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PAMI *Research Update*

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Sustainable Manure Management

Demonstration of Swine Manure Injection Technology

Over the past four years at 8 sites in three soil zones, PAMI has carried out demonstrations and research of a new technology to improve swine manure management. This technology has been developed in part by PAMI at Humboldt, Saskatchewan, in co-operation with many partners. Manure is applied to cropland by injecting it into the soil at controlled rates through a pump distribution manifold and injectors. This technology has advantages over other traditional systems that spray or dribble manure through the air and apply it to the top of the soil.

PAMI Manure Injection Research Truck.

Why Was The Technology Needed

Putting manure on the soil with an irrigation gun or truck and splash plate causes a release of ammonia and odour to the air. The manure must then be worked in by cultivation to prevent further ammonia loss. The ammonia loss is a loss of valuable nitrogen (N) nutrient. Research by PAMI and U of S demonstrated that even when working manure into the soil within 24 hours after application, large nutrient losses still occurred. Sometimes working in manure is delayed by equipment breakdown, an unexpected rainfall, or a heavy frost in cases of fall application. Any of these conditions can cause a risk to the environment as rainfall or snow melt can run off into surface water. Also, leaving the manure on the surface for an extended period increases the nutrient loss to the air. Odour released when doing surface application and manure storage agitation is one of the major odour sources from swine production and it annoys rural residents. Injecting the manure instead of surface placing it had the potential to eliminate some or all of these problems.

Splashplate injector system.

At A Glance

- The technology for manure application has advanced to allow low odour, sustainable application.
- PAMI has helped to develop and introduce the technology to industry.
- Most of the entire hog industry has adopted the technology in order to provide lower odour, sustainable manure management.

What Technology Existed

As early as 1990, some manure was being injected but it was done through large hoses behind openers on a cultivator or a tool bar behind a tanker truck. Openers were often on a 3 ft spacing. While effective in getting the manure on the land, there were problems. Manure was often left uncovered due to a high volume being applied in a narrow row. This caused an odour problem and there were large amounts of manure in rows with none between the wide rows. This caused uneven crop maturity and no studies had been done to measure effectiveness. The outlet hoses were large to accommodate straw and debris, and the distribution of manure between hoses may not always have been accurate. Some operators were placing manure at very high rates as this kept the cost of application low. There seemed to be little testing of the manure to determine its nutrient value. Many in industry knew it was possible to test for nutrients, but they did not know how to use the information to determine a correct or sustainable application rate. The economics involved with first year crop damage were not usually accounted for in planning application rates.

Odour was seen as an unavoidable problem.

The Technology Development Phase

PAMI and partners became involved in a number of technology development projects to solve some of the swine manure management problems. Odour control of manure storages (EMS) was addressed by research from 1990 onward to develop an economic means to cover lagoons. Basic research with different inexpensive floating materials was carried out and good quality barley straw was found to be an effective means of controlling odour for up to 2 months after application.

Although PAMI had found a way to control odour, there was no easy means to apply the straw to a manure storage (EMS). To solve this problem, PAMI entered in to a cooperative project with Highline Mfg. Inc. to develop the "Top Gun". Straw covering is now considered to be an effective means of eliminating odour from the manure storage. Research is still ongoing to find a less costly means of odour control that requires even less management effort.

High disturbance injection - effective but not always the best method.

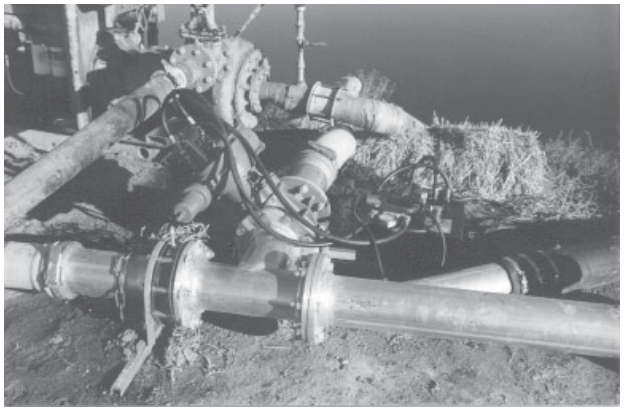
Floats in place on a liquid cell - a method that does not work.

Straw being spread on a lagoon with a "Top Gun".

The Highline Mfg. Inc. "Top Gun".

Projects were carried out to improve the control of irrigation-type pipelines through development of remote radio control systems. These control systems would facilitate a pump shutdown in case of leaks, and could be used to reduce flow at headlands to prevent over-application. While successful, this technology innovation has not been put to use in modern drag systems.

New technologies using the hose system from storage to the umbilical system are now common. The hose has some advantages and is more user-friendly to install and take up than a pipeline. Powered hose reels allow placing hose with less manpower than pipe systems and are cleaner to handle.

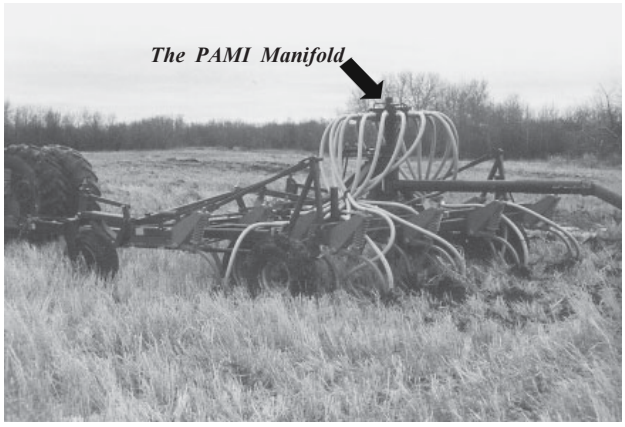


Experimenting with remote pump control.

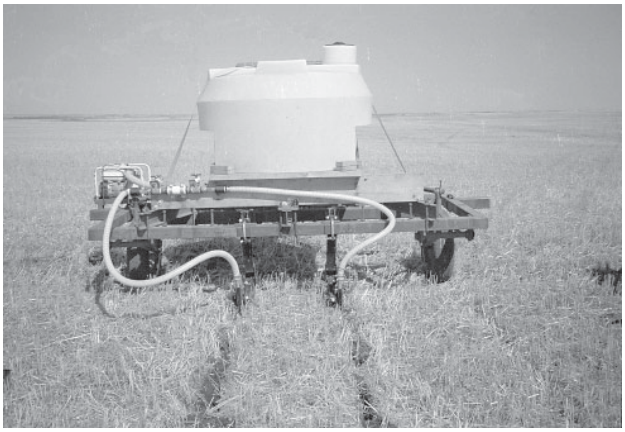
Manure Injection Opener

The problem with distribution to narrower row space and the handling of straw and debris was solved by PAMI and others by developing better distribution manifolds and using chopper pumps to shorten debris.

Manure injection openers for low disturbance work were in demand to allow injection into reduced tillage fields as well as into pasture, grassland, and possibly even into growing crop. Low disturbance injection would make more land available for manure application, reduce the incentive for operators to over apply to a limited land base, and would increase the potential number of sites for barn establishment. PAMI developed a low disturbance opener for manure injection in cooperation with Bourgault based on the Bourgault mid-row bander, and Bourgault is now marketing the system. Other coulter type injectors have also been introduced to the market. Some of the injectors are low disturbance and some are medium disturbance.



PAMI manifold distributor demonstration.



Testing of low disturbance openers.

PAMI/Bourgault Low Disturbance Manure Injection Opener.

Manure Sampling

Manure sampling studies were carried out to find simpler and safer ways of taking samples. While more work is needed, a number of simple sample methods have been found which work well.

Sampling a non-agitated storage prior to pump-out involves some planning. Samples taken from a non-agitated storage can be used to estimate the nutrient content that will be available when the storage is agitated. Several methods have been used that are relatively successful. In all cases with sampling of manure storages, appropriate safety policies must be followed. *The Pork Producers Guide to Managing Swine Manure* available from SaskPork has more information on the various methods.

Soil sampling for nutrient analysis.

Demonstrating the Technology

This project was a demonstration project involving research and demonstration sites in six different areas of the province. Other PAMI and Uof S Department of Soil Science manure injection sites were also used to enhance demonstration opportunities. Over the four years, an extensive effort of field days, press releases, articles, and publications were used. The demonstrations transferred new manure management technology to the hog industry, demonstrated its benefits, and acquainted the public with the enhanced protection of the environment available and the lower odour levels that could be expected.

In part, this project can claim to be responsible for the current level of adoption of manure injection into soil as a standard in the industry and the use of low disturbance injection when required. The public has become better informed and much of the objection to the hog industry due to odour from manure application has been eliminated.

A number of related projects were used in demonstrations to provide a more complete view of manure land application, and its technical progress and demonstration. One such

Tubular sampling.

A simple bucket sampler can be made to collect samples.

Showing the public the results from manure injection.

project was the Gray Soil Zone Manure Injection project, which was developed and funded by the Agri-Food Innovation Fund (AFIF) as an extension of this project and allowed the technology to be shown in areas where hog production is not as prevalent. The research results achieved and demonstration records have been collected from several areas of the province over several years. This report documents the advancement of manure management technology, its adoption by the hog industry, and the increase in public understanding over the past few years.

As stated previously, PAMI's swine related research began in 1990. The research started with respect to reduction in odour and improvements in equipment. It has recently been focusing on land application of manure in various cropping scenarios and the effects on crop growth and nutrient levels in the soil, as well as greenhouse gas emissions.

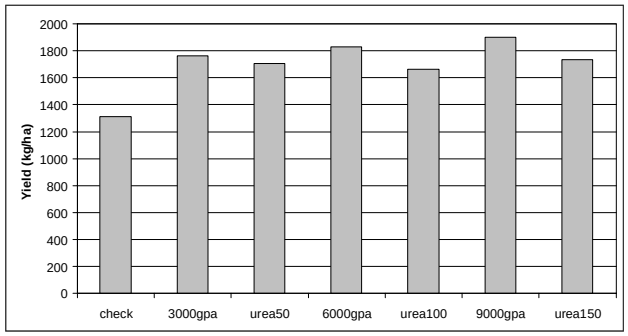
Some research results were obtained directly from this project, but because of limited multi-site replication, the test results in themselves are not statistically reliable, but they do, in nearly all cases, confirm the multi-site replicated research results. In particular, the projects done at Beechy, Riverhurst, and Eagle Creek were large-scale tests, which are often of more interest to producers, but did not provide data which could be directly compared to other research site data.

Research results from all sites confirmed results from replicated scientific manure research done at baseline sites with the exception that manure injection at St. Denis never produced equal results to urea application. Differences between sites and crop rotations make the demonstration site data difficult to use for direct scientific analysis.

These and other PAMI research and demonstration projects were done as a cooperative venture between PAMI, PFRA, Agriculture and Agri-Food Canada, the University of Saskatchewan Department of Soil Science, the Wheatland Conservation Area, the Kelvington ADD Board, and other organizations. These other organizations have all actively participated in ongoing extension activities with respect to hog manure management. In particular, the Saskatchewan Agriculture and Food initiatives to organize tours of research areas have helped this project and have greatly increased public awareness because of increased press participation. This and similar projects informed all of the hog industry of the potential of better manure management techniques.

Demonstration at Kelvington – PAMI and the Kelvington ADD Board

The demonstration at Kelvington was done in cooperation with the ADD Board. The manure-use demonstration, in this area of the province, has continued on a year-to-year basis with the East Central Research Foundation. In the first year, 3,000, 6,000 and 9,000 gpa of swine manure were injected with low disturbance injectors and results were compared to the application of urea at comparable rates of N. Manure was applied with and without sulfur application to balance the N:S ratio for canola. Yield response to manure in these canola plots was as good as to urea but the results of application of sulfur were inconsistent and higher rates of manure were of no benefit in this one-year test. The demonstration was well attended and local farmers were impressed with the response to manure.



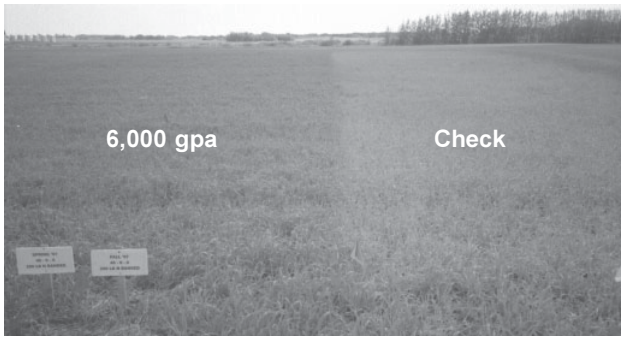
Kelvington yield results (canola).

Demonstration at Swift Current – PAMI and Wheatland Conservation Area Inc.

In this demonstration, both high disturbance and low disturbance injection systems were used. Yield protein and 1,000 kernel weights were monitored. The 3,000, 6,000, and 9,000 gpa rates of manure application with both opener systems were compared to urea at 50 lb/ac, 100 lb/ac, and 150 lb/ac actual N. Both high and low disturbance checks were used. Durum wheat was seeded in both 1999 and again in 2000 without further nutrient application. In 1999, in all cases, hog manure out yielded urea, and at all rates higher levels of protein were found with manure than with urea. Higher levels of hog manure or different disturbance type of opener did not translate into higher yield. The 1,000 kernel weights showed no difference from manure over fertilizer results.

In 2000, the low rates of application from the fall of 1998 did not appear to have provided any carryover. The two higher rates of manure produced excellent yields higher than the carryover from the highest rate of urea. The low disturbance injection performed better than the high disturbance (more carryover of nutrients) with higher yield and protein.

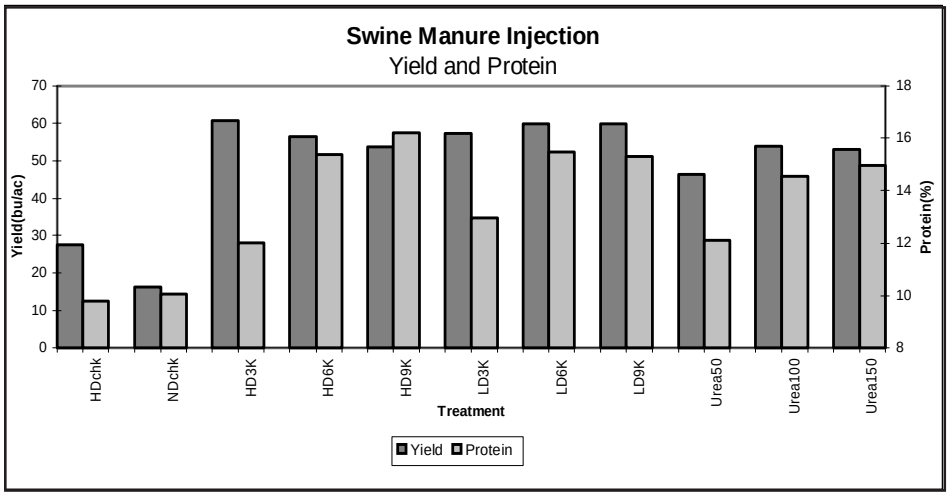
In 2001, a follow-up year, the study was continued to assess the carryover effect on barley and peas. Apparently there was either enough residual N from manure carryover at the 9,000 gpa rate to still limit pea production or the high yields of 1999 and 2000 exhausted all moisture reserves and the pea crop suffered as a result. Nodulation studies did not indicate that N level was a problem for the pea crop but it may have been. In any case, barley still had a positive response from carryover N but the pea yield decreased with increasing N application, even though it had been applied three years previously. The 2001 year was very dry, which may have contributed to this result. Other studies have shown that the carryover from a 9,000 gpa application to a third year crop is unusal.



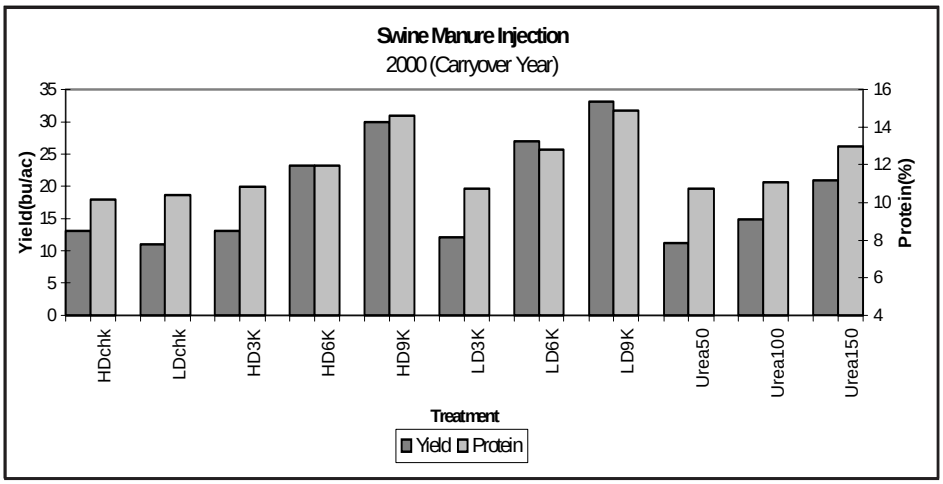
The benefit of manure application was clearly visible.

Table - Effect of manure application treatment on crop in 2000.

Treatment	Yield (bu/ac)	Protein (%)
Low Disturbance – 9,000 gpa	33.3	14.8
High Disturbance – 9,000 gpa	29.7	14.5
Low Disturbance – 6,000 gpa	26.5	12.8
High Disturbance – 6,000 gpa	23.1	11.9
Urea – 150 lb/ac	20.5	12.9
Urea – 100 lb/ac	15.1	11.1



Results In The Year Of Application At Swift Current.



First year of carryover benefit at Swift Current.

Field day participants - 1999.

Farmers are eager to obtain first hand information.

Demonstration at Rosetown (Beechy, Plenty, Riverhurst and St. Denis) – PAMI and Eagle Creek Stock Farms Ltd.

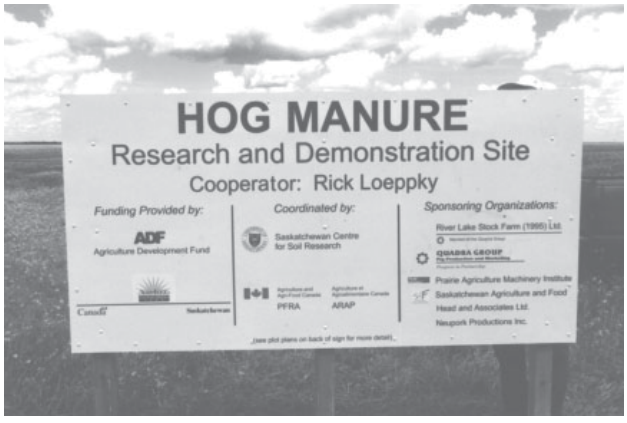
This demonstration was organized by the PFRA Rosetown and Quadra Management Group through Eagle Creek Stock Farms Ltd. and involved four Quadra barns in full-scale demonstration of hog manure on sites between 80 and 105 acres. Three treatments were applied: manure with no commercial fertilizer, no manure but fertilizer to soil test requirement, and manure with supplemental fertilizer as per soil test. Manure application rates were between 5,500 and 8,100 gpa.

In 1999, good growing precipitation produced above average yields with significantly higher yields on manure sites in three out of four locations, and increased protein at Beechy and Eagle Creek.

In 2000 and 2001, much drier conditions at Beechy, Plenty, and Riverhurst resulted in below average yields. The Riverhurst site was fallowed in 2001 due to very dry conditions. Little difference in yield or protein ocurred at any site. At St. Denis, the fertilized treatment always yielded more than the manure treatment, but the reason for it is not known, though sulfur added to the fertilizer for canola may have benefited the fertilized results. The manure applied to St. Denis did have a lower nutrient content than at other sites.

Soil sampling showed that in the very dry years, some nutrients remain after three crops. There was concern that some nutrients may be moving downward and that deeper rooting crops may be needed to extract them. This illustrates that a two year application rate may ensure more efficient uptake than a three year rate and deeper rooted crops such as perennial forages may sometimes be needed to recover deeper nutrients where prolonged drought after application prevents crop usage of the nutrients.

A modern high disturbance manure injection truck injecting plots at Rosetown.

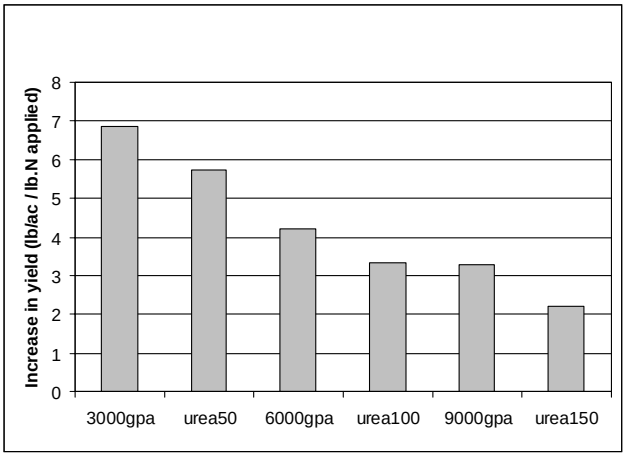


A sample of the signs used at demonstration sites.

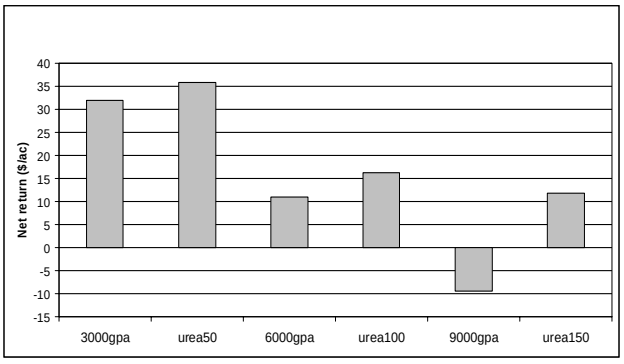
Economic Analysis

The results from the St. Denis site were found to be different than the results, costs, and returns at any other site. The cause is not known, but since it was the only site where urea outperformed manure in all years suggests that either a unique soil, manure, or water availability condition occurred.

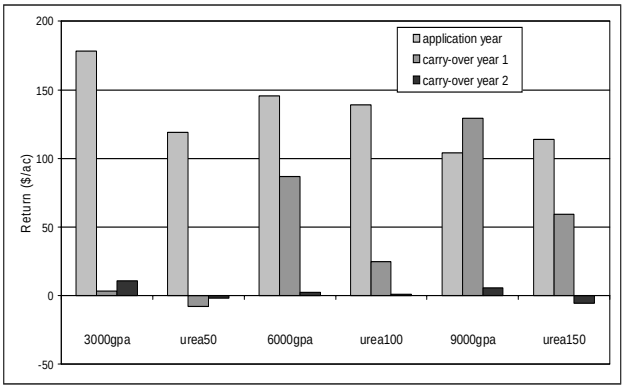
The variance in data sets between each site prevented an overall economic analysis of all sites. Some site experiments were one year, some three years, and all sites were using different crop rotations. In general, crop response to manure N exceeded crop response to urea N at all sites except for pea crops in the third year after fertilization at Swift Current. For whatever reason, the higher the manure application rate in 1998, the lower the pea yield in 2001. Barley still showed a positive yield reponse so it is likely that N carryover had reduced nodulation in peas, although nodulation surveys did not indicate this. The following graph shows the economic returns calculated from the limited results where they were comparable.



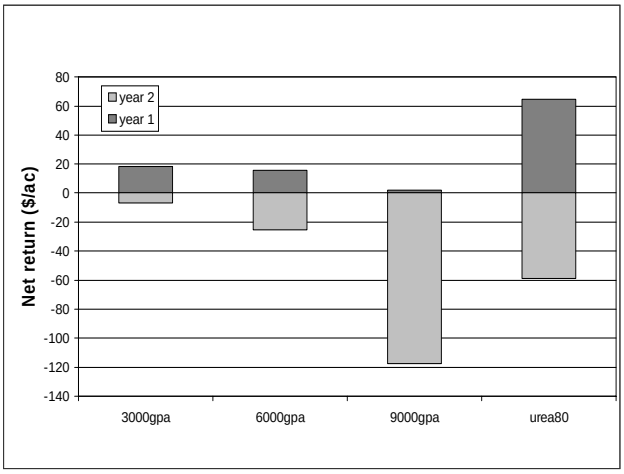
Crop response - year 1 average yield increase in lb/ac / lbN applied over check of manure and fertilizer treatments at Kelvington, Swift Current, Melfort, and Loon Lake.



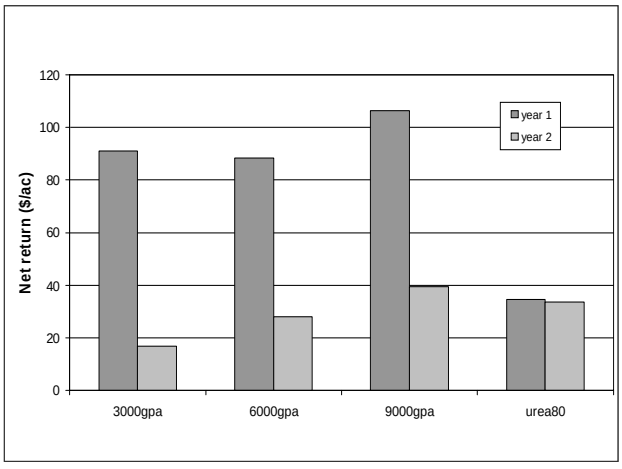
Net return at Kelvington in year 1 from manure and fertilizer applied.



Net returns at Swift Current over three years from a single manure or fertilizer application.



Net returns at Melfort over two years from a single manure application of 6,000 and 9,000 gpa, and annual applications of urea 80 lb N/ac and 3,000 gpa.



Net returns at Loon Lake over two years from a single manure application of 6,000 and 9,000 gpa, and annual applications of urea 80 lb N/ac and 3,000 gpa.

Industry Advancement

Since PAMI has been involved in hog manure demonstration and research, several unknowns have been answered. The industry in general and the general public have become more knowledgeable and more confident about manure application and utilization. The following is an overview of the advancement that has come about because of this and similar research and demonstration projects.

Odours: Many different approaches have been previously used to apply hog manure to crop land, and many resulted in a large degree of odour release. Most of these used either irrigation guns or trucks with spreaders, which spread the manure on the surface and then worked in. A lot of odour was generated and nutrients were lost. It is now common practice that manure is injected below the soil surface. When this is done properly, there is virtually no odour released. The reason for injection is primarily to prevent loss of N, but a very important secondary result is the reduction of odour. Another benefit of injection is that concerns of surface runoff due to heavy rain or spring snow melt are addressed. High disturbance injection systems have been improved to allow higher application rates without plugging or odour release. In response to the increase in direct seeding, low disturbance injection systems have also been developed.

The umbilical injection system at work.

These systems have now been demonstrated to the public and have been adopted by industry. Since it is now understood that odour release can be virtually eliminated when applying manure to the land, minimum odour has become a public expectation. Some surface application is still being done, but it is decreasing rapidly. As well, straw covering systems to reduce manure storage (EMS) odour are being used by many barns as a means of reducing odour in the vicinity of the barn. Where needed because of local residences, this and other cover types have been proven to be an effective solution.

Another manure storage covering method.

Manure Nutrient Levels: It has always been known that manure contains nutrients that are beneficial to crop growth, in particular N. Because of the vast numbers of manure samples taken during this and other research, the quantities and variability of nutrients is better understood. Although sampling at each barn is still required, enough is known about manure nutrient levels and their crop availability that the manure can be applied confidently to obtain the desired crop response.

Wheat response to swine manure application.

PAMI has been involved in work to determine better sampling methods. Current work has focused on education of the need to carry out nutrient analysis prior to determining application rates and this is now well accepted in industry. Better means of measuring N levels at time of application are needed and work is ongoing in this area. The current delay to get lab results means producers have to test ahead of application time and this is often forgotten until it is too late. On-site samples can provide a good indication, but may not always be accurate.

Crop Response: It was well known that when manure was applied to crop land, the crop yield increased. It was also known that when too much manure was applied, crop lodging could be a problem and cause losses.

Crop lodging due to excessive manure application.

A lot of work has now been done to increase understanding of crop response to hog manure application and its relationship to commercial fertilizer. Because of the amount of research done in this area, it is now accepted that most crops will respond similarly to hog manure and urea (when applied at similar levels) and that carryover into subsequent years does occur. More carryover of manure N does occur, as it is not all plant available in the first year. This carryover is dependent on application rate, crop nutrient usage, growing season weather, and other factors, but many of these factors are now understood and good estimates can be made. Researchers have assembled a good basic knowledge of crop response to hog manure and have disseminated this information to users to help them determine manure application rates and crop nutrient requirements. Some initial examination as to the best incorporation of manure strategies with crop rotation and the effect of manure on plant disease and crop quality has also been done. While these are not serious concerns, more work is needed in this area.

Long Term Application Effects: Because not much detail was previously known about manure application and crop response in general, little was also known of the long-term effects of repeated manure application. The public was justified in having questions and concerns about nitrate movement through soil and into water sources based on situations gone wrong in other jurisdictions. For this reason, some of the research done in the past few years has been specifically designed to address these concerns.

The long-term baseline studies have had manure applied at higher than normal rates for successive years in order to examine nutrient movement in the soil. The results from this research indicate that if manure is over applied in one location for many years, it could potentially cause groundwater problems, as was noted in other jurisdictions. While it was known that many of the problems in the other areas were at least partially due to very high levels of rainfall, it was not known how our dry climate would affect N movement. However, this and other research has also shown that based on the information to date, if manure is applied at a sustainable level, there is little or no risk of groundwater problems. The sustainable level is defined as the level at which the crop will utilize the nutrients applied. Even a rate sufficient for three crop years will generally not move down through the soil profile, but the carryover of benefit to the third year is very poor. Therefore, an application rate this high is generally not of economic benefit. The third year's nutrients cause crop lodging in year one and the nutrients are lost to the atmosphere before year three arrives. Again, this information has been made available to the hog industry and potential manure users to help maintain a sustainable rate of manure application by the hog industry in Saskatchewan.

Other Factors: Besides measuring manure nutrient levels and crop yields, other important items have been investigated and continue to be investigated. The effect of land application on manure microbes is being investigated on more than one site. Also, the effect of manure application on greenhouse gas release is being studied. These two items have been included as a part of long-term studies, as it was seen to be a proactive approach that the industry could take to assure the public that manure is being handled in a sustainable manner.

Application on Different Crops: Manure was traditionally applied only to annual crop land, and mostly in the spring or fall, as only high disturbance soils openers were available. Surface application was also sometimes done and, when land was frozen or heavy rains occurred, the manure could not be worked in.

Manure injection into pasture grass.

This often led to public concerns with odour and surface water contamination. Because of the increases in continuous cropping and direct seeding, other types of low disturbance openers have been developed. These openers make more crop land available to receive manure. Other research has been done to investigate manure application and re-

Forage grass reponse to low disturbance injection.

sponse on grassland and in alfalfa. Some consideration must be given to higher nitrate levels in grass, which can be produced when applying high levels of manure. This is especially important when the manure application on grassland is followed by drought conditions.

As well, research is underway to determine if post emergent injection can be used to effectively boost protein in wheat or barley. Results have been excellent in a normal year but were disappointing as may be expected during the 2001 drought. These types of opportunities will make even more land available for manure application and, therefore, reduce the risk of over applying to a given plot of land because no other land is available.

June 27 injection into AC Barrie wheat at 3,000 gpa.

Low disturbance post-emergent injection of swine manure.

Effect on the Media: When the expansion of hog production began, the public's concern with the unknowns caused quite a lot of media attention. Many of the questions could not be answered because no local information was available. In many cases, this lack of information was used as a reason for the public to assume the worst. During this time, the media were asking industry and research personnel for stories and information, and getting the media interested in the hog industry was an easy task. It was viewed as a "news-worthy" story that captured the public's attention.

Considerable research has now been done and there are scientific answers to many of the public's questions. The media has been informed of the information via press releases, trade shows, technical presentations, and tours. Thanks to the media who have been very receptive to putting out the research results. This approach has been so effective that public concerns with hog industry expansion have greatly diminished.

The research community has been effective at carrying out appropriate research, advancing the technology, and lessening the level of public concern. Events such as the Walkerton, Ontario, tragedy reinforces the need for sound technology, sustainable manure management, and effective technology transfer to industry. A vigilant industry must ensure that technology is developed and used to ensure public health and safety. Opportunities for growth in the Saskatchewan hog industry can only be fulfilled if the public is properly protected and informed, and this project has served to fulfill both of these needs.

Just a few of many headlines from various newspapers across the prairie provinces.

For more information on hog manure call PAMI and ask for:

- Research Update #698 - Hog Lagoon Odour Control
- Research Update #729 - Pipeline Manure Injection System
- Research Update #730 - Swine Manure Mangement Methods
- Research Update #732 - A Slurry Injection System For An "Off-the Shelf" Cultivator
- Research Update #744 - Low Distrubance Liquid Manure Injection
- Research Update #751 - Is Swine Manure Injection Into Alfalfa Stands a Good Idea?
- Research Update #753 - Will Injection of Swine Manure Into Grasslands Increase Yield?

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