COTTON RESEARCH AND DEVELOPMENT CORPORATION

FINAL REPORT

DAN 55C

AN INVESTIGATION INTO ANHYDROUS AMMONIA APPLICATION EQUIPMENT AND ITS POTENTIAL CAUSE OF STRIPING

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Project Number	:	DAN55C
Project Title	:	AN INVESTIGATION INTO ANHYDROUS AMMONIA APPLICATION EQUIPMENT AND ITS POTENTIAL CAUSE OF STRIPING
Field of Research	:	Crop management - development **Field Code** : 4.1
Organisation	:	NSW Agriculture
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Commencement Date	:	December 15, 1990
Completion Date	:	June 30, 1991
Objectives	:	

1. To develop a method for the measurement of mass flow of anhydrous ammonia fluid.
2. To determine the level of variability in output from the outlets of application rigs using either the "gas", "cold flo" or "liquid" processes (stage 2).
3. If indicated by stage 2 that the level of variability is unacceptable, modify/develop the application rig to ensure even distribution of N. This may include the development of a device for the continuous monitoring of the flow and distribution of anhydrous ammonia during application in the field (stage 3).

Due to the submission being made "out of season" and the subsequent delays in approval and funding, objective 3 was omitted from the program. However, research into other aspects of the this problem of "striping" were initiated in the areas of :

- using plant N and yield to determine evenness of uptake of NH_3,
- developing field detection systems for evenness of application

AN INVESTIGATION INTO ANHYDROUS AMMONIA APPLICATION EQUIPMENT AND ITS POTENTIAL CAUSE OF STRIPING

SUMMARY

Introduction

In February 1989, the NSW Agriculture Agricultural Engineering Research Unit (AERU) at Trangie ARC was approached by the Australian Cotton Growers Research Association (ACGRA) to address the problem of "striping" (a growth disorder due to lack of nitrogen fertiliser).

Striping was thought to be caused by either or both of the following two factors :

(i) soil compaction (or other damage)
(ii) poor anhydrous ammonia metering and/or distribution and/or application to the soil.

Striping due to compaction was seen to be very regular in the field (ie. confined mainly to the central trafficked rows of each pass) and as such was easily detected and separated from striping due to (ii), which was seen to be more widely distributed across each pass and more irregular within passes and fields.

In March 1989, at the direction of Don Saville (Regional Director of Research, Trangie), members of the AERU were requested to initiate investigations into the engineering aspects of anhydrous ammonia application. The high priority given to the topic of "fertiliser application", at the Engineering Priority Setting Workshop in February, 1990, highlighted the importance of such research.

The request for research assistance was two-fold:

1. To determine whether the striping problem is induced by either poor metering, distribution or application by existing anhydrous ammonia application systems.

2. To develop a monitoring system, regardless of the outcome of 1, to detect problems with present or future anhydrous ammonia application systems.

Mr Alan Palmer, Research Engineer, Mr Pat Weldon and Mr Roger Lund, Senior Technical Officers with the AERU, have assisted in both these aspects of the research.

Summary of results and benefits to industry

1. Measurements taken on an application rig whilst operating in the field, using primitive temperature and pressure transducers, suggest that mass flow of anhydrous ammonia in a conventional NH_3 system may vary between rows and also along rows, supporting the initial hypothesis.

2. Empirical calculations performed using this field data suggest that the distribution of the anhydrous ammonia in the manifold system is "driven" by the gas and therefore, due to the design of the manifold and its cast (unmachined) nature, represents a major problem in the accurate distribution of anhydrous ammonia.

3. The metering and distribution of the NH_3 is highly dependent on the pressure of the anhydrous ammonia before and after the meter and manifold. As these tank and line pressures are determined greatly by the ambient conditions and the selection (and location) of such criteria as hose sizes and lengths, more consideration should be given to reducing the effects of these dependent variables (eg. by increasing hose diameters and fitting set orifices to provide predictable back pressures on the manifold). To enable an understanding to be reached on the consequences of such actions, it is necessary to simulate (and control) typical field ambient conditions (temperature), replicate typical operating parameters (tank and line pressures, flow rates, form of NH_3 etc..) and equipment (meter type, hose length, hose bend radius, etc..).

4. Following discussions with research staff, metering equipment and anhydrous ammonia distributors and rig operators and a brief survey of application equipment, the conclusion was reached that the approaches used by operators varied substantially. Whilst great effort was made by the distributors to educate grower body management staff regarding set-up and operating procedures, the determination of the efficiency of application was highly dependent on the ability of the operator. As a result, a significant degree of the potential problems could be overcome by educating the operators, not just management staff.

5. Approaches to various occupational health and safety and noxious goods regulating bodies regarding the use of anhydrous ammonia suggest that little attention has been paid to the dangers associated with its use in (semi) enclosed environments. As such, this has required the installation of specific safety equipment and the setting up of specific operating procedures to minimise the hazards of working with this potentially lethal substance.

6. A technique, appropriated from USA via researchers in the wheat industry in Queensland, for the detection of NH_3 in the field was demonstrated at the Macquarie Cotton Field Day.

Difficulties encountered

1. The complete lack of experience with both anhydrous ammonia and the cotton industry by all AERU staff meant that the intricacies of the practices and products used in the industry were not well understood. To exemplify this problem, the ability to achieve various objectives was subsequently over-estimated due to a poor understanding of the safety requirements surrounding the use of NH_3 in an enclosed environment and the resultant extra input required to make the testing facility safe.

2. Difficulties were found in obtaining information from supply organisations on potential technology and methodology for the measurement of various properties of anhydrous ammonia. Many suppliers were not keen to work with this difficult product, with the result being that much of the research equipment was either very expensive (through low demand) or had to be designed from the ground up.

3. The history of development and use of this product and associated technology shows that very few companies have been willing to experiment with it with subsequent retarded improvement in technology.

Recommendations for future research

1. The results of this research indicate that there is sufficient evidence to suggest that both metering and distribution equipment could be significant contributors to poor application of anhydrous ammonia and hence the problem of "striping". Further research is required to substantiate and quantify this and to also recommend on possible means of alleviating this problem.

2. Substantial improvements in the efficiency of current practices could be made if :

   (a) more attention was given to setting up equipment according to recommendations;
   (b) more effort was directed to educating operators of application equipment in the important aspects of calibration, safety and operation. This has proven difficult in the past due to the itinerant nature of the operators.

3. Safety standard regulations regarding the use of this product are stringent in Australia with the resultant impact being a high safety record in the industry. However, with increasingly stringent Occupational Health and Safety regulations and the concern that a "familiarity breeds contempt" attitude prevails in parts of the industry, a continued effort should be made to educate/remind users of this product of its potential dangers.

4. A simple and inexpensive method of determining the location in the soil of applied NH_3 has been appropriated. This method however will need further work to establish its potential advantages in determining such problems as improper application levels (leading to striping), improper placement (leading to toxicity) in relation to plant roots or unacceptable losses (due to inappropriate tool selection or operation or improper soil moisture).

Budget Summary

	Salary $	Travel $	Operating $	Capital $	Total $
1990/91					
Original	0.00	2100.00	14451.00	12288.00	28839.00
Actual	0.00	1656.10	18152.40	9030.50	28839.00

Note : A "capital" allocation of $3538 was made for the purchase of a "voltage reference source". This device was able to be secured within the Department and hence this allocation was transferred into "operating".

Publications arising from the project

Research Papers - in preparation

1. Weldon P.A and Gould N.S. The development of a mass flow measurement technique for anhydrous ammonia, Agricultural Engineering Australia

Advisory Communications

2. Gould, N.S. (1991) Anhydrous ammonia application equipment - engineering research, NSW Agriculture and Fisheries : Cotton Irrigator No 10, May 1991, pp 9-10

DETAILED REPORT

Project : An investigation into anhydrous ammonia application equipment and its potential cause of striping

The issue of striping is vexed, with argument split as to the causes of this supposedly serious problem. A survey conducted in conjunction with the Macquarie Cotton Growers Association's Field Day in March 1990 clearly established this issue as high priority. However, meter suppliers in Australia and manufacturers overseas were less than convinced that their metering and distribution systems were at fault and that striping was indeed a major industry issue, especially in the northern cotton growing areas.

The Agricultural Engineering Research Unit (AERU), in clearly identifying how to effectively research this issue, split the problem areas into three categories :

1) metering and distribution

: the effect of poor control of mass flow rate and distribution on the amount of NH_3 actually delivered to individual rows,

2) application and retention

: the effect of form and concentration of N on the ability of the soil to retain it without significant losses,

3) soil characteristics and plant uptake

: the effect of soil compaction or other impediments on root growth and nutrient availability.

Initial research by the AERU was directed at category 1 issues and included both measurements of an existing anhydrous system (at Auscott, Warren) and empirical calculations, in an effort to determine the approximate state of the anhydrous throughout the application system and therefore the important variables which determine how the metering and distribution systems work. It was postulated that, due to the unusual results of initial calculations, it was highly likely that users of anhydrous ammonia were not aware of the true state of the fluid as it was being applied.

<u>Field measurements</u>

Temperature and pressure measurements were taken at the manifold, and at the top of 2 shanks. These measurements, whilst taken with equipment of less accuracy than desirable, suggest that :

(a) manifold pressure is a large degree less than that expected (from information supplied by John Blue Co).
(b) due to the decrease in the fluid temperature from the manifold to the top of the shank, the anhydrous ammonia must still be "flashing off" ie. changing from liquid to gas, as it progresses down the line.
(c) both the temperatures and pressure (ie. mass flows) are variable along the runs.

More accurate and prolonged measurement is needed to determine whether this variability is real, induced or inherent error in measurement.

Empirical calculations

The calculations determined that :

(a) in the manifold approximately 0.16 of the fluid's mass is in the vapour state,

(b) as volume (NH_3 gas) = 239 x volume (NH_3 liquid), from (a), the NH_3 gas occupies 38.3 times that occupied by the liquid.

(c) the pressure loss from the tank through the meter to the manifold could be as high as 55 psi (given application rates of 150 kg N/ha and ambient temperatures of 85 F (30 C)).

(d) the pressure loss from the manifold to the top of the shank could be as high as 30 psi.

These results suggest strongly that :

(i) the distribution of the anhydrous ammonia in the manifold system is "driven" by the gas and therefore, due to the design of the manifold and its cast (unmachined) nature, represents a major problem in the accurate distribution of anhydrous ammonia.

(ii) the metering and distribution of the NH_3 is highly dependent on the pressure of the anhydrous ammonia before and after the meter and manifold. As these pressures are determined greatly by the ambient conditions and the selection (and location) of such criteria as hose sizes and lengths , more consideration should be given to reducing the effects of these dependent variables. (eg. by increasing hose diameters)

In an effort to address some of these problems and also the request to monitor flow and/or distribution of NH_3 continuously in the field, the engineers determined that the NH_3 should be kept in either an "all liquid" state, or "all vapour" state, so that flow measurement equipment could be used.

To achieve an "all liquid" state would be to move in the direction of "cold-flo" (which still contains some 15% of its volume as vapour at the point of application) or alternatively to the newly released Dickey-john system which is supposedly (stated but not proven) "all liquid" at the point of measurement of flow rate.

To achieve an "all vapour" state would result in a number of complications. Firstly, taking an average situation of applying 150 kg N/ha at 8 kmh using an 8 row x 1 metre spacing application rig, would require approximately 1500 kJ/min heat to convert all the liquid into vapour. This amount of energy represents most of the heat developed by a D8 Caterpillar engine's cooling and exhaust systems (working at maximum power), which would need to be redirected to a heat exchanger located on the application rig; a major logistical and engineering problem. Secondly, the volume of NH_3 vapour being applied at any one moment in time is immense. It is believed that therefore there would not be enough capacity in the soil to bond all the N without major losses. Three potential advantages of this system would however be (a) the soil fragmentation (rupturing), (b) the reduction of draft due to the release of this high velocity (approximately 265 kmh) vapour, and (c) the even distribution of the gas across the rig and into the soil.

Field operation simulation

To enable field conditions to be simulated, a facility has been developed at Trangie which, through containment in a coolroom, is able to generate air temperatures of 0 - 41 °C. Hence tank pressures of up to 1500 kPa (218 psi) and flow rates of up to 2268 kg N/hr (5000 lbs N/hr) can be tested. The various metering devices used by the cotton industry (ie "gas" (Continental and John Blue meters) "Cold-Flo" (Crop King BIG N bottles) and "liquid" (Dickey-john)) can be placed within the facility and tested for metering and distribution accuracy.

Temperature and pressure transducers are being developed to enable the measurement of mass flow rate. These temperature and pressure measurement devices and a mass measurement transducer will be incorporated in the facility, with the ultimate purpose of providing the ability to calibrate metering mechanisms for the entire industry on a regular basis. (This service is currently provided by Incitec. Due to the assumptions made, their process could provide inaccurate results, which has been the experience of many growers in the field.)

Two different thermocouple systems are being developed to overcome the potential problems of dynamic thermal effects, generated by movement of fluid past the sensor.

Through the measurement of temperature and pressure, it is hoped that a relationship can be developed between mass flow rate and these variables. An understanding of the density of the fluid and the ratio of liquid to vapour can also be reached using a enthalpy-pressure chart.

Industry situation

Investigation into the problem of striping and the proportioning of cause to various potential problem areas led to a very mixed variety of opinion to both the importance and the cause of striping. However, one problem was very evident, that is a lack of understanding of the importance of the dangers associated with the use of NH_3. Industry standards have been sufficiently high to not generate the string of fatalities that have seen the great reduction in its use in the USA. These standards need to be maintained and the general understanding of the toxicity of this product lifted before unfortunate incidents occur.

Lack of information on plumbing of liquid and gas lines and means of reducing blockage problems in these lines was also mentioned as an industry problem. Lack of recognition of the importance of having the meter level on the machine at all times and the distribution lines of equal length was also noted.

Field Detection System

A technique, appropriated from USA via researchers in the wheat industry in Queensland, for the detection of NH_3 in the field was demonstrated at the Macquarie Cotton Field Day. This technique, which has yet to be rigorously field tested, has the potential to inform growers of incorrect levels of application, improper closure of application slots or location in relationship to plant roots.

Additional Research

Greg Constable (Research Agronomist, Narrabri) suggested that whilst yields for various crops could be accurately predicted given known levels of N, no information existed on how adjacent rows of cotton (or other crops) with various amounts of N placed under them fought for that available N or the resultant crop yields.

An experiment to obtain this information was initiated at Narrabri in the 1990/91 season. This experiment included single rows of cotton under which various common levels of N were applied as granular urea. The treatments included nil N application, solid 150 kg N ha^{-1}, and striping of nil and 300 kg N ha^{-1} and 100 and 200 kg N ha^{-1}.

Results from this preliminary experiment suggest that the effect on yield is only very slight.

Subsequent research

Project No. : DAN59N

Project Title : An investigation into anhydrous ammonia application equipment and its potential cause of striping

The newly funded project of the same title, initiated in July 1991 and proposed to be completed in June 1994, addresses the following issues :

1) To fine tune the development of the mass flow measurement device and initiate determination of metering/distribution accuracies of each of the three methods used for application (gas, cold-flo, liquid). There are many unknowns in this process, much being dependent upon the ability to accurately determine relevant properties of the NH_3 in the lines. If a suitable technique can be developed, there will be scope to also establish a permanent commercial facility providing a service to growers for the testing and calibration of metering and distribution systems.

2) To determine and rectify possible faults in the metering and distribution systems. This will involve extensive discussion with both users and manufacturers.

3) To provide, if necessary, a long term solution to fault finding, through the provision of a on-board application rig monitoring system, comprising the mass flow measurement device in (1) and other electronic componentry. This device could also be designed to provide other benefits, such as in-field calibration, speed sensing, push-button flow rate selection and automatic flow control at the end of runs. To expedite this research, it is hoped to involve private agricultural electronic services in the development.

4) The calibration of the field detection system, which then can be passed on to advisory staff and selected growers for field verification before final release to the industry.

The issues of education with regard to safety and to meter set-up and operation will not be formal aspects of the research and advisory program, although these topics may be discussed with growers and associated bodies during deliberations relating to issues (1) - (4).