorn silage yields. Hog Farm, Cornell University, Ithaca, NY, 1989-1990.

	% Cover						Silage Yields
Treatments*	August						T/A 65%
1989	RC/RG	Weeds					
1. Broadcast herb.	-	1					9.2
2. Cultiv. only + RC/RG	36	29					9.5
3. Band herb. + cult. + RC/RG	13	6					10.9
LSD .05		4					NS
	August		December **				
1990	RC/RG	Weeds	RC/RG	Weeds	CT	TC	
1. Broadcast herb.	-	9	-	16	7	23	11.3
2. Cultiv. only + RC/RG	29	44	106	24	4	137	10.3
3. Band herb. + cult. + RC/RG	32	13	105	11	4	121	11.7
LSD .05		12		5	2	10	NS

* RC/RG = Red clover and ryegrass seeded at cultivation.

** CT = Corn trash; TC = Total cover.

Table 32. Effects of tillage, fertilizer source, weed control and cover crop management on ground cover, cover crop biomass and corn grain yields. Musgrave Research Farm, Aurora, NY, 1989-1990.

	% Cover			lbs/A DM		Grain Yields
Treatments*	July					bu/A 15%
1989	Oats	Weeds				
1. CT, B'cast herb., IF	-	13				162
2. CT + Band herb. + M, Oats	11	5				117
3. RT + Band herb. + M, Oats	11	11				98
LSD .05		8				24
	July			November		
1990	SOR	CC	Weeds	CC	SOR	
1. CT + B'cast herb.	-	-	4		-	105
2. CT + Band herb. + SOR	-	26	10		263	108
3. CT + Band herb. + CC	23	-	9	363	-	110
4. RT + Band herb. + SOR	-	10	13		288	101
5. RT + Band herb. + CC	23	-	10	522		106
			NS			NS

* CT = Conventional tillage; RT = Ridge tillage; IF = Inorganic fertilizer; M = Manure; SOR = Sorghum seeded at cultivation; CC = Crimson clover seeded at cultivation.

Figure1a. Farming Systems Trial Rotations

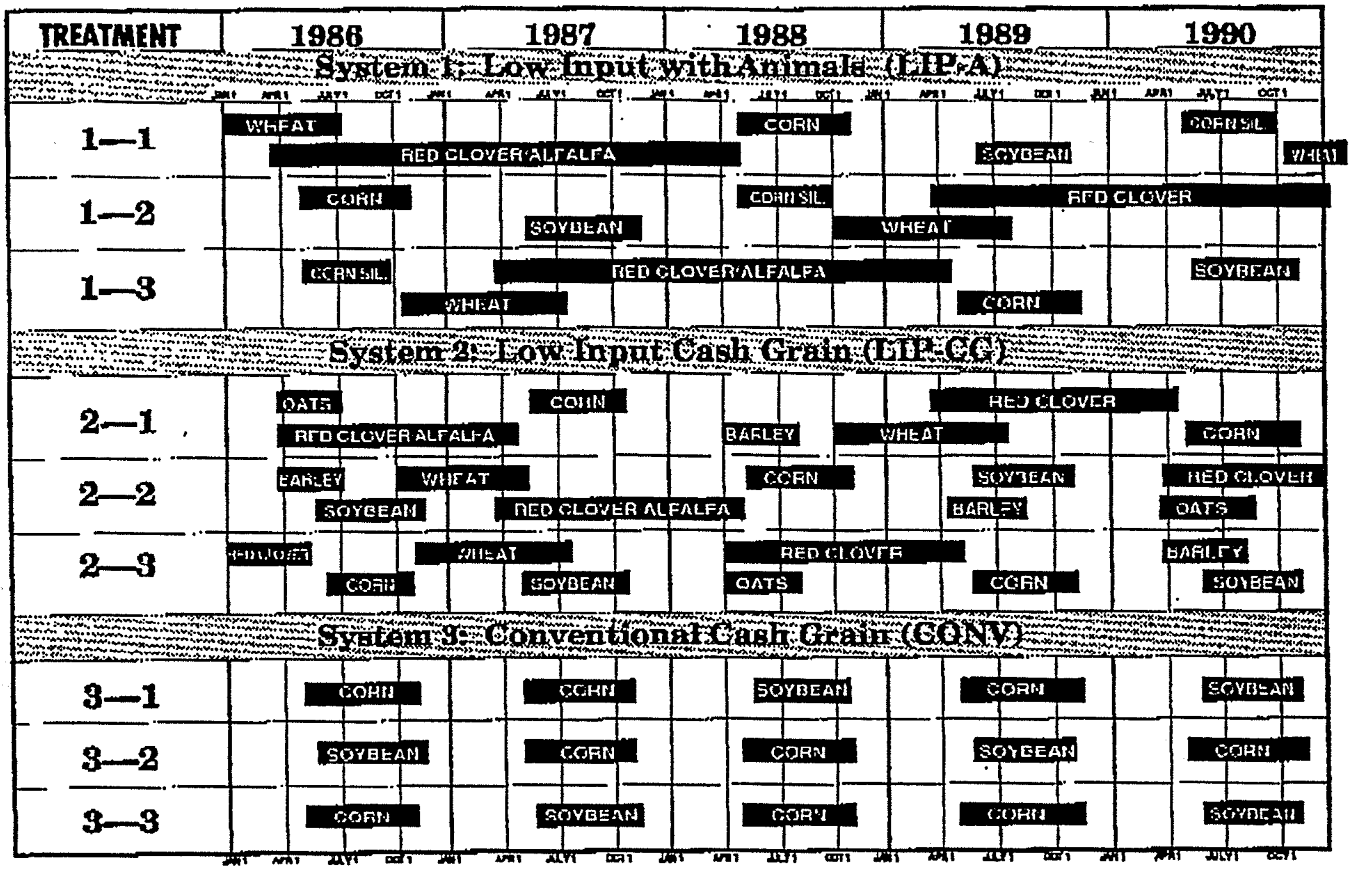


Figure 1b. Farming Systems Trial Rotations

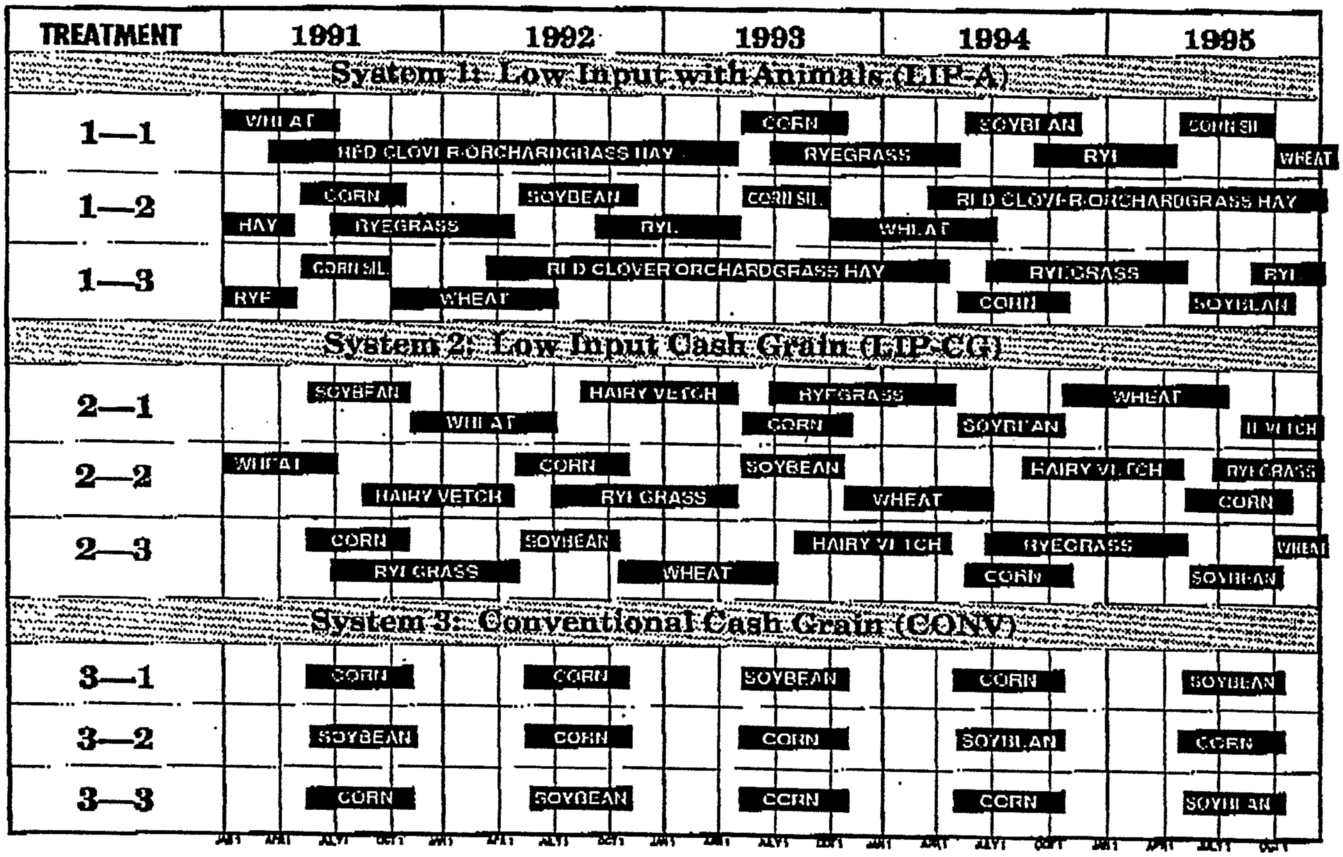
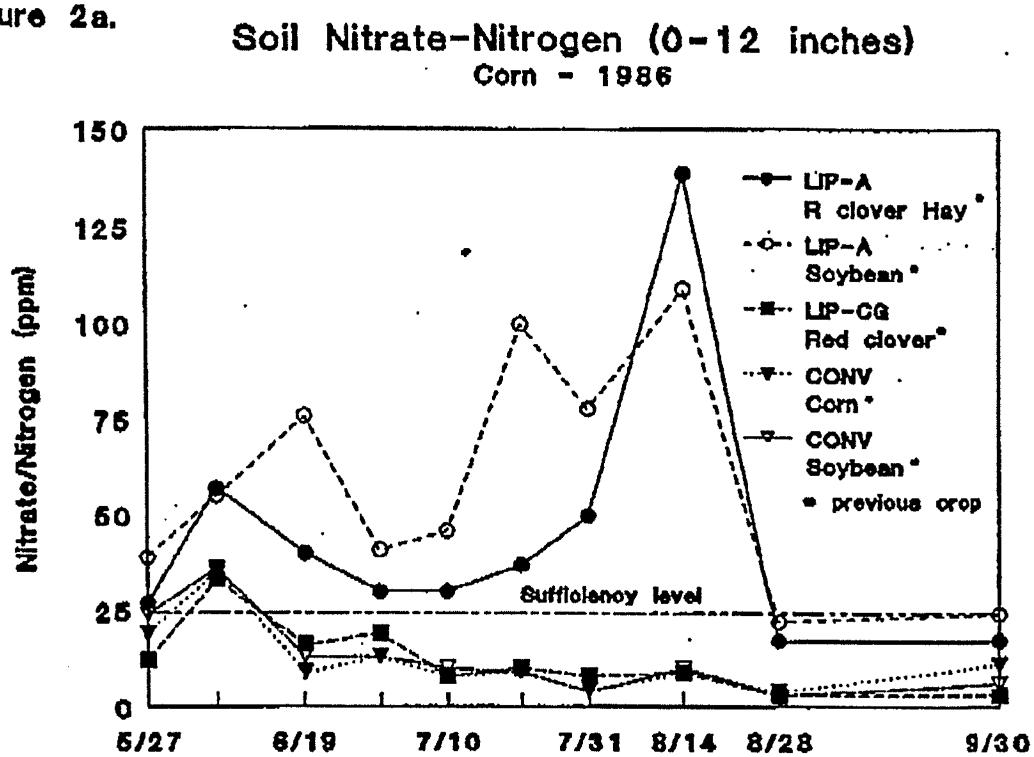
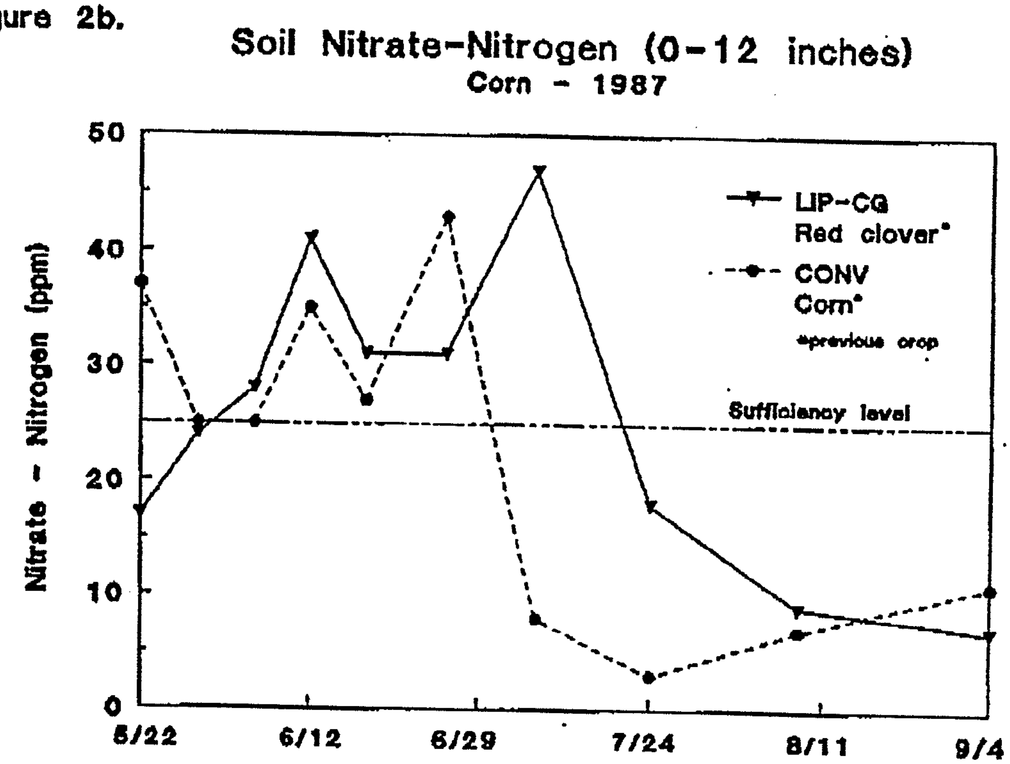


Figure 2a.



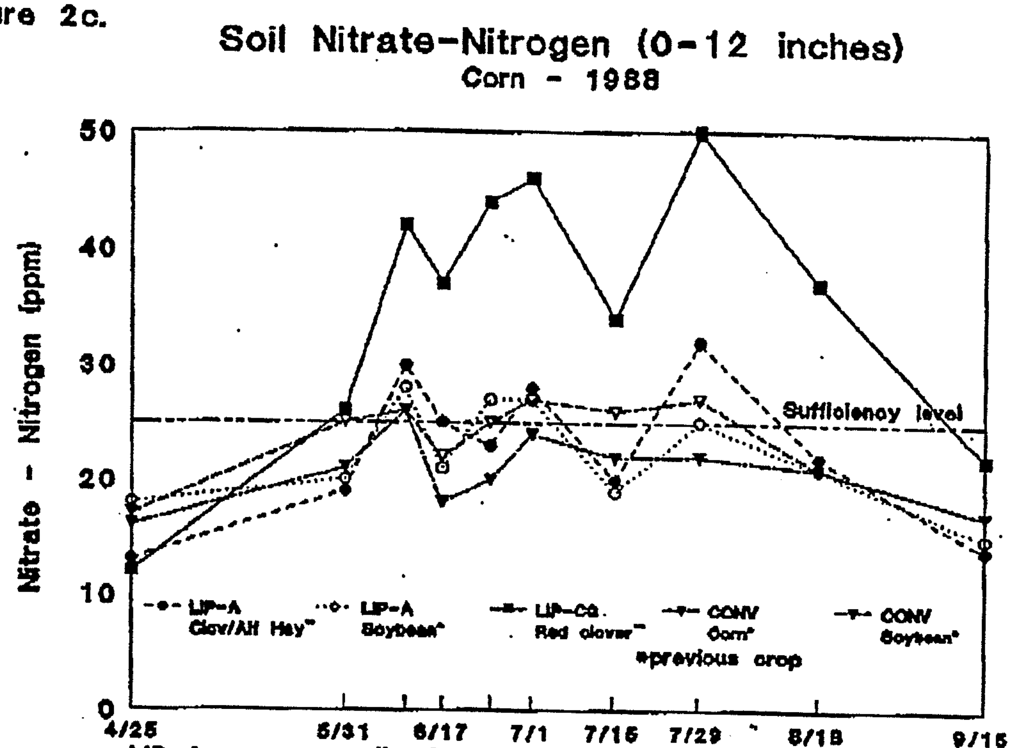
LIP-A manure application and plowdown - April 25
LIP-CG red clover green manure plowdown - April 26
Conv fertilizer N sidedressed - June 5

Figure 2b.



LIP-CG red clover green manure plowdown - May 1
CONV fertilizer N sidedressed - June 16

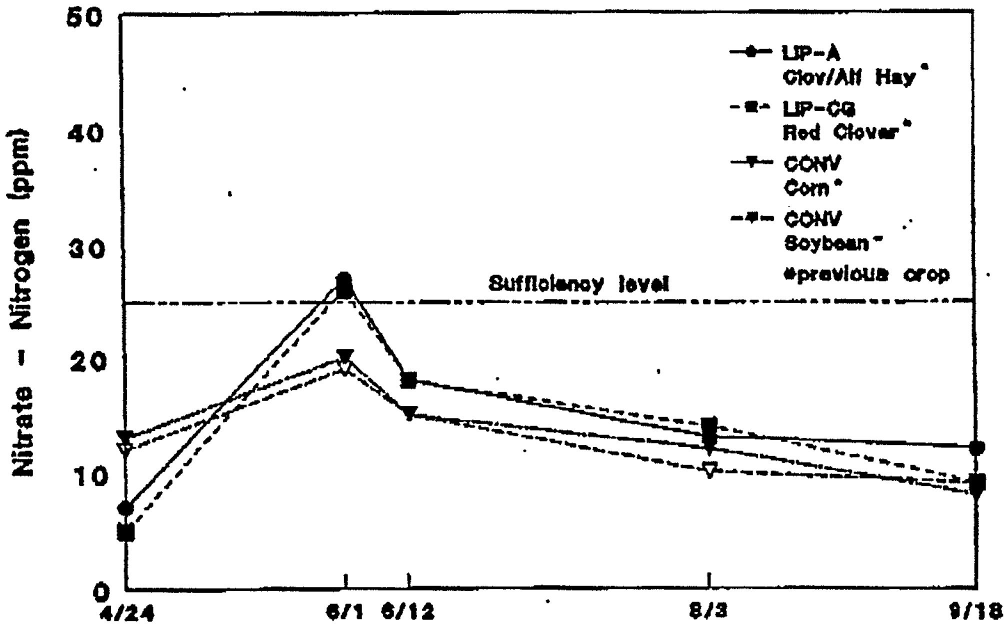
Figure 2c.



LIP-A manure application and plowdown - April 22
LIP-CG red clover green manure plowdown - May 3
CONV fertilizer N sidedressed - June 20

Figure 2d.

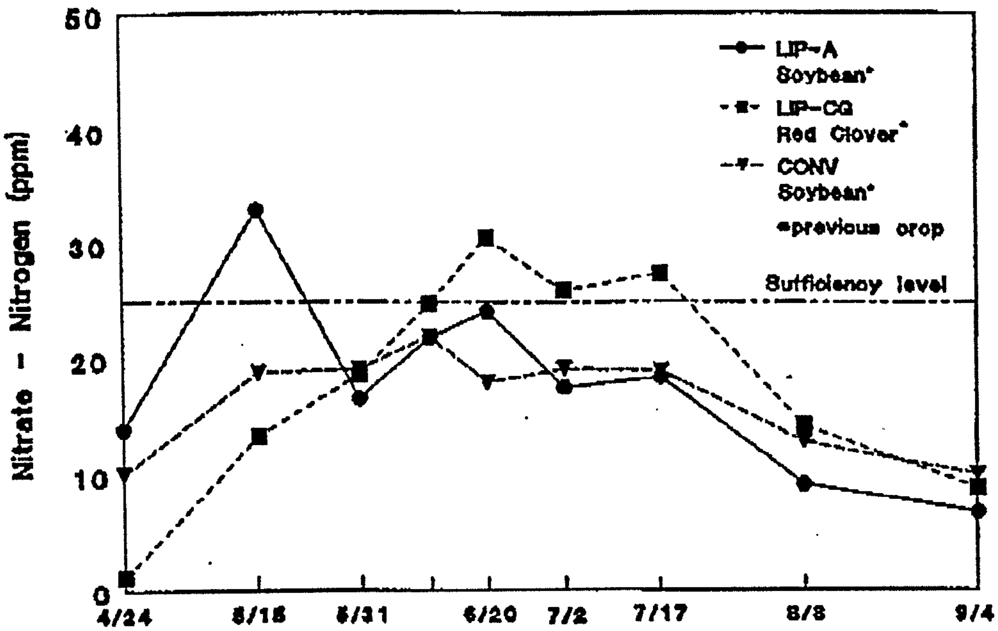
Soil Nitrate-Nitrogen (0-12 inches)
Corn - 1989



LIP-A manure application and plowdown - April 20
LIP-CG red clover green manure plowdown - May 4
CONV fertilizer N sidedressed - June 27

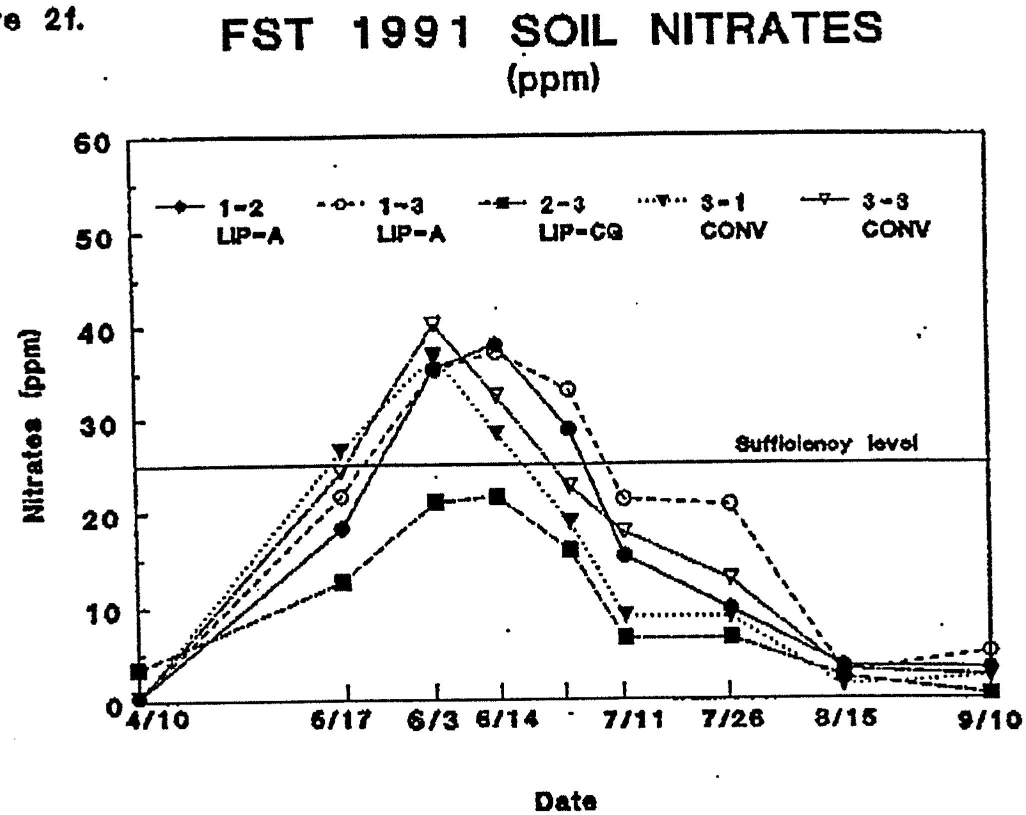
Figure 2e.

Soil Nitrate-Nitrogen (0-12 inches)
Corn - 1990



LIP-A manure application and plowdown - April 18
LIP-CG red clover green manure plowdown - May 2
CONV fertilizer N sidedressed - June 20

Figure 2f.



FST 1991 SOIL NITRATES
(ppm)
1-2 LIP-A
1-3 LIP-A
2-3 LIP-CG
3-1 CONV
3-3 CONV
Sufficiency level
Nitrates (ppm)
0
10
20
30
40
50
60
4/10
5/17
6/3
6/14
7/11
7/26
8/15
9/10
Date

Figure 3a. Water Infiltration Rate

SEPT 1990

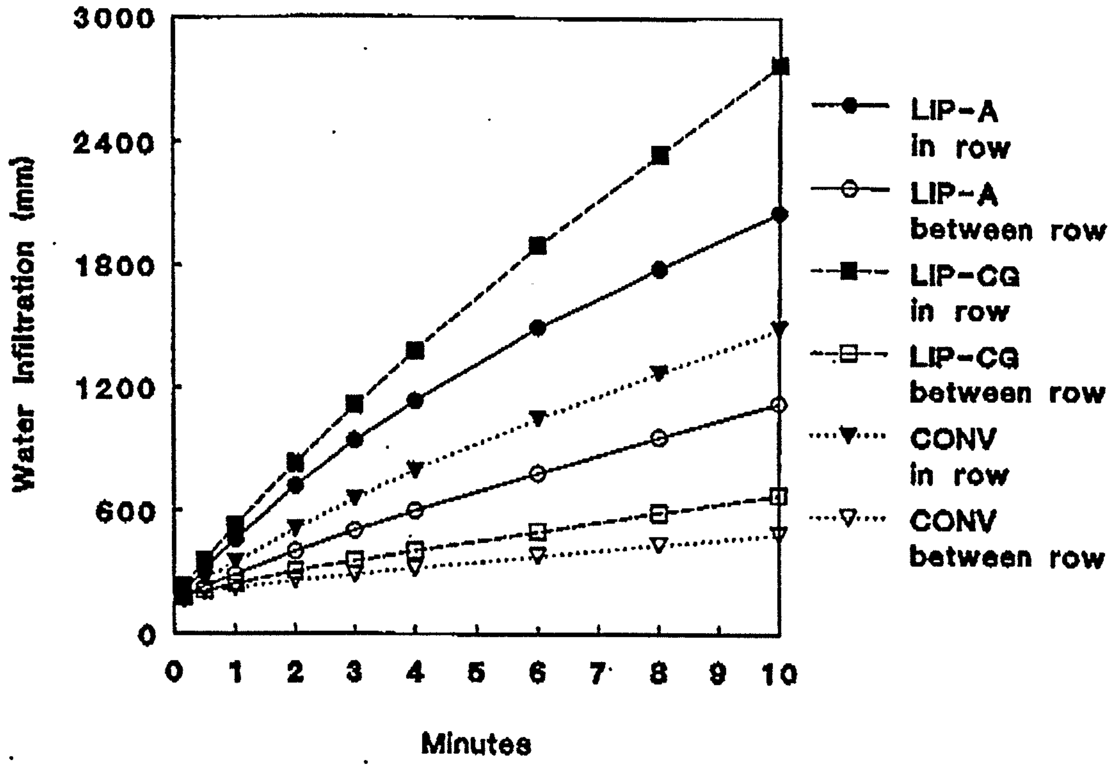


Figure 3b.

Cumulative water infiltration (mm)
FST, 1991

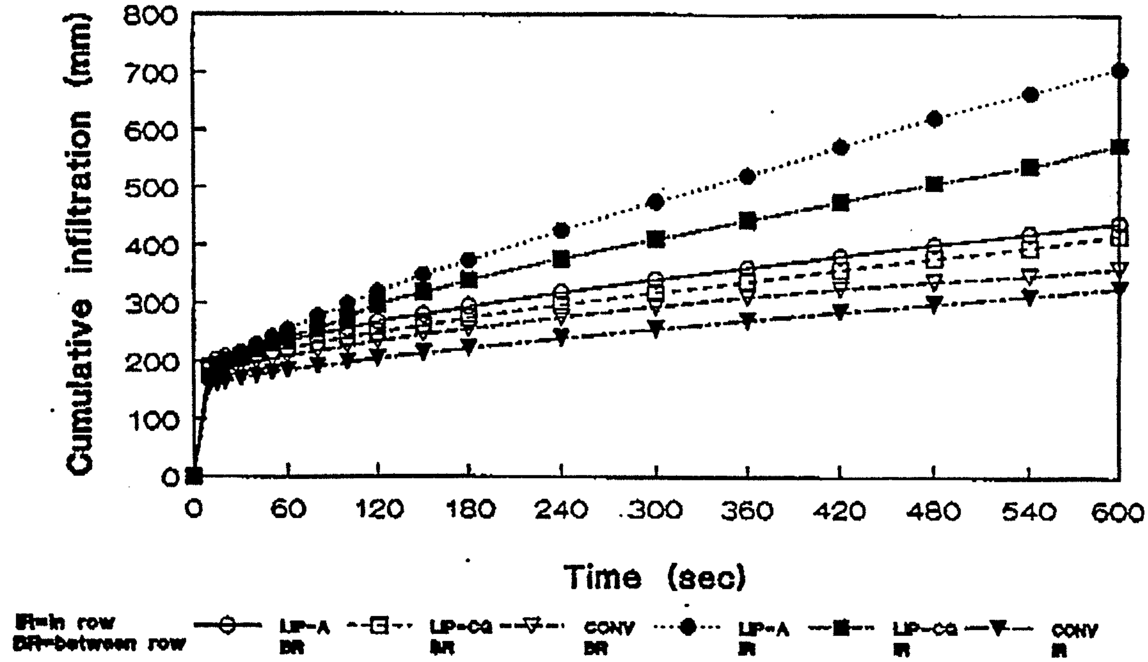


Figure 4. Annual Above Ground Residue Returns FST 1981-1990

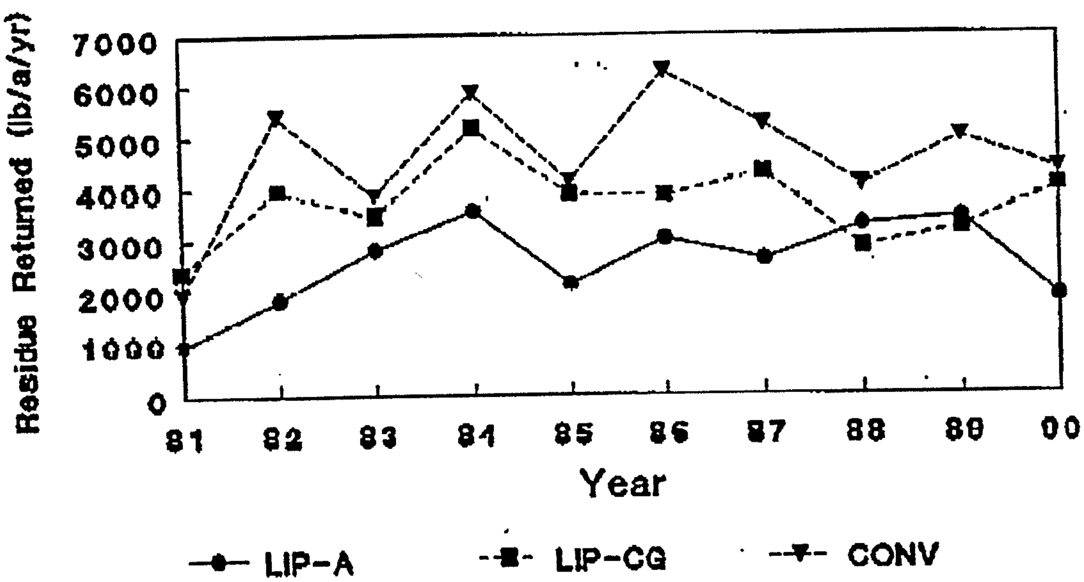
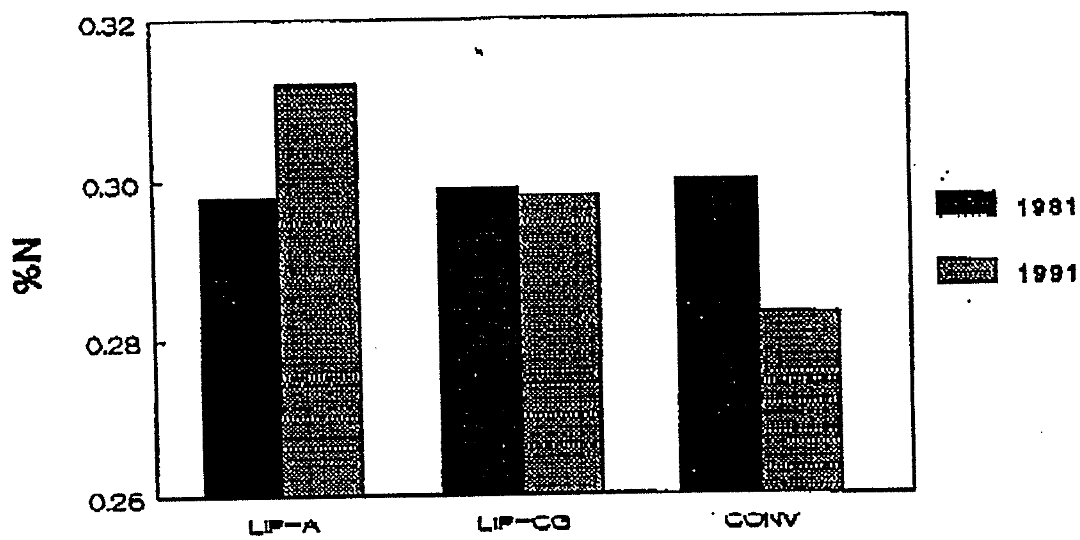


Figure 5.

Total Soil Nitrogen



1981 (0–10cm) from M. Wander
1991 (0–25cm) from J. Doran