NITROGEN FERTILIZERS AS HERBICIDES

by

RICHARD ALLEN PENCE

B. S., The Ohio State University, 1968

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1970

Approved by:

Major Professor

TABLE OF CONTENTS

INTRODUCTION

The effect of nitrogen fertilizers on seed germination has been the subject of many reports during the last 40 years. It was known that nitrogen fertilizers would reduce germination, therefore, many of the reports were concerned with fertilizer placement and the effect on germination. There were very few reports of nitrogenous fertilizers used as weed seed eradicating agents. However, DeFrance (8) reported in 1943 that these materials did have promise for use as herbicides.

Many of the reports indicated that ammonia, the ammonium ion, and ammonium hydroxide were toxic and would inhibit germination. Therefore, it appears that any nitrogenous fertilizer could be used as a soil sterilant, provided; 1) the material existed in one of the toxic forms or a toxic form was produced on decomposition, and 2) high rates were used.

Today various chemicals and fertilizers are successfully used as soil sterilants (6). They are applied in the preparation of seedbeds and in soil to be used for greenhouses and plantbeds. Examples of the many materials used include: methyl bromide, calcium cyanamide, Vapam, Eptam, Mylone, ammonium sulfamate, ammonium thiocyanate, and synthetic urea (Uramon). Most of these materials have the disadvantage of being expensive and/or they have a long residual toxicity to both plants and animals.

This study was designed to evaluate nitrogen fertilizers for use as temporary soil sterilants. The materials used were anhydrous ammonia, calcium cyanamide, and Aqua Uran.

LITERATURE REVIEW

A variety of nitrogen fertilizers are manufactured which contain nitrogen in the ammonia and/or nitrate form. Cyanamid and urea do not contain either of these forms (Cyanamid is a commercial product consisting principally of calcium cyanamide and carbon and contains a minimum of 20% nitrogen (9)). However, the nitrogen in both of these materials is soon changed to the ammonium form (2). Ammonia, nitrate, and ammonium have been reported to be toxic to plants (1,3,7,11,20,23,24).

Calcium cyanamide was the earliest manufactured nitrogen material in the United States. It is not a very economical form of nitrogen for commercial use since it is expensive to produce. It does have certain advantages, however. For example, it can perform as an effective weed killer in some instances and its calcium content helps to neutralize acid soils (18).

Volk (25) reported that cyanamid, upon absorption, was immediately effective in killing certain seeds. The normal reaction of moderate amounts of cyanamid, in the presence of adequate buffering acidity in moist soil, results in the formation of hydrogen cyanamide, which is toxic to plants (12,25).

Wilton and Carrol (22) found that an application of 20 lb/ 1,000 sq. ft. of cyanamid worked into the soil surface, gave fairly satisfactory control of many common lawn weeds. Maxton (13) reported cyanamid reduced germination of several crop seeds at 1,000 lb/A. Colby and Feeny (6) found some initial herbicidal activity at 1,000 lb/A, but there was no prolonged reduction in weed seed germination. Willis and Pilard (24) observed cyanamid at 75 lb/1,000 sq. ft. gave satisfactory inhibition of weed seeds, and the toxicity of the soil disappeared after six to eight weeks. Klingman (12) reported that ½ lb/sq. yd. was required to produce any herbicidal activity, however, at this rate a three week residual toxicity resulted. The residual toxicity varied depending on soil moisture, temperature, pH, and texture (12).

Repeated use of cyanamid at ½ lb/sq. yd. for weed control treatment for tobacco beds on light sandy acid soil resulted in a residual pH value of 7.8-8.0 (25).

Anhydrous ammonia is commonly used as a nitrogen fertilizer in the United States and several foreign countries. Although some has been used in irrigation water, it is mostly applied directly to the soil (1).

Mortland (14) found that the loss of anhydrous ammonia was negligible when applied at a depth of one to two inches, at a rate of 60 lb. of nitrogen/A and in a soil of intermediate texture, moisture content, and pH.

It was reported (16,17,19) that soil moisture influences the retention of ammonia. There was a small loss on a Putnam silt loam with 15-18% moisture regardless of depth of application, but the loss increased as the soil was drier or contained more than 18% moisture. When anhydrous ammonia was applied only three inches deep the loss was slightly higher from a wet soil (19). Losses on wet soils occur because of upward movement and evaporation of water. In dry soils there is probably a mass flow outward because of pressure (17).

Retention studies show that increasing the clay content of soil raises the capacity of soil to absorb ammonia. The greater loss in sandy soil correlates with low exchange capacity (19).

Soils composed of aggregates ¼-1 inch in diameter retain ammonia more efficiently than screened soil where all the particles were less than ¼ inch in diameter. Apparently the ammonia could move laterally and downward from the point of injection at a more rapid rate in the cloddy soil. Therefore, the ammonia could rapidly come in contact with more soil surface under cloddy conditions resulting in more efficient absorption (19).

More ammonia is lost when applied to an alkaline soil. It has been suggested that ammonia is absorbed in greatest quantities in an acid condition where there is a supply of hydrogen ions to react with ammonia (14).

Two types of losses can occur when more anhydrous ammonia is applied than the soil can absorb. A direct loss of ammonia may result or ammonium hydroxide will be dissolved in the soil water. The ammonium hydroxide is subjected to loss if the soil water is evaporated from the soil surface (19).

Andrews (1) reported that under field conditions, anhydrous ammonia was absorbed in a zone with a cross section having an area of about 16 square inches, when applied on a sandy loam soil, six inches deep, at a rate of 100 lbs. of nitrogen/A, in 42 inch rows. The movement of anhydrous ammonia injected six inches below the soil surface was much greater laterally and upward from the point of injection (19).

Anhydrous ammonia is the most active alkaline nitrogen fertilizer (2). The immediate soil response is a marked increase in soil alkalinity where the ammonia has been applied (1,2,16,19,20). The increase in alkalinity is only temporary as bacteria convert ammonia to nitrate and organic nitrogen compounds which are acid (1,3).

When applied to the soil, anhydrous ammonia reacts with water to form ammonium hydroxide. This diffuses through the soil solution until it comes in contact with sufficient clay or organic matter to form a clay-ammonium or organic-ammonium compound (1,2). Ammonium hydroxide will reduce the germination of seeds. However, seeds that do germinate in the presence of ammonium hydroxide will produce normal seedlings (7,10).

Experiments (11,20,23) indicated that ammonia will prevent germination. Hunter and Rosenar (11) found that the extent of injury to moist corn seeds or seedlings by ammonia, in a restricted atmosphere, was dependent upon the concentration of the ammonia. At higher concentrations the seeds become dark-colored and failed to germinate. At lower concentrations germination was apparently normal, but there was subsequent darkening of the tip, yellowing along the entire length, and exudation of a yellowish liquid from the radicle; this was accompanied by darkening of the coleoptile tip, cessation of growth, and eventual death of the seedling.

Anhydrous ammonia is being tested for other agricultural uses (2,21) including: 1) fusarium root rot control, 2) mold control for harvested fruits and nuts, 3) algae and water moss elimination in irrigation reservoirs, 4) insect and pest control in stored grains, seeds, and nuts, and 5) desiccation and defoliation.

Nitrogen solutions are nitrogenous fertilizers disolved in water (9). They are used primarily as liquid fertilizers for direct soil or foliar applications, or for addition to irrigation water (18).

Aqua Uran is a trade name of a 32% nitrogen solution sold by the Allied Chemical Company. This material contains 34.8% ammonium nitrate and 45.1% urea. These materials decompose into ammonium ions and nitrate (15). Both of these products are toxic to plants, but ammonium is probably more toxic than nitrate.

Cummins (7), reported that ammonium ions are formed when urea comes in contact with water. Brage <u>et</u> <u>al</u>. (3) found that 0.02 gram of dry urea in a petri dish would produce enough ammonium ions to stop the germination of wheat seed on a blotter paper medium.

A soil sterilant, as used in weed control, is any chemical applied to the soil which prevents the growth of green plants. The sterilizing effect is not permanent and the length of the residual toxicity will vary depending on the chemical used, soil texture, pH, and moisture (10,12). The materials are usually applied as gases, dry or in solution, and are usually incorporated into the upper two or three inches of the soil (6).

The herbicidal effects of any soil sterilant are determined by the following factors: 1) absorption of the chemical by the soil, 2) inherent toxicity of the chemical, 3) decomposition or chemical change tending to reduce the toxicity, 4) leaching of the chemical, 5) fertility, salt concentration, or reaction of the soil, and 6) species tolerance. Seldom does any one of the factors alone determine the results of the chemical treatment (6).

Klingman (12), reported methyl bromide can control all living plant, stem or root tissue, most seeds, nearly all insects, and most disease organisms. It is used for seedbeds of tobacco, flowers, vegetables, and tree seedlings. This material has to be applied under an air tight cover at a rate of one to two lb/100 sq. ft..

Vapam, Eptam, and Mylone are proprietary materials that should be sealed in by moistening the soil surface (6). Uramon, ammonium nitrate, ammonium sulfate, and sodium nitrate at rates of 100 lb/1,000 sq. ft. gave good weed control (6).

When using the above chemicals in preparation of turf seedbeds, a good practice seems to be early spring or summer treatment for fall seeding, or fall treatment for spring seeding according to Crafts and Robins (6).

MATERIALS AND METHODS

This investigation was carried out in two phases; 1) a greenhouse study using anhydrous ammonia and 2) a field study using anhydrous ammonia, Aqua Uran, and calcium cyanamide. All treatments were replicated and randomized in a split block design.

Greenhouse Study

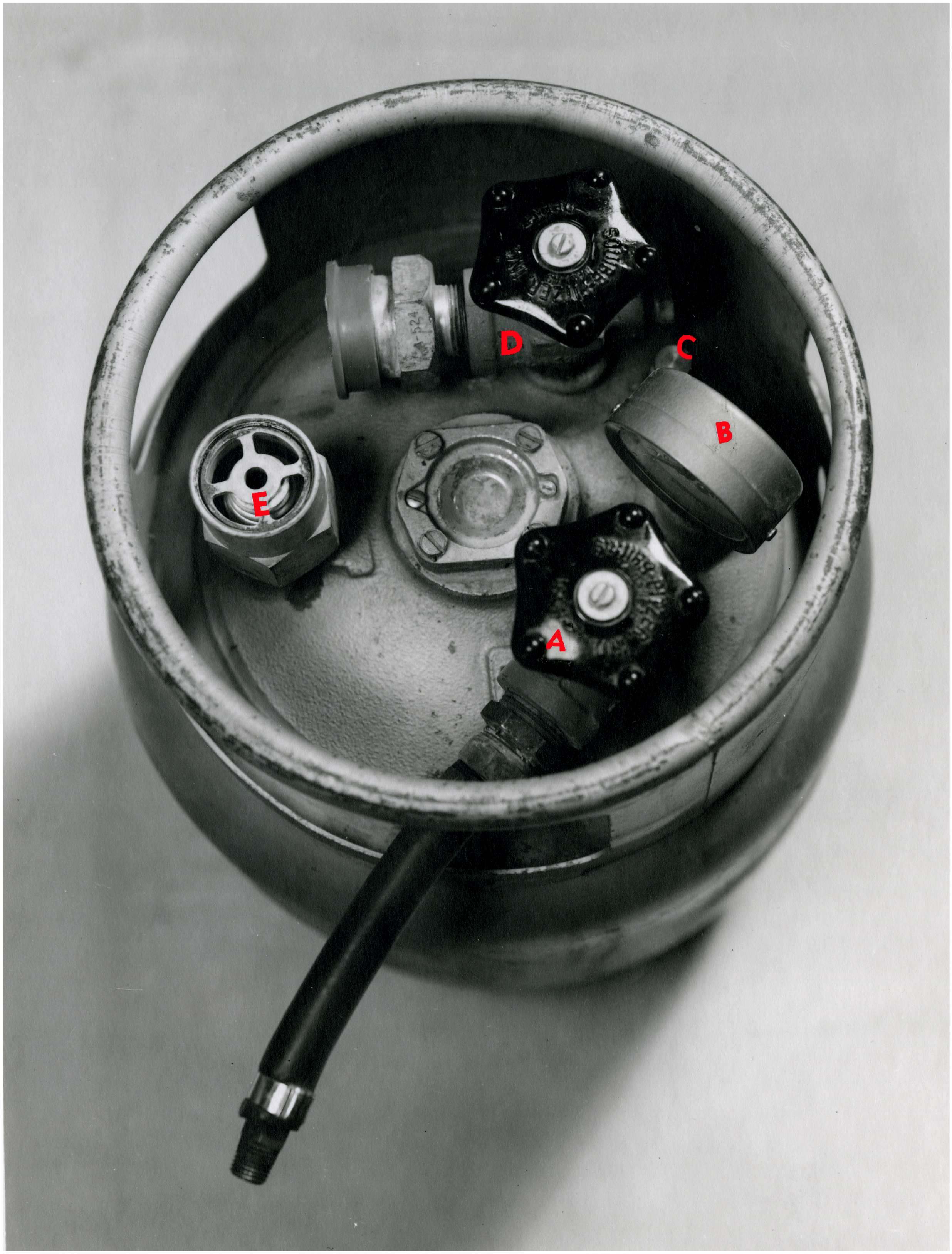
The first phase was initiated in April, 1969. Silt loam soil was collected from a weedy area, screened, and placed in a ground bed containing 46.8 cm of soil. The collected soil was spread in a 5.2 cm layer over the bed.

The ground bed was divided into plots measuring 1.26 M X 1.26 M with a 30 cm border between plots. Metal covers 1.26 M X 1.26 M X 10 cm were inverted and pressed into the soil, leaving a space of five cm between the soil surface and the top of the cover. An 18.8 liter butane tank was converted to a nurse tank (plate 1) to store the anhydrous ammonia. To obtain the desired rates of 0,225.8, 451.6, and 903.2 Kg of N/Ha the anhydrous ammonia was injected into a carbon dioxide capsule (plate 2) and weighed. The anhydrous ammonia was then released above the moist soil surface under the metal covers which were removed 18 hours after treatment.

At the time of treatment, crabgrass *Digitaria sanguinalis* (L.) Scop., seedlings were at the one-two leaf stage. After treatment the soil was kept moist to stimulate germination of

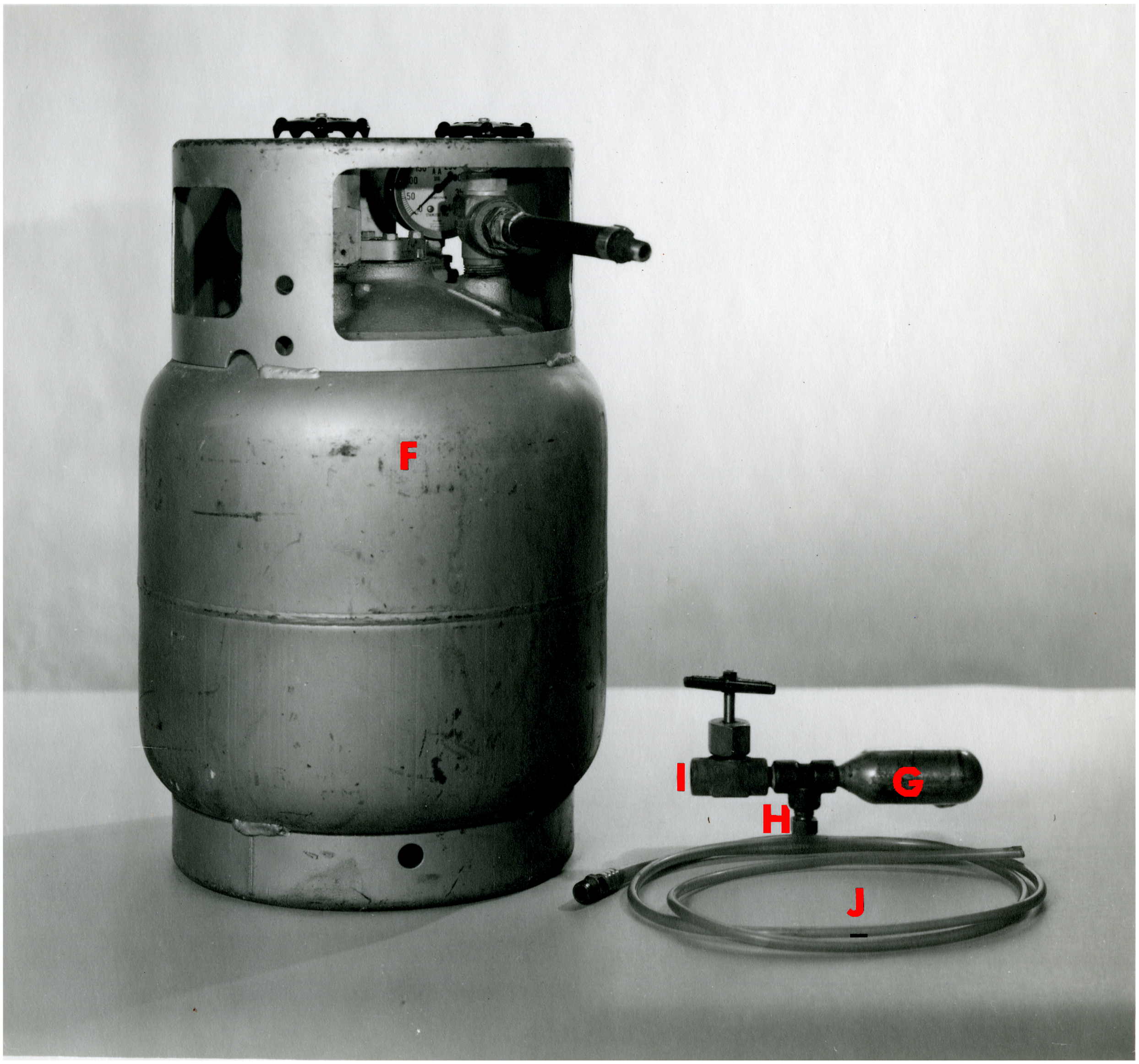
EXPLANATION OF PLATE I

The tank used to store the anhydrous ammonia. Modifications included: A. steel needle valve used to release anhydrous ammonia as a liquid, and also the tank was filled through this valve, B. pressure guage, C. Bleeder valve to determine when tank was 85% full, D. Steel needle valve used to release anhydrous ammonia as vapor, E. safety valve set at 350 psi.


D
C
B
E
A
524

EXPLANATION OF PLATE II

Equipment used to store and also apply the anhydrous ammonia. Anhydrous ammonia was forced as a liquid from nurse tank (F) into the carbon dioxide capsule (G). The carbon dioxide capsule has a saftey valve (H), and also a steel needle valve (I). Anhydrous ammonia was released from the capsule through the plastic hose (J) and into the covered plot.


F
I
H
G
J

weed seeds. Weed counts were taken from each plot one month after treatment. Because of the large number of weeds in the check plots, the weeds in one square foot were counted and from this the total number of weeds was estimated.

Field Studies

The second phase was initiated in July, 1969. Anhydrous ammonia, Aqua Uran, and Calcium cyanamide (table 1) were used at 0, 225.8, 451.6 and 677.4 Kg of N/Ha. Plots were 1.26 M X 1.26 M with a 30 cm border between plots. The soil was a silt loam.

Treatments were made to existing bluegrass Poa pratensis (L.) sod infested with dandelions Taraxacum officinale (Weber), and crabgrass. Also treatments were made to a tilled silt loam soil with no existing vegetation. The sodded area was mowed at 2.5 cm and verticut to a soil depth of one cm. All debris was removed before treatment. The soil area was tilled to a depth of 10.2 cm then hand raked to remove the larger clods.

Anhydrous ammonia was applied in the same manner as in the greenhouse study, except .005 inch plastic sheets were used instead of metal covers to cover the soil surface. The plastic was held two inches above the soil surface with 15 X 15 cm mesh concrete reinforcing wire. The cover was removed 15 hours after treatment.

Diluted Aqua Uran was applied with a sprinkling can. To the desired amount of Aqua Uran two liters of water were added to obtain better coverage of the plots.

Calcium cyanamide was applied as a dry granular material and then watered in. The desired amount was spread over the plots with a shaker can.

Bluegrass, tall fescue (Festuca elatior L.), and bermudagrass (Cynodon dactylon (L.) Pers.), were seeded in strips 37 cm X 147 cm in each plot two days after treatment.

Sod injury data were collected on four different dates and germination data were collected once on the sod area. The sod injury was rated by the following scale:

9 =	91 - 100%	Sod Killed
8 =	81 - 90%	" "
7 =	71 - 80%	" "
6 =	61 - 70%	" "
5 =	51 - 60%	" "
4 =	41 - 50%	" "
3 =	31 - 40%	" "
2 =	21 - 30%	" "
1 =	11 - 20%	" "
0 =	0 - 10%	" "

Grass germination was also rated on a 0 - 9 scale with the percentage approximating the amount of germination. Weed counts were taken four times in the tilled soil area, however, no grass germination data were taken because the plots were partially destroyed by vandals.

A second soil area was treated in August, 1969. The treatments were made in the same manner as in the first soil area. Bluegrass, tall fescue, and bermudagrass were seeded in 37 cm rows on three different dates. The first seeding was made 18 hours after treatment, the second seeding 10 days after treatment and the third seeding 20 days after treatment.

Grass germination data (0 - 9, 9 = best germination), were collected 10 days after each seeding and weed counts were made on September 2 and September 26.

Soil samples were taken one month after treatment at one, two, and three inch depths to determine the effect of the treatments on weed seeds at these depths. The soil samples were placed in 9 X 12 cm plastic pots in a greenhouse to determine if any germination would occur. Weed counts were made one month after the samples were taken.

Additional soil samples were taken at one, two, and three inch depths one month after treatment to determine the pH and total amount of nitrogen. Nitrogen determinations were made by the steam distillation method of Bremner and Keeney (4).

Table 1. Fertilizers used in this study.

Material	% Nitrogen
Anhydrous ammonia	82 %
Aqua Uran	32 %
Calcium cyanamide	21 %

RESULTS AND DISCUSSION

Greenhouse Study

The purpose of this study was to determine the effect of anhydrous ammonia on germinating weed seeds. The weed seeds present were crabgrass, ivy-leaved morning glory Impomoea hederacea (L.) Jacq., and pigweed Amaranthus retroflexus (L.).

The crabgrass seedlings, which were at the one-two leaf stage at the time of treatment, were killed within 15 hours when treated with anhydrous ammonia at 225.8, 451.6, and 903.2 Kg of N/Ha. In the plots treated with 451.6 and 903.2 Kg of N/Ha germination of weed seeds (table 2) was greatly reduced, however, germination of weed seeds in the 225.8 Kg plots was only slightly reduced. The weed seed germination in the 225.8 Kg plots indicated the higher amounts of nitrogen did reduce germination and the lack of weeds present was not entirely due to the initial vegetation killed.

Table 2. The mean number of weeds per plot in the greenhouse study one month after treatment.

Kg of N/Ha	Mean Number of Weeds
0.0	10,000.0
225.8	353.3
451.6	2.6
903.2	0.0

Field Studies

The primary purpose of the field studies was to determine whether anhydrous ammonia, Aqua Uran, and calcium cyanamide would kill existing vegetation and prevent the germination of weed seeds in a tilled soil with no existing vegetation. The secondary purpose was to determine the residual toxicity of the materials.

Vegetation Study. This study indicated that anhydrous ammonia at the rates used was the only material that killed the vegetation. Therefore, the data from the Aqua Uran and calcium cyanamide plots were not analysed.

The main significant effect (table 11) on the variation in the amount of vegetation killed was accounted for by the amounts of nitrogen. All vegetation (table 3) was not killed with 225.8 Kg of N/Ha. Significant regrowth was noticed by September 2, and by September 18 there was about 50% regrowth of vegetation in these plots. This vegetation regrowth was primarily bluegrass and dandelions, which were present at the time of treatment, however, only the tops were killed and regrowth from the roots resulted.

There was no difference between the 451.6 and 677.4 Kg of N/Ha in the amount of vegetation killed. In fact, there was only minimal regrowth of vegetation throughout this study following these two rates of nitrogen in the ammonia form.

Table 3. Sod killed as a result of rates of nitrogen and the interaction rate X date of observation

Rate Kg of N/Ha	Date Observed Aug. 7	Aug. 18	Sept. 2	Sept. 18	Mean
0.0	0.00	0.00	0.00	0.00	0.00
225.8	8.25	7.25	6.00	4.25	6.44
451.6	9.00	9.00	8.75	8.00	8.69
677.4	9.00	9.00	9.00	8.50	8.88

L.S.D. .05 Rate 1.13 Rate X Date 2.68

Means based on a scale 0-9 (9 = 91 - 100% Kill).

Grass Germination in the Sod Plots. Grass germination data from the vegetation plots treated with Aqua Uran and calcium cyanamide were not analysed because no germination was observed. The lack of germination was probably due to the competition of the existing vegetation and not due to the treatments since no germination occurred in the untreated plots.

Variation in grass germination (table 12) was mainly due to the amount of nitrogen and the grass species. All plots to which anhydrous ammonia were applied had more germination than the check plots (table 4), however, the 451.6 and 677.4 Kg of N/Ha plots had less germination than the 225.8 Kg of N/Ha plots.

As the amount of nitrogen increased the germination of tall fescue and bluegrass was reduced, however, bermudagrass germination was not affected by the amounts of nitrogen used (table 4). Tall fescue germination was better than bluegrass germination following the 451.6 Kg rate of nitrogen, but there was no difference between these two grasses at 225.8 and 677.4 Kg of N/Ha.

Table 4. Grass germination on the sod plots as affected by rates of nitrogen, grass species, and the interaction rate X grass.

Rate Kg of N/Ha	Grass Species			Mean
	Bermudagrass	Tall Fescue	Bluegrass	
0.0	0.00	0.00	0.00	0.00
225.8	8.25	6.50	5.75	6.83
451.6	7.50	4.00	1.50	4.33
677.4	8.50	.70	.75	3.33
Mean	6.06	2.81	2.00	

L.S.D. .05 Rate 1.18 Grass 1.02 Rate X Grass 1.18

Mean based on a scale 0-9 (9 = 91 - 100% germination).

Results of the Soil Area Treated July 31. Weed seeds present were crabgrass, pigweed, ivy-leaved morning glory, and velvet leaf *Abutilon theophrasti* (Medic.). Variation (table 13) in the number of weed seeds that germinated was caused by fertilizer, rates of nitrogen, dates the weeds were counted, and the interaction rate X date.

Anhydrous ammonia reduced the germination of weed seeds more than either Aqua Uran or calcium cyanamide (table 5). An application of 225.8 Kg of N/Ha did reduce germination (table 5) however, reduction in these plots was less than the 451.6 and 677.4 Kg of N/Ha plots. Increasing nitrogen from 451.6 to 677.4 did not significantly reduce germination.

Table 5. Mean number of weeds in the tilled soil plots treated July 31 as affected by form of nitrogen, rate of nitrogen and date of observation.

Form of Nitrogen	Mean Number of Weeds per plot
Anhydrous Ammonia	1.90
Calcium Cyanamide	2.97
Aqua Uran	3.31
L.S.D. .05 - .83	
Rate of Nitrogen	
0.0 Kg of N/Ha	4.85
225.8 Kg of N/Ha	3.48
451.6 Kg of N/Ha	1.35
677.4 Kg of N/Ha	1.22
L.S.D. .05 = .96	
Date of Observation	
August 7	.65
August 18	1.63
September 2	3.65
September 18	5.00
L.S.D. .05 = .96	

There was a significant reduction in the weed seed germination with the calcium cyanamide and Aqua Uran but it was less than the reduction caused by anhydrous ammonia at all rates of nitrogen used.

No barrier was placed around each plot therefore, the increase in the number of weeds at each date (table 5) was probably due to weed seeds washing or blowing into the plots and germinating. There was a significant increase (table 6) in the number of weeds in the 225.8 Kg plots by September 2, however, the increase was not significant until September 18 in the 451.6 and 677.4 Kg of N/Ha plots.

Table 6. Mean number of weeds in the tilled soil area treated July 31 as affected by the interaction rate X date.

Rate Kg of N/Ha	Observation Date			
	Aug. 7	Aug. 18	Sept. 2	Sept. 18
0.0	9.83	3.33	7.00	8.25
225.8	1.16	2.08	4.92	5.76
451.6	.25	.50	1.67	3.50
677.4	.33	.58	1.50	2.50

L.S.D. .05 = 1.92

Results of the Tilled Soil Area Treated August 12. The weeds present in this area were the same as those in the soil area treated July 31. The analysis of variance (table 14) for the number of weed seeds that germinated indicated the main variations were due to fertilizer source and rates.

All rates of anhydrous ammonia reduced weed seed germination (table 7). There was no difference in the reduction of weed seed germination between anhydrous ammonia and calcium cyanamide at 451.6 and 677.4 Kg of N/Ha. However, calcium cyanamide at 225.8 Kg did not reduce weed seed germination.

Aqua Uran at 677.4 Kg of N/Ha significantly reduced weed seed germination when compared to the 225.8 Kg plots, but the reduction was not greater than the 451.6 Kg or check plots (table 7). There was a slight increase in germination in the 225.8 Kg plots and this increase caused the reduction with 677.4 Kg of N/Ha to be significant.

Table 7. Mean number of weeds in the soil area treated August 12, as affected by forms of nitrogen, rates of nitrogen and the interaction of fertilizers X rates.

Rate Kg of N/Ha	Anhydrous Ammonia	Calcium Cyanamide	Aqua Uran	Mean
0.0	15.25	13.63	12.88	13.02
225.8	3.00	12.25	15.88	10.38
451.6	2.13	4.50	11.25	5.95
677.4	0.75	0.38	9.63	3.92
Mean	5.28	7.94	12.41	

L.S.D. .05 Fertilizer 2.75 Rate 3.18 Fertilizer X Rate 5.45

Grass Germination in the Soil Plots Treated August 12. The main effect (table 15) on grass germination was caused by the seeding dates. Germination of all grass species seeded 20 days after treatment was less than the germination on the first two seeding dates (table 8). The reduction was probably due to cooler soil temperatures and not a result of the treatments.

Anhydrous ammonia at 677.4 Kg of N/Ha reduced bluegrass germination (table 9). Bermudagrass and tall fescue germination were not affected by anhydrous ammonia at any of the rates of nitrogen used.

Germination of all grasses was reduced in the plots treated with calcium cyanamide at 677.4 Kg of N/Ha (table 9).

Bluegrass germination at this rate of nitrogen was significantly less than either bermudagrass or tall fescue.

Table 8. Means of grass germination in the soil area treated August 12, as affected by date of seeding.

Date		Mean
August 13	(18 hours after treatment)	7.10
August 23	(10 days after treatment)	7.04
September 2	(20 days after treatment)	4.60
L.S.D. .05	.45	

Germination rating based on scale 0-9 (9 = 91 - 100%).

Table 9. Mean grass germination in the soil area treated August 12 as affected by the interaction form of nitrogen X rate X grass.

Fertilizer	Rate Kg of N/Ha	Grass Species Bermudagrass	Tall Fescue	Bluegrass
Anhydrous Ammonia	0.0	5.91	6.33	7.66
	225.8	6.16	6.74	6.41
	451.6	6.83	7.74	6.83
	677.4	6.91	7.49	5.25
Aqua Uran	0.0	5.91	6.74	6.49
	225.8	7.66	5.60	5.60
	451.6	7.24	5.83	4.83
	677.4	6.49	6.41	5.49
Calcium Cyanamide	0.0	5.74	6.16	5.99
	225.8	6.83	7.16	6.66
	451.6	5.74	5.99	6.83
	677.4	4.02	5.82	2.03
L.S.D. .05	1.28			

Germination based on 0-9 (9 = 91 - 100%).

Bermudagrass germination was increased with Aqua Uran at 225.8 and 451.6 Kg of N/Ha and was higher than either tall fescue or bluegrass at these rates of Aqua Uran (table 9). Tall fescue germination was not reduced at any of the rates of nitrogen used, however, bluegrass germination in the 451.6 Kg of N/Ha plots was less than in the check plots.

Weed Seed Germination at Three Soil Depths. Differences in weed seed germination were not significant at the .05 level.

Results of the Soil Tests for Nitrogen. All treated plots contained more nitrogen than the check plots and nitrogen was most concentrated in the top inch of the soil (table 10).

The plots treated with anhydrous ammonia at 451.6 Kg of N/Ha had more nitrogen than the plots treated with 677.4 Kg of N/Ha, which indicates a loss of nitrogen when anhydrous ammonia was applied at the higher rate. The Aqua Uran plots had more nitrogen at all rates used than either anhydrous ammonia or calcium cyanamide. The calcium cyanamide plots had more nitrogen at 225.8 Kg of N/Ha than anhydrous ammonia, however, at the higher rates, the anhydrous ammonia plots had more nitrogen.

The Change in Soil pH. All materials used caused a change in the soil pH (table 10). The change was slight with anhydrous ammonia, and there was no definite pattern in the change caused by the different rates of nitrogen. Aqua Uran at 225.8 Kg lowered the pH slightly but the 451.6 and 677.4 Kg rates caused a sharp decrease in the soil pH. Calcium cyanamide raised the soil pH considerably, regardless of application rate.

Table 10. Nitrogen and soil pH at the different soil depths as affected by forms of nitrogen and rates in the soil area treated August 12.

Form of Nitrogen	Rate Kg of N/Ha	Soil Depth	pH	Nitrogen ppm
Anhydrous ammonia	0.0	1"	7.2	57.49
		2"	7.2	49.43
		3"	7.6	41.88
	225.8	1"	7.5	120.37
		2"	6.9	77.72
		3"	7.0	50.40
	451.6	1"	7.4	347.09
		2"	6.7	256.95
		3"	6.9	205.13
	677.4	1"	7.4	244.40
		2"	6.9	233.94
		3"	6.9	187.27
Aqua Uran	0.0	1"	7.6	95.28
		2"	7.5	69.56
		3"	7.4	49.68
	225.8	1"	7.4	112.86
		2"	7.2	109.31
		3"	7.2	94.04
	451.6	1"	6.7	345.31
		2"	6.4	339.64
		3"	6.6	234.23
	677.4	1"	6.7	476.53
		2"	6.4	299.18
		3"	6.4	283.21
Calcium cyanamide	0.0	1"	7.1	61.05
		2"	7.7	59.56
		3"	7.6	49.68
	225.8	1"	7.8	99.37
		2"	7.6	93.70
		3"	7.6	68.85
	451.6	1"	7.8	168.58
		2"	7.7	143.74
		3"	7.6	130.25
	677.4	1"	8.0	153.31
		2"	7.9	149.77
		3"	7.8	145.16

CONCLUSION

This study indicated that anhydrous ammonia at 451.6 Kg of N/Ha would kill existing vegetation and reduce weed seed germination. The 225.8 Kg rate did not produce the desired results and the 677.4 Kg rate did not give better results than the 451.6 Kg rate.

Vegetation killed by anhydrous ammonia may in part be due to desiccation, because ammonia reacts with the water in the tissues to form ammonium hydroxide. The same reaction may desiccate the seeds which would prevent germination.

Anhydrous ammonia appeared to have a very short residual toxicity because the grasses did germinate when seeded 18 hours after treatment. Bermudagrass germination was not affected by this material, however, it appears that tall fescue and bluegrass may be more susceptible to the high nitrogen residue and should not be seeded so soon after treatment.

Based on the amount of nitrogen in the Aqua Uran plots it appears that some nitrogen was lost at all rates of anhydrous ammonia, however, at 225.8 and 451.6 Kg of N/Ha the loss was minimal. The results of the change in the soil pH correspond with the results obtained by Andrews (1) and Brage et al. (3).

Aqua Uran at 677.4 Kg of N/Ha showed a minimum amount of herbicidal activity. Higher rates of this material would be needed to produce the desired results. The soil tests indicated that a very small amount of nitrogen was lost when this material was used. The decrease in the soil pH was due to the large amount of nitrates present (2).

Calcium cyanamide at 451.6 and 677.4 Kg of N/Ha had some herbicidal activity, but again, higher rates of nitrogen would be needed for use as a soil sterilant. This material reduced grass germination which indicated some residual toxicity, therefore, higher rates would be expected to cause a longer toxic period.

Soil tests indicated that the calcium cyanamide plots had less nitrogen than Aqua Uran or anhydrous ammonia plots. The nitrogen was probably not lost but was probably in the hydrogen cyanamide form and thus not distilled out in the nitrogen determinations. The increase in the soil pH would be expected since this material contains about 38% calcium (25).

This study indicated that nitrogenous fertilizers do have a potential for use as temporary soil sterilants. Considering the materials and rates of nitrogen used in this study, it appears that anhydrous ammonia has the most promise for this use. However, further studies are needed before they can be recommended for use as temporary soil sterilants.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to his major professor, Dr. Ray A. Keen, Department of Horticulture and Forestry, for his counsel, guidance, and encouragement throughout this investigation and in preparing this manuscript.

Special thanks to the members of the graduate committee, Dr. Ronald W. Campbell and Dr. Kurt C. Feltner for their careful review of this manuscript.

Thanks to Dr. Arthur E. Dayton and Fredric J. Deneke for their assistance with the statistical design and analysis.

To my wife, Sheila, I am extremely greatful for her patience and encouragement throughout this investigation and for the typing of this manuscript.

LITERATURE CITED

1. Andrews, W. B., 1956. Anhydrous ammonia as a nitrogen fertilizer. Advances in Agronomy 8:61-125.

2. Agriculture Ammonia Handbook. M-3-1963. Agriculture Ammonia Institute. 703 Dupont Building, 22 South Second Street, Menphis, Tennessee.

3. Brage, B. L., Zech, W. R., and L. O. Fine. 1960. Germination of small grain and corn as influenced by urea and other nitrogen fertilizers. Soil Sci. Soc. Am. Proc. 24:294-296.

4. Bremner, J. M., and D. R. Keeney. 1965. Determination of nitrogen by steam distillation. Analytica Chemica Acta. 37:485-495.

5. Colby, S. R., and R. W. Feeny. 1967. Herbicidal interactions of potassium oxide with calcium cyanamide. Weeds 15:163-167.

6. Crafts, A. S., and W. W. Robins. 1962. Weed Control, Textbook and Manual p. 55. McGraw Hill Company, Inc.

7. Cummins, D. G., and W. L. Park. 1961. Germination of corn and wheat as affected by various fertilizer salts at different soil temperatures. Soil Sci. Am. Proc. 25:47-48.

8. DeFrance, J. A. 1943. The killing of weed seeds in compost by the use of certain fertilizers and chemicals. Am. Soc. Hort. Sci. 43:336-342.

9. Dictionary of Plant Foods, Farm Chemicals. A Guide to Fertilizer Materials and Terms. Nitrogen Division, Allied Chemical Corporation.

10. Frans, R. E., Skogly C. R., and G. H. Ahlgren. 1956. Influence of soil type on soil sterilization with sodium arsenates. Weeds 1:11-14.

11. Hunter, A. S., and W. A. Rosenar. 1966. The effects of urea biuret, and ammonia on germination and early growth of corn. Soil Sci. Soc. Am. Proc. 3:77-81.

12. Klingman, G. C. 1961. Weed Control: As a Science p. 196-218. John Wiley and Sons, Inc.

13. Maxton, J. L. 1927. Effect of fertilizer on germination of seeds. Soil Sci. 23:335-341.

14. Mortland, M. M. 1958. Reaction of ammonia in soils. Advances in Agronomy 10:325-348.

15. Nitrogen is Not Necessarily Nitrogen. Agriculture Division, Allied Chemical Corporation, 2580 South 90th Street, Omaha, Nebraska 68121.

16. Papendick, R. I., and J. F. Parr. 1966. Retention of anhydrous ammonia by soil III; Despensing apparatus and resulting ammonia distribution. Soil Sci. 102-193.

17. Parr. J. F., and R. I. Papendick. 1966. Retention of anhydrous ammonia by soil II; Effect of ammonia concentration and soil moisture. Soil Sci. 101; 109-119.

18. Pratt, C. J., and R. Noyer. 1964. Nitrogen Fertilizer Chemical Process. Chemical Process Monograph, No. 4. Noyers Development Corporation. 16-18 Railroad Avenue, Pearl Rives, New York.

19. Stanely, R. A., and G. E. Smith. 1956. Effect of soil moisture and depth of application on retention of anhydrous ammonia. Soil Sci. Soc. Am. Proc. 20:557-561.

20. Stout, M. 1941. Factors effecting the germination of sugar beets and other seeds with specific reference to the toxic effects of ammonia. Jour. Agri. Res. 63:687-713.

21. U.S.D.A. Agriculture Research. 1969. Anhydrous ammonia, a control for root rot. January 17:11.

22. Welton, F. A., and J. C. Carrol. 1941. Control of lawn weeds and the renovation of lawn. Ohio Agri. Exp. Sta. Bull. 619.

23. Willis, L. G., and W. H. Rankin. 1930. Free ammonia injury which concentrated fertilizers. Ind. and Eng. Chem. 22:1405-1407.

24. Willis, L. G., and J. R. Piland. 1931. Ammonium calcium balance; A concentrated fertilizer problem. Soil Sci. 31:5-17.

25. Volk, G. M. 1950. Factors determining efficiency of cyanamid and uramon for weed control in tobacco beds. Soil Sci. 69:377-390.

APPENDIX

Table 11. Analysis of variance for sod injury.

Source of Variation	Degrees of Freedom	Mean Squares	F Value
Rate	3	275.63	1575.00**
Replication	3	.07	4.05
Date	3	5.75	32.86**
Rate X Date	9	2.43	13.89**
Error	45	.17	
Total	63		

*indicates significance at the .05 level: ** .01 level.

Table 12. Analysis of variance for grass germination on the sod plots.

Source of Variation	Degrees of Freedom	Mean Squares	F Value
Rate	3	96.03	47.50**
Replication	3	11.42	5.64**
Grass Species	2	73.94	36.55**
Rate X Grass Species	6	16.35	8.09**
Error	33	2.02	
Total	47		

*indicates significance at the .05 level: ** .01 level.

Table 13. Analysis of variance for weed control in the soil area treated July 31.

Source of Variation	Degrees of Freedom	Mean Squares	F Value
Fertilizer	2	34.40	6.09 *
Rate	3	147.50	26.13**
Replication	3	3.38	.59
Date	3	184.90	32.76**
Fert X Rate	6	8.92	1.58
Fert X Date	6	6.99	1.24
Rate X Date	9	16.54	2.93**
Fert X Rate X Date	18	4.42	.78
Error	141	5.64	
Total	191		

*indicates significance at the .05 level: ** .01 level.

Table 14. Analysis of variance of weed control in the soil area treated August 12.

Source of Variation	Degrees of Freedom	Mean Squares	F Value
Fertilizer	2	414.89	13.53**
Rate	3	482.53	15.74**
Replication	3	226.78	7.40**
Date	1	.38	.01
Fert X Rate	6	108.37	3.54**
Fert X Date	2	11.92	.39
Rate X Date	3	4.13	.13
Fert X Rate X Date	6	7.03	.23
Error	69	30.66	
Total	95		

*indicates significance at the .05 level: ** .01 level.

Table 15. Analysis of variance for grass germination in the soil area treated August 12.

Source of Variation	Degrees of Freedom	Mean Squares	F Value
Fertilizer	2	16.79	4.38 *
Rate	3	23.30	6.08**
Replication	3	4.53	1.18
Date	2	293.48	76.54**
Grass	2	.09	.02
Fert X Rate	6	6.65	1.73
Fert X Date	4	8.72	2.27
Fert X Grass	4	11.23	2.92 *
Rate X Date	6	7.86	2.05
Rate X Grass	6	5.37	1.40
Date X Grass	4	46.18	12.04**
Fert X Rate X Date	12	3.06	.80
Fert X Rate X Grass	12	19.27	5.03**
Rate X Date X Grass	12	1.97	.51
Fert X Rate X Date X Grass	24	3.11	.81
Error	329	3.83	
Total	431		

*indicates significance at the .05 level: ** .01 level.

NITROGEN FERTILIZERS AS HERBICIDES

by

RICHARD ALLEN PENCE

B. S., The Ohio State University, 1968

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY

1970

The effect of nitrogen fertilizers on seed germination has been the subject of many reports during the last 40 years. It was known that nitrogen fertilizers would reduce germination but there were very few reports of these materials being used as weed seed eradicating agents.

The purpose of this study was to evaluate nitrogen fertilizers for use as temporary soil sterilants. The study was carried out in two phases: 1) a greenhouse study using anhydrous ammonia at 0, 225.8, 451.6, and 903.2 Kg of N/Ha, and 2) a field study using anhydrous ammonia, Aqua Uran, and calcium cyanamide at 0, 225.8, 451.6, and 677.4 Kg of N/Ha.

In the greenhouse study anhydrous ammonia killed weed seedlings and weed seeds. In the field anhydrous ammonia at 451.6 and 677.4 Kg of N/Ha killed existing bluegrass sod. Aqua Uran and calcium cyanamide did not kill any sod at the rates used.

All fertilizers reduced weed seed germination when applied to a tilled soil with no existing vegetation. Anhydrous ammonia reduced weed seed germination more than either Aqua Uran or calcium cyanamide.

Bluegrass, (Poa pratensis L.), tall fescue, (Festuca elatior L.), and bermudagrass (Cynodon dactylon (L.) Pers.), germinated when seeded 18 hours after treatment. However, tall fescue and bluegrass germination was reduced as the amounts of nitrogen increased.

These results indicate that anhydrous ammonia has promise for use as a temporary soil sterilant, but the need for further testing is apparent. Aqua Uran and calcium cyanamide had minimal herbicidal activity at the rates used.