Anhydrous Ammonia, the Effect of Time, Rate and Technique of its Application in the Production of Sugar Beets

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Introduction

Though anhydrous ammonia has been used as a fertilizer on a commercial scale for more than twenty years its potentialities are just now becoming recognized throughout many of the eastern states. In consequence any discussion of its use would be incomplete without a brief description of the material itself as well as the methods of its use and the results obtained therefrom.

Anhydrous ammonia is composed of one part of nitrogen and three parts of hydrogen by volume. It is 82.25 percent nitrogen and 17.75 percent hydrogen by weight. At normal atmospheric temperature and pressure, ammonia is a colorless, pungent gas that boils at a minus 28° F. and freezes at a minus 107.9° F. Water has a great affinity for anhydrous ammonia, one volume at 32° F. absorbing as much as 1,020 volumes of ammonia. Soil particles have an even greater affinity for ammonia than has water, especially soils of a relatively high base exchange capacity.

Synthetic anhydrous ammonia was first produced here in the United States by the Mont Cenis modification of the Bosch-Haber process. In the process air was converted to liquid air by compressing and cooling. The liquid air was then fractionated into its component parts—nitrogen, oxygen, and the rare elements argon-zenon and krypton. Hydrogen was produced by the thermal decomposition of natural gas into its component parts, solid carbon and gaseous hydrogen. The purified nitrogen and hydrogen were then brought together in proper proportion under high temperature and pressure in the presence of a catalyst, with ammonia as the end product. More recently newer, simpler very high pressure processes have been developed which obtain the pure nitrogen and hydrogen by controlled burning of natural gas, the actual synthesis being carried out as in the Haber Bosch process.

Role of Anhydrous Ammonia in Soil

When placed in the soil anhydrous ammonia enters into the base exchange complex and there is held tenaciously. In fact, the penetration of ammonia in soil is inversely proportional to the base exchange capacity. Once fixed in soil, ammonia is tightly held and is available for direct plant absorption. The tightly held ammonia which is not used directly by the plant undergoes conversion to nitrate nitrogen by bacterial action and then will move with the soil moisture into the continually changing root zone.

The application of ammonia is carried out by either of two means, Nitrogation Service[2] or Nitrojection Service[2]. The Nitrogation Service as

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the name suggests is the application of ammonia by its absorption in irrigation water and the subsequent proper distribution of that water. The Nitrojection Service is the application of ammonia by its direct injection into soil, no added water being necessary.

Now let us consider the use of ammonia as a nitrogen fertilizer for sugar beet production, particularly the effect of time, rate and method of applications on the production of sugar beets or, more specifically, the production of sugar.

The Effect of Time of Application

The greatest increase of total sugar production has been shown when ammonia is applied in the early stages of plant growth. This is true whether application is by the Nitrogation or the Nitrojection Service.

With irrigation applications as shown in Table 1 a series of split applications was used. The first series reported includes two 75-pound per acre applications, a preplant application and an application at thinning time. The second series includes a 75-pound per acre application at thinning time and an application with the second regular irrigation.

Harvest data are reported in Table 1.

Table 1.—The Effect of Time of Ammonia Application (Nitrogation Service).

Woodland, California — Yolo Clay Loam Soil		
Treatment	Tons Beets/Acre	Lbs. Sugar/Acre
Check	13.14	4,861.80
75 lb/A—Shell NH_3—Pre-irrigation and 75 lb/A—Shell NH_3—First regular irrigation	15.28	5,011.84
75 lb/A—Shell NH_3—First regular irrigation 75 lb/A—Shell NH_3—Second regular irrigation	13.78	4,657.64

It will be noted that sugar production increases were obtained with the first series of split applications and that while the second series of applications increased the total tonnage of beets produced, the total sugar produced was below that of the check. Later experience has shown that by delaying harvests a few weeks even the later-fertilized beets matured and sugared up as fully as did the early-fertilized beets.

With direct applications of ammonia, pieplant applications may be made without the necessity of a preplant irrigation provided, of course, sufficient soil moisture is present.

In the direct injection experiments were included a preplant application of 75 pounds of ammonia per acre followed by a second application of 50 pounds per acre at thinning time to compare with a single preplant application of 125 pounds per acre. The harvest data from the experiment are reported in Table 2.

From the data in Table 2 it can be seen that no significant difference could be found between these two treatments and that very real increases of total sugar were realized with both treatments.

No applications late in the growing season were included in this series of experiments for earlier work had already proven them less effective.

Table 2.—The Effect of Time of Ammonia Application (Nitrojection Service)

Salinas, California — Salinas Clay Loam Soil		
Treatment	Tons Beets/Acre	Lbs. Sugar/Acre
Check	14.81	5,589.29
75 lb/A—Shell NH_3—Preplant		
50 lb/A—Shell NH_3—After thinning	20.43	8,662.92
125 lb/A—Shell NH_3—Single preplant application	21.06	8,605.11

The Effect of Rate of Application

Experiments designed to check the effect of rate of application were carried out in the Woodland area of California, using split applications of 100, 150 and 300 pounds of ammonia per acre. The harvest data are reported in Table 3.

Table 3.—The Effect of Rate of Ammonia Application (Nitrogation Service)

Woodland, California — Yolo Loam Soil			
Treatment	Tons Beets/Acre	% Sugar	Lbs. Sugar/Acre
Check	13.10	18.8	4,925.60
50 lb/A—Shell NH_3—May 12 and			
50 lb/A—Shell NH_3—June 2	14.90	19.7	5,870.60
75 lb/A—Shell NH_3—As above			
75 lb/A—Shell NH_3—As above	16.05	19.7	6,323.70
150 lb/A—Shell NH_3—As above			
150 lb/A—Shell NH_3—As above	16.90	17.7	5,982.60

While applications were made somewhat later than desirable on this series of experiments due to late spring rains, significant tonnage and total sugar increases were shown with the 100- and 150-pound treatments. The 300-pound treatments showed greater total tonnage increases but reduced sugar. With the present winter carryover and spring harvest practices gaining in favor in California these heavier rates of applications may prove interesting in that longer maturing periods may be possible which should permit the absorption of higher amounts of ammonia, its assimilation—and the translocation of the formed sugar back into the storage root.

The above experimental data which led to our recommendation of 150 pounds of ammonia per acre for commercial applications has been substantiated in successive years in all of California's beet-producing areas.

Two rather unique experiments were conducted to test the effect of very high rates of application in the Woodland area of California on Yolo Clay loam. In these experiments applications up to 750 pounds of ammonia per acre were made. The first experiment applied as a side dressing shortly after thinning produced rather amazing results. The harvest data are reported in Table 4.

The interesting fact shown in Table 4 is that application rates as high as 750 pounds per acre do not damage beet crops even when applied as a side dressing after thinning time provided, of course, that the ammonia is properly placed.

Table 4.—The Effect of Rate of Ammonia Application (Nitrojection Service)

Woodland, California — Yolo Clay Loam Soil			
Treatment	Tons Beets/Acre	% Sugar	Lbs. Sugar/Acre
Check	27.9	15.4	8,593.20
150 lb. NH_3/A At thinning time	36.1	13.0	9,386.00
450 lb. NH_3/A At thinning time	37.8	13.7	10,357.20
750 lb. NH_3/A At thinning time	35.6	14.3	10,181.60

A second experiment testing the effect of high rates of application was carried out the following year but differed from the first experiment in that the applications were made as pieplant applications. The harvest data are reported in Table 5.

Table 5.—The Effect of Rate of Ammonia Application

Woodland, California — Yolo Clay Soil			
Treatment	Tons Beets/Acre	% Sugar	Lbs. Sugar/Acre
Check	21.20	19.50	8,268.00
250 lb/A—Shell NH_3—Preplant	25.40	18.70	9,499.60
500 lb/A—Shell NH_3—Preplant	23.50	17.80	8,366.00
750 lb/A—Shell NH_3—Preplant	22.80	17.30	7,888.80

In this experiment it can be seen that tonnage was effectively increased with even the highest rates of application but a greater period for maturity was indicated with these higher application rates by the lower sugar at harvest time. Each increase in rate of application brought a decrease in sugar per acre by a lack of sugar translocation at the time of harvest.

Top Weight Versus Root Weight Relationship

The time and rate of ammonia application markedly influence the ratio of top weight to root weight in sugar beets. This ratio change is shown in Table 6.

Table 6.—Top Weight Versus Root Weight Ratio

Woodland, California — Yolo Loam Soil (Nitrogation)			
Treatment	Ave. Top Wt.	Ave. Root Wt.	Ratio
Check	.98 lbs.	1.45 lbs.	1—1.47
100 lbs./A—Shell NH_3—Preplant	1.10 lbs.	1.58 lbs.	1—1.43
50 lbs./A—Shell NH_3—Preplant and 50 lbs./A after thinning	1.15 lbs.	1.54 lbs.	1—1.34
75 lbs./A—Shell NH_3—Preplant and 75 lbs./A after thinning	1.52 lbs.	1.87 lbs.	1—1.22

In these data we have three comparisons: The first shows that fertilization increases the top growth in greater degree than it does the root growth. The second comparison shows that small split applications increase the top growth rates to a still greater degree than the root growth. Heavier split applications up to 150 pounds per acre increased top growth even more than do the lighter applications. The overall changes range from a 1 to 1.47 top-root ratio with the unfertilized beets to 1 to 1.22 with 150 pounds of ammonia in split application.

The Technique of Ammonia Application

In discussing the effect of time and rate of application of ammonia on the production of sugar beets we have referred frequently to Nitrogation Service and Nitrojection Service. These twin Shell patented processes are in reality two complementary methods of application. The Nitrogation Service is the method of applying ammonia by absorption in the irrigation stream and the subsequent proper distribution of the irrigation water. The Nitrojection Service is a method of direct injection of the ammonia into the soil without the use of irrigation. It may be practiced at any time of the year that soil may be cultivated.

The effectiveness of the Nitrogation Service method is governed to a large degree by the degree of care exercised in the control of the irrigation water. In areas where water is expensive and is carefully supervised, and a uniform irrigation is obtained, a very uniform application of ammonia follows. On the other hand, careless water supervision with excessive runoff will of course waste fertilizer.

Another factor of importance in the Nitrogation Service is the concentration of ammonia used. The greatest success has been achieved where concentrations of ammonia are not allowed to exceed 110 parts of ammonia per million parts of solution. This rate of applications will permit the application of 100 pounds of ammonia per acre with a 4-acre-inch irrigation. Application of more than 100 pounds per acre require the application of more than 4 acre inches of water for that irrigation or requires a split application with two successive early irrigations. At least one irrigation and preferrably two should follow the last application of ammonia at normal irrigation intervals to insure maximum utilization of the applied ammonia.

Simple metering equipment has been designed to control the flow of ammonia into the irrigation stream. It consists primarily of a flexible manifold to combine the flow from two or three ammonia cylinders, a single metering orifice, a device by which to determine the pressure of the ammonia in the tanks and a flexible hose to carry the ammonia from the metering orifice to the irrigation stream. With this simple meter the orifice may be changed to maintain uniform flows under changing temperature which causes changing pressure conditions.

The Nitrojection Service employs a similar metering principle as in the Nitrogation Service, but the ammonia is delivered underground instead of into irrigation water.

The actual injection is carried out by conducting the ammonia down the back of a specially designed cultivation shank and releasing it into the soil at a point 6 inches underground. Almost any type of cultivator equipment can be used for this work from row crop tractors for row crop application to large trailer injectors for open field preplant applications.

We mention that the shank is specially designed. It has a dual purpose: it ruptures the soil, increasing the internal pore space between soil particles, and it is self-sealing. Both features are important, the first because of the fact that a standard application of 100 pounds of ammonia per acre puts underground about 2 cubic feet of ammonia vapor for each linear foot of shank travel; the second because the ammonia is under pressure and unless the shank channel seals behind the shank, quickly, ammonia will be lost from the soil into the air.

Two methods of application are practiced as preplant application for sugar beets. The first and most widely used is the application in the rough list before bed shaping in bed-planted beets. If the planting is two rows per bed the injection is made in the bed center directly between the positions where the two beet rows will be planted. If the planting is a single row[7] per bed the placement is off center in the bed 4 inches or more from the point the row will be planted. This placement is necessary to insure that the tap root of the germinating beet will not grow immediately into an area of high nitrogen concentration and be injured; yet, it permits lateral roots to develop into the fringe areas of lower concentration, thereby assimilating nitrogen in the very early stages of growth.

Evidence of stimulation of the seedling at emergence time is not at all uncommon with both these methods of placement.

Where flat planting is practiced it is wise to make the ammonia injection at right angles to the direction the beet rows will be planted. This obviates the planting of an entire row—directly above the point of ammonia application, eliminating possible damage to an entire row if planted too close to the point of the injection.

In side dessing applications of ammonia by the Nitrojection method the injection is made as close to the growing beet as possible without mechanically loosening the beet in the soil or cutting more than 10 percent of the roots. Conditions usually permit the shank to travel 10 to 12 inches away from the beet row.

Application as close as possible to the growing beet using the above precautions is advisable in order that the beet roots develop in the fertilized area at an early date to permit early and complete utilization of the applied nitrogen.

Summary

1. Anhydrous ammonia applied by either Nitrogation Service or Nitrojection Service has been demonstrated to be an effective fertilizer for sugar beets.

2. One-hundred and fifty pounds of ammonia per acre is an ideal rate of application, but rates up to 750 pounds per acre have been used without injury to growing plants.

3. Ammonia should be applied in the early stages of plant growth, i.e., preferably a preplant application or as a split preplant-thinning time application.

4. Ammonia applications increase production of both tonnage of beets and sugar and also increase top growth, decreasing the ratio of top weight to root weight from 1:1.47 in unfertilized beets to 1:1.22 in beets fertilizer at 150 pounds per acre in split application.