DEFOLIATION OF DELTAPINE SMOOTH LEAF COTTON WITH ANHYDROUS AMMONIA GAS

by

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ABSTRACT

Anhydrous ammonia gas was applied on September 1 and 15; October 1 and 15; and November 1, 1963, to Deltapine Smooth Leaf cotton (Gossypium hirsutum L.) for evaluation as a cotton defoliant under field conditions at the University of Arizona Campbell Avenue Farm, Tucson, Arizona. Three concentrations of anhydrous ammonia gas were applied on September 1 and 15 and October 1 and two concentrations on October 15 and November 1, 1963.

The average per cent abscission of upper and lower leaves increased with increasing concentrations of anhydrous ammonia gas at all application dates. Adequate abscission (80% or more) of upper and lower leaves was induced with 60,000 ppm of anhydrous ammonia gas at all application dates except November 1. Adequate abscission of upper and lower leaves was induced with 40,000 ppm of anhydrous ammonia gas only on September 15. The 20,000 ppm concentration failed to induce adequate abscission at any application date.

September 1 was the optimum date to induce the highest per cent of adequate defoliation of upper and lower leaves with 60,000 ppm, while September 15 was the optimum date to induce the highest per cent of adequate defoliation of upper and lower leaves with 40,000 ppm.

Generally, defoliation required a longer period of time and the defoliation percentage decreased as the season advanced regardless of the concentration of anhydrous ammonia gas applied.

For the September 1 application only, some treated abscised leaves contained more nitrogen than untreated leaves.

INTRODUCTION

Cotton producers are constantly searching for methods of improving cotton quality and reducing production costs to meet the competition of synthetic fibers which are challenging cotton in the textile market.

Defoliation of cotton is an important production practice because of the improvements it offers in preserving the natural qualities of cotton and increasing the efficiency of machine harvesting. Over 50 per cent of the cotton produced in the United States is treated with defoliants. However, the problems associated with obtaining satisfactory defoliation are almost as numerous today as they were when defoliation first became a cotton production practice.

The chemicals used for defoliation of cotton are commonly described as harvest-aid chemicals and can be separated into three classes: (a) defoliants which do not immediately kill the leaves but accelerate the abscission process, (b) desiccants which dry and kill the leaves, and (c) second-growth inhibitors which keep the plant from producing new leaves after defoliation or desiccation.

The use of anhydrous ammonia gas as a harvest-aid chemical to defoliate cotton is a relatively new process investigated by the Chevron Chemical Company, Ortho

Division. Because anhydrous ammonia is applied as a gas, it has inherent qualities that may alleviate problems associated with some of the chemicals currently being used for defoliation.

The purpose of this study was to investigate the use of anhydrous ammonia gas as a cotton defoliant under field conditions in Arizona. The primary objective was to determine the concentration of anhydrous ammonia gas needed to obtain optimum defoliation and the per cent defoliation obtained at different dates considering soil moisture and weather conditions. A final objective was to determine if the nitrogen content of leaves defoliated with anhydrous ammonia gas was different than untreated leaves.

REVIEW OF LITERATURE

Natural defoliation in cotton usually begins in the basal portion of the petiole following a certain period of senescense. Hall and Lane (12) observed that visual symptoms characteristic of natural abscission closely paralleled those of leaves treated with ethylene and a defoliant. In both cases the leaves became chlorotic and dehydrated before abscission.

Induced abscission is usually preceded by some degree of biological, chemical, or mechanical injury to the bladė or petiole (1). Jackson, as reported by Hall (11), treated various portions of the upper surface of cotton leaves with a defoliant and found the rate of abscission proportional to the leaf area treated. Johnson (16) found that chemicals which caused mild injury to the leaves were usually more effective defoliants than were very toxic chemicals which caused rapid chlorosis and dehydration of the leaves and prevented abscission. Eaton (4) reported little similarity between the chemical structure of defoliants and physiological activity. However, many of the chemicals Eaton tested were oxidizing agents and caused similar symptoms prior to abscission.

Esau (5) refers to the abscission region or zone as a layer of cells near the base of the petiole that becomes structurally weakened, following cytological and chemical changes, which facilitate mechanical separation of the petiole. Gawadi and Avery (6) studied the morphology and anatomy of abscission in cotton. These workers found that normal abscising leaves developed an abscission layer of two or three tiers of cells in more than one plane but usually diagonally. When abscission was induced in young leaves by deblading, cell division occurred in the abscission zone and the petiole abscised in four to five days. Young leaves treated with ethylene chlorohydrin abscised in two or three days without cell division in the abscission zone. Debladed petioles treated with one per cent lanolin paste of β-naphthoxy-acetic acid, which inhibits cell division in the abscission zone, abscised as readily as untreated debladed petioles. Gawadi and Avery concluded from this work that cell division in the abscission zone was not required for abscission in cotton.

Many researchers have investigated the biochemistry of abscission in cotton to determine the specific mechanisms involved. Hall (9) was the first to report that abscission in cotton could be retarded by the application of auxin (indoleacetic acid) to the petiole. Addicott, Lynch, and Carns (2) proposed that the principal regulator of abscission is the auxin gradient across the abscission zone.

Abscission did not occur with auxin gradients characteristic of healthy mature plants: high auxin distal and low auxin proximal to the abscission zone. Abscission did occur when the ratio became balanced and was accelerated when the gradient was reversed. Carns, as reported by Hall (11), found the auxin gradient across the abscission zone decreased as abscission approached.

Gawadi and Avery (6) demonstrated the ability of ethylene chlorohydrin to stimulate rapid abscission of both debladed cotyledonary and mature cotton petioles. Also Hall et al. (14) showed that ethylene was produced by both excised and intact cotton leaves. Under field conditions, the production of ethylene became noticeable when plants reached the flowering stage of growth and was highest at maturity. Jackson, as reported by Hall (11), found that cotton leaves produced ethylene gas when treated with any of seven defoliants tested. Hall (11) reported that injury to the cotton leaf stimulates ethylene production. Gewadi and Avery (6) suggested that as the hormone supply of the leaf diminishes, ethylene, or a similar substance, accelerates the aging process. Hall (9) agreed with Gewadi and Avery's theory that leaf abscission is dependent on the hormone-ethylene balance in the petiole.

Tharp (22) reported that little difference existed in the defoliability among Upland and American-Egyptian varieties of cotton. The results obtained from this work showed that differences were primarily related to maturity status and not physiological variations. However, wide variations in defoliability have been identified in non-commercial species and experimental breeding stocks. Tharp further reported on the effect of maturity on defoliability. Defoliation efficiency was directly and proportionately correlated with leaf maturity. Physiologically immature leaves would not abscise quickly or easily when treated with any commercial defoliant.

Lane, Hall, and Johnson (19) investigated the effect of temperature on abscission in cotton. Main-stalk petioles were treated with disodium 3,6-endoxa-hexahydrophthalate (Endothal) at temperature intervals of 9 degrees from 41 to 95 F. Between 59 and 95 F, the rate of chemically induced abscission doubled with each 18 degree increase in temperature. The rate of natural abscission induced by deblading was slower and less consistent than chemically induced abscission at any temperature.

Hall and Liverman (13) studied the effect of light on abscission in cotton. Intact mature cotton leaves were treated with ethylene chlorohydrin at various light intensities. Abscission was promoted by increasing light intensities up to 2,500 foot candles. From 2,500 to 8,000 foot candles abscission decreased from 85 to 20 per cent.

A minimum of research has been conducted concerning the effect of relative humidity on abscission in cotton.

However, Tharp (22) mentioned that under arid conditions leaves became dehydrated and this retarded penetration and translocation of defoliants, which in most cases influenced leaf-chemical reaction efficiency. The rate and per cent of abscission were best when the relative humidity was 50 per cent or higher.

Considerable research has been conducted concerning the effect of soil moisture on abscission in cotton. Hall (8) treated cotton with two types of defoliants and noted that cotton grown without adequate moisture consistently resulted in less defoliation than cotton which received adequate moisture. Hall (11) observed that a rapid decrease in soil moisture usually caused cotton plants to shed their basal leaves. However, a gradual decrease in soil moisture, resulting in drought near the end of the season, made defoliation extremely difficult. He concluded that in abscission, low soil moisture functioned indirectly by possibly increasing ethylene production and decreasing auxin production in the leaves. Brown and Addicott (3) suggested that low soil moisture influenced the turgor pressure within cells of the abscission zone which regulates tensions and compressions that facilitate mechanical separation of the petiole. In a supplemental irrigation study in Texas, Hall (10) found that Deltapine cotton which received a medium moisture level resulted in the highest defoliation and least regrowth.

Tharp (22) reported on the influence of leaf coverage and defoliation. Since defoliants are not truly systemic, thorough coverage is often inadequate in dense, rank, and lodged cotton. Leaves not covered adequately respond poorly to defoliants.

Tharp (22) mentioned that harvest-aid chemicals increased the efficiency of machine harvesting equipment and the preservation of the natural quality of cotton.

Riley and Williamson (21) studied microclimatic changes in cotton fields treated with defoliants in the Mississippi Delta region. Defoliation increased sunlight penetration from 20 to 80 per cent and quadrupled wind movement at mid-plant height. They considered a seed moisture content of 10 per cent, which corresponded to a field relative humidity of 50 per cent, a safe level to begin machine harvest. As a result of more rapid drying, defoliated fields with a relative humidity of 50 per cent would allow a total of one hour more per day for machine harvesting. Similar tests conducted by Haddock (7) at Weslaco, Texas, indicated defoliation increased machine harvesting time three hours for every four days.

Jones (18) found that defoliation reduced the moisture content of various plant parts. Lint grade was increased from low middling light spot in a non-defoliated field to low middling with defoliation. Tests in

Mississippi indicated that defoliation improved cotton quality in 14 of 18 cases studied (23).

Ranny and Thomas (20) evaluated the influence of bottom defoliation in conjunction with and without fungicide applications on boll rot and cotton quality. In one test at Stoneville, Mississippi, bottom defoliation permitted 54 per cent more cotton to be harvested by machine the first harvest. No benefit from the use of fungicides was demonstrated. No influence in yield or seed quality was demonstrated in any of the treatments. According to Ranny and Thomas, tests by growers in the Mississippi Delta region indicated boll rot was reduced 25 per cent and three times as many bolls were open and fluffy when bottom defoliation was used.

Johnston (17) stated that effective defoliation could be considered an economic means of insect control. Because of ecological changes resulting from defoliation, overwintering populations of the boll weevil (*Anthonomus grandis* Boh.) and pink bollworm (*Pectinophora gossypiella* Saunders) were considerably reduced.

Hawkes (15) reported that one application of 75 to 100 pounds of anhydrous ammonia gas per acre resulted in adequate defoliation. Absorption of the gas was through the stomata causing rapid desiccation of the leaves probably due to protoplasmic poisoning. Damage to the petiole was not apparent as natural growth processes in the abscission zone caused abscission in a few days. It was suggested that possible retention of ammonia by plants would increase soil fertility. Soil residues from certain commercial harvest-aid chemicals were shown to be toxic to succeeding crops of barley (*Hordeum vulgare* L.) and sugar beets (*Beta vulgaris* L.).

MATERIALS AND METHODS

This study was conducted under field conditions at the University of Arizona Campbell Avenue Farm, Tucson, Arizona. Deltapine Smooth Leaf cotton (Gossypium hirsutum L.) was planted May 1, 1963, in a Gila sandy loam in eight 36-inch spaced rows, 180 feet long. One preplant application of barnyard manure at an unrecorded amount was the only fertilizer supplied throughout the growing season. Irrigation water was applied by farm personnel as normally practiced for cotton production at the Campbell Avenue Farm. Precipitation during late summer and early fall contributed considerable soil moisture. No insect control measures were used during the entire season.

A chamber with an internal volume of 2,000 cc. was designed and constructed by the author to enclose one cotton leaf while it was attached to the plant (Fig. 1). The chamber was constructed from 3/8-inch, clear plexiglass with the upper and lower faying surface sealed with soft polyurathane foam. A small relieved area in one side of the chamber in both faying surfaces of the seal prevented petiole damage when the leaf was enclosed. An electrically driven, high-speed shrouded fan within the chamber adjacent to the rubber injection diaphragm, insured immediate mixing of injected gas to a uniform concentration. The lid and

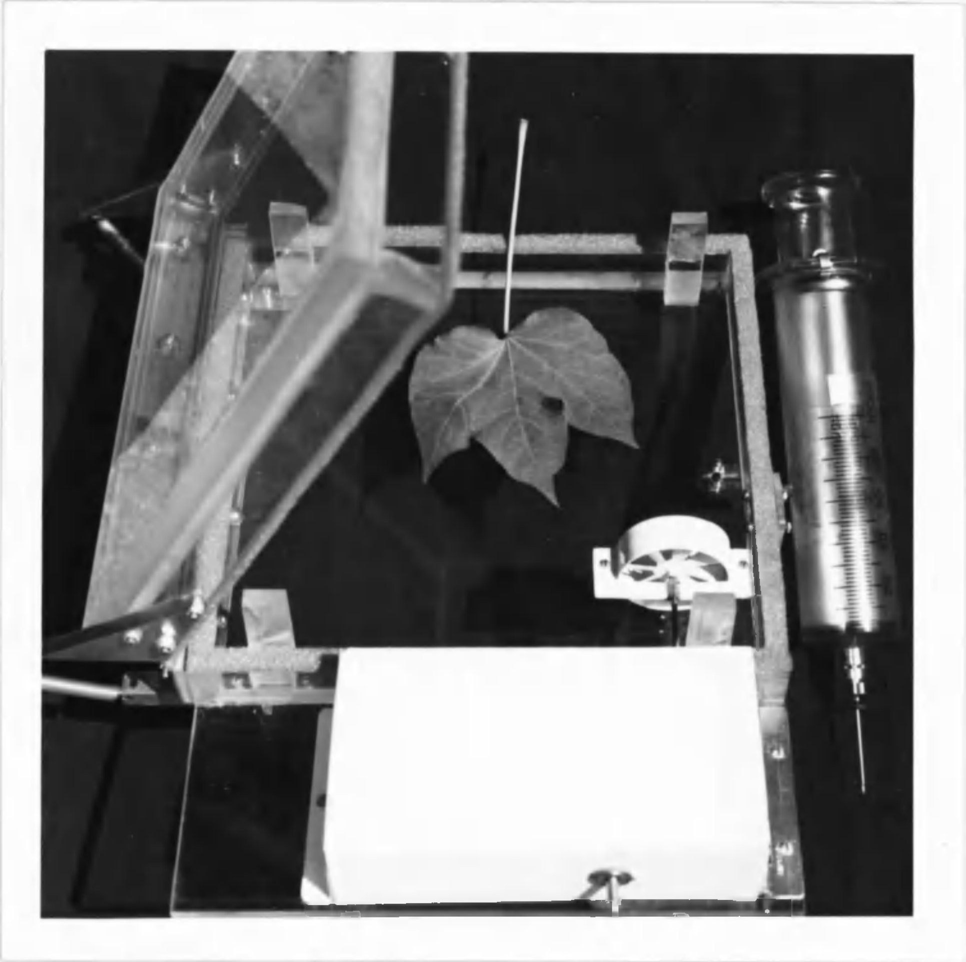

Figure 1. Leaf chamber used to enclose one intact cotton leaf for treatment with various concentrations of anhydrous ammonia gas.

The syringe was used to inject a desired quantity of anhydrous ammonia gas into the chamber.

its securing latch were spring loaded to facilitate quick removal of the treated leaf from the chamber.

A continuous flow of anhydrous ammonia gas from a five-gallon tank was regulated into a one-gallon sampling chamber where the gas assumed atmospheric pressure (Fig. 2). The excess gas was bubbled into a water container to exclude air from the sampling chamber. Selected quantities of anhydrous ammonia gas to be injected into the leaf chamber were extracted from the sampling chamber through a rubber diaphragm with a syringe (Figures 1 and 2).

Five plots, each consisting of seven rows 20 feet long, were laid out in an area of the field where plant height and stand were uniform. A recording hygrothermograph was installed in the center of the middle plot at a level of 30 inches above the furrow to record air temperature and relative humidity.

Applications of anhydrous ammonia gas were made on the following dates: September 1 and 15, October 1 and 15, and November 1, 1963. All treatments were made between 1:00 and 3:00 p.m. Three concentrations (20,000; 40,000; and 60,000 ppm) of anhydrous ammonia gas were applied to leaves of plants in one of the five plots selected at random. Each rate was applied separately to leaves of plants in one of the three center rows selected at random. Twenty upper and 20 lower leaves were treated with the rate selected for that row. The 20,000 ppm rate was

Figure 2. Five-gallon ammonia tank with regulator and sampling chamber used in the field to supply anhydrous ammonia gas at atmospheric pressure for treating individual cotton leaves.

discontinued after October 1 because of inadequate defoliation with that concentration.

Leaf exposure time to anhydrous ammonia gas injected into the chamber was 6 seconds in all treatments. This simulated the exposure time of existing four-row experimental equipment in use. Treated leaves were tagged to identify their position and concentration of anhydrous ammonia gas applied. At the time of each application, 20 upper and 20 lower untreated leaves were collected from untreated plants in the plot and were air dried, and stored in polyethylene bags. Following each application, daily observations were made at 6:00 p m. for 14 days to record and collect the number of treated leaves that had abscissed. Abscissed leaves were air dried and stored in polyethylene bags.

Soil samples were taken from the first and second foot of soil for moisture determinations on the date of each application. After all applications were completed, total nitrogen analyses were made by the Kjeldahl method to compare treated abscissed leaves collected from the first, third, and fifth application dates to untreated leaves collected at the same time as those receiving the treatments. These tests were made to determine the quantity of nitrogen remaining in leaves treated with anhydrous ammonia gas compared with the check. Nitrogen determinations were made by the Soil and Water Testing Laboratory of The University of Arizona.

RESULTS AND DISCUSSION

Defoliation results from applications of various concentrations of anhydrous ammonia gas applied to leaves on the upper and lower portions of cotton plants on September 1 and 15, October 1 and 15, and November 1, 1963, are shown in Figures 3, 4, 5, 6, and 7, respectively.

One criterion commonly accepted by researchers in evaluating a harvest-aid chemical for commercial use is that it should induce 80 per cent or more defoliation in about two weeks following initial application. Therefore, concentrations of anhydrous ammonia gas inducing an average of 80 per cent or more defoliation of upper and lower leaves within 14 days after application were considered adequate.

The 60,000 ppm concentration induced the highest per cent defoliation of upper and lower leaves at all application dates except November 1 when neither treatment induced satisfactory defoliation. The 40,000 ppm concentration induced adequate defoliation of upper leaves at all application dates except October 15 and November 1. However, the average defoliation of upper and lower leaves induced by 40,000 ppm on October 1 may have been increased because the upper leaves were severely damaged by grasshoppers (species unknown). It is the author's opinion that

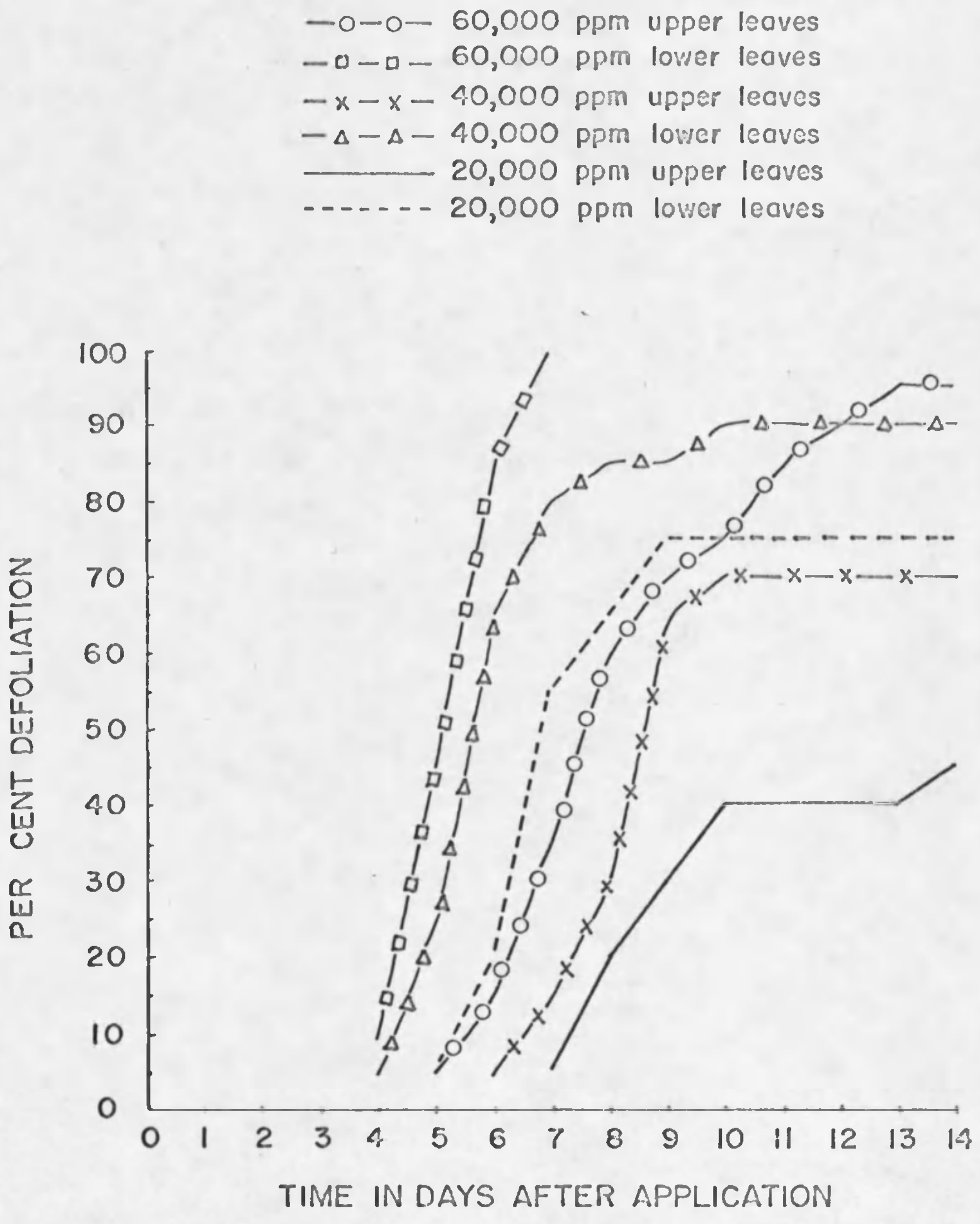

Figure 3. Per cent defoliation of Deltapine Smooth Leaf cotton plants obtained when three rates of anhydrous ammonia gas were applied on September 1, 1963.

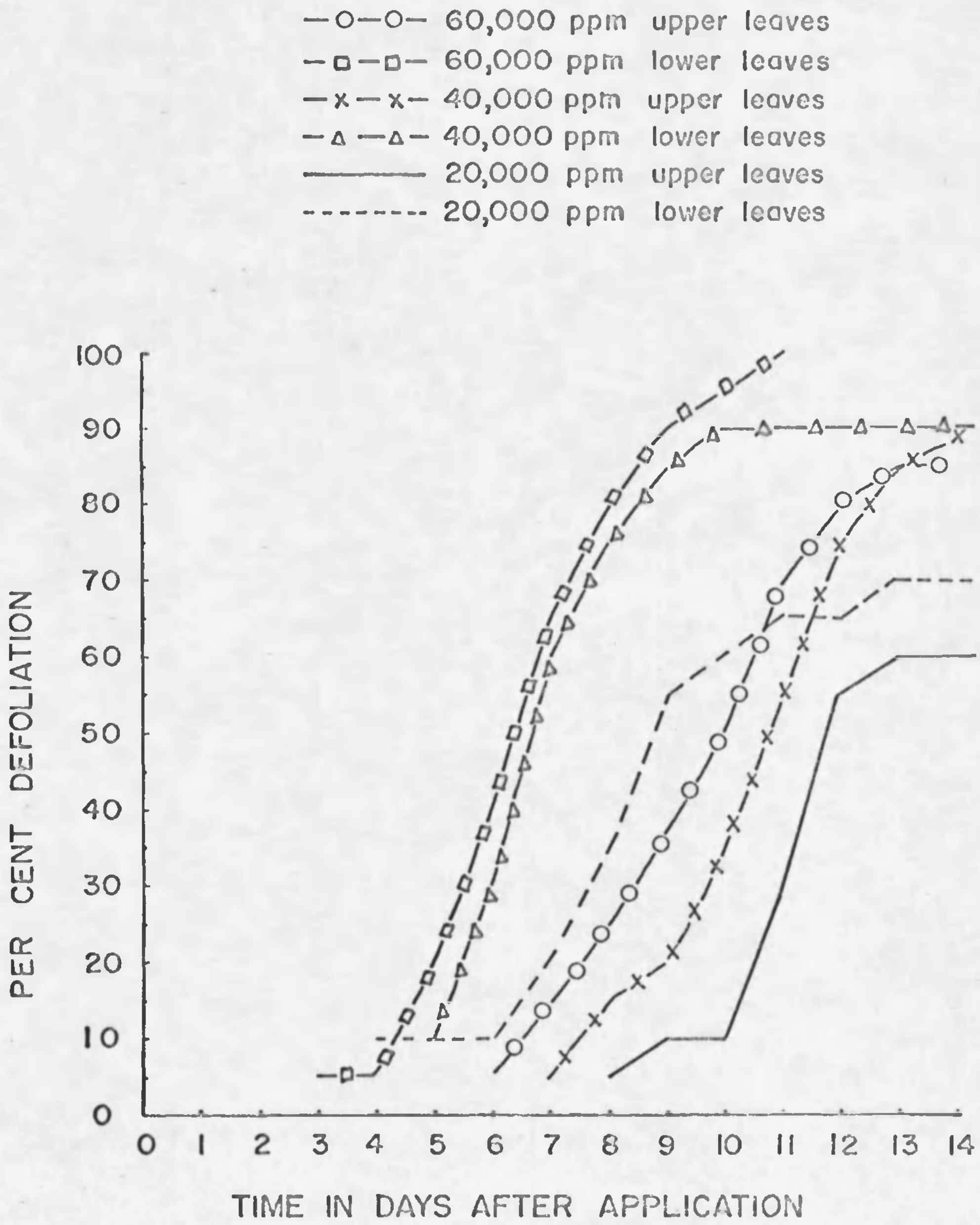

Figure 4. Per cent defoliation of Deltapine Smooth Leaf cotton plants obtained when three rates of anhydrous ammonia gas were applied on September 15, 1963.

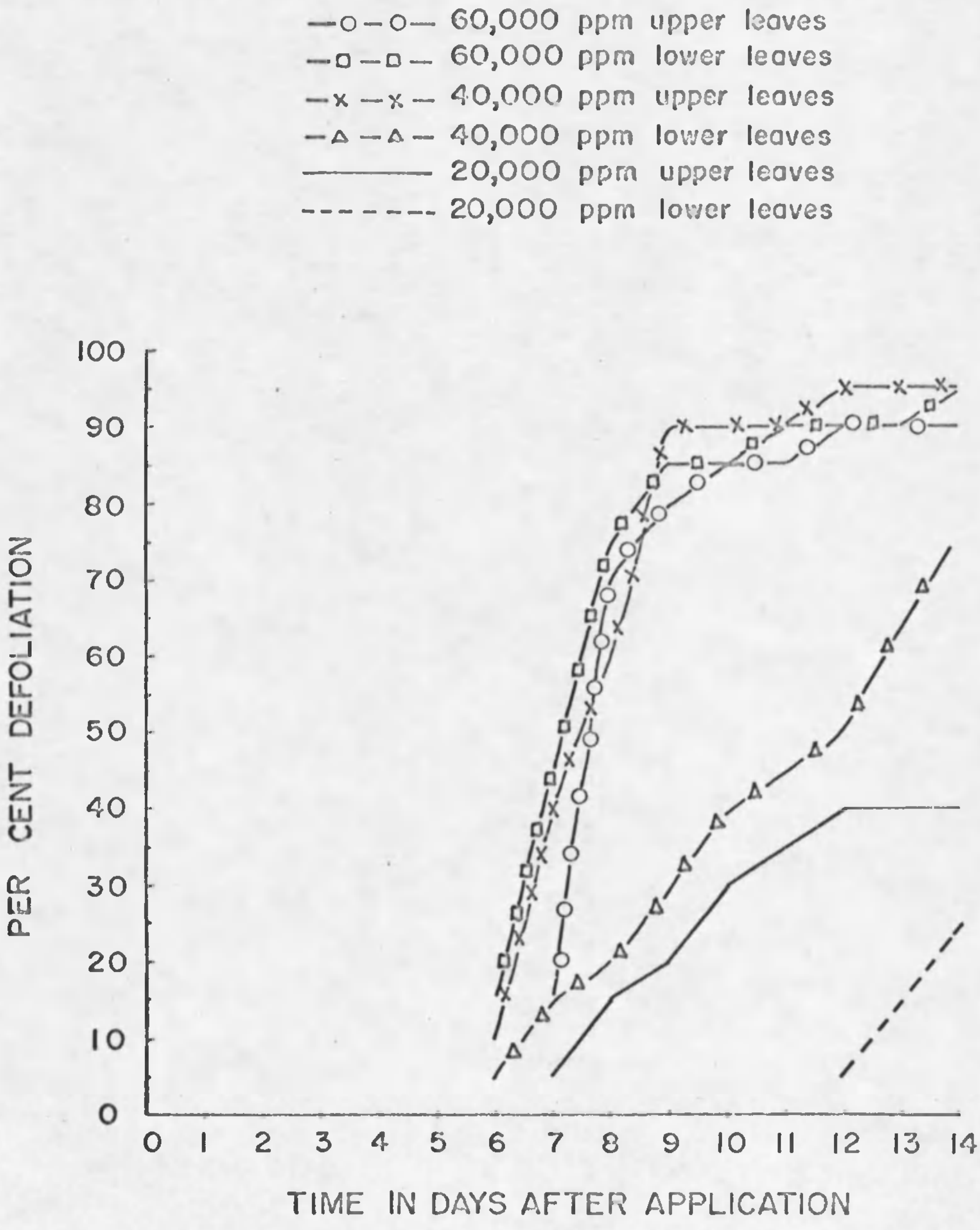

Figure 5. Per cent defoliation of Deltapine Smooth Leaf cotton plants obtained when three rates of anhydrous ammonia gas were applied on October 1, 1963.

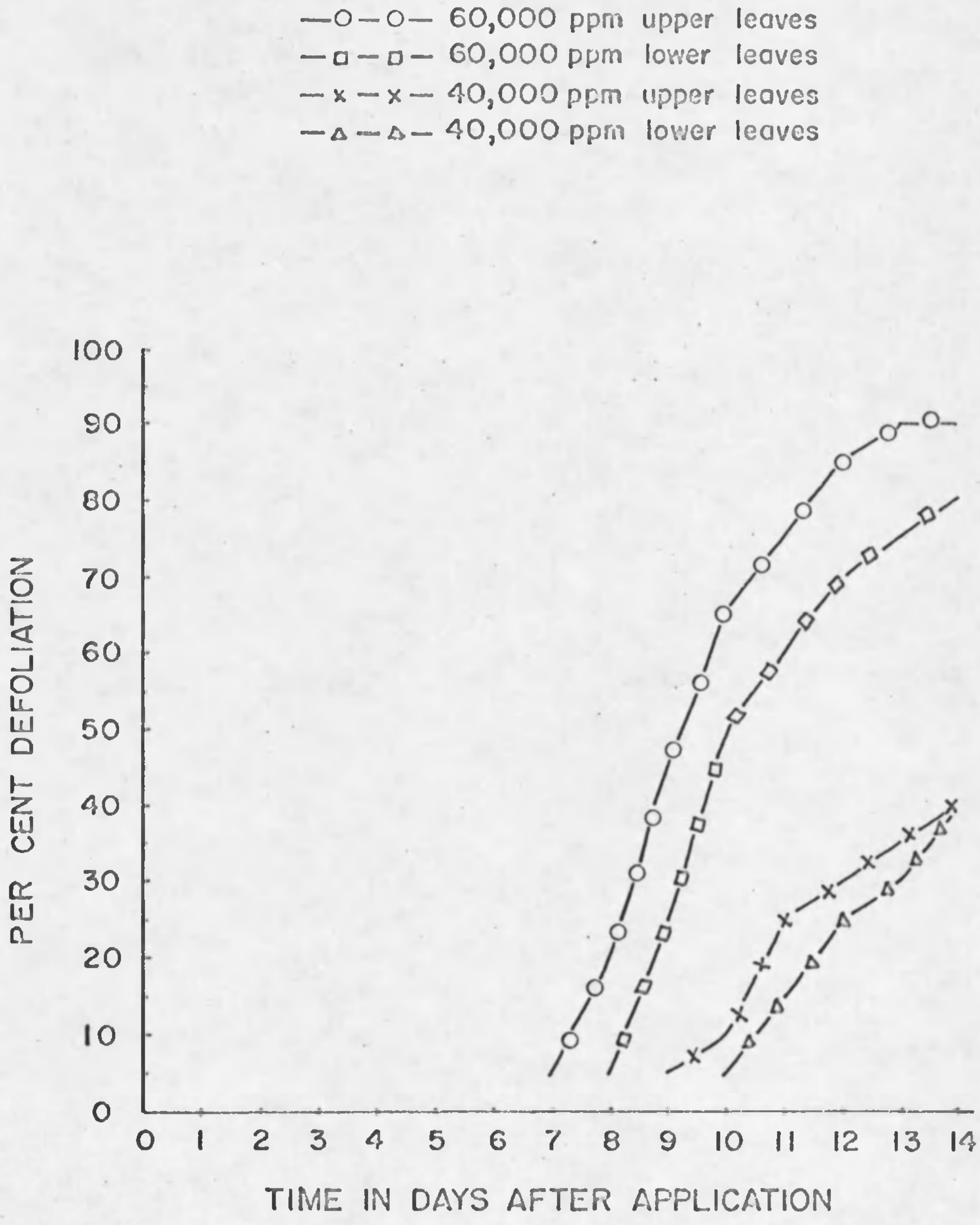

Figure 6. Per cent defoliation of Deltapine Smooth Leaf cotton plants obtained when two rates of anhydrous ammonia gas were applied on October 15, 1963.

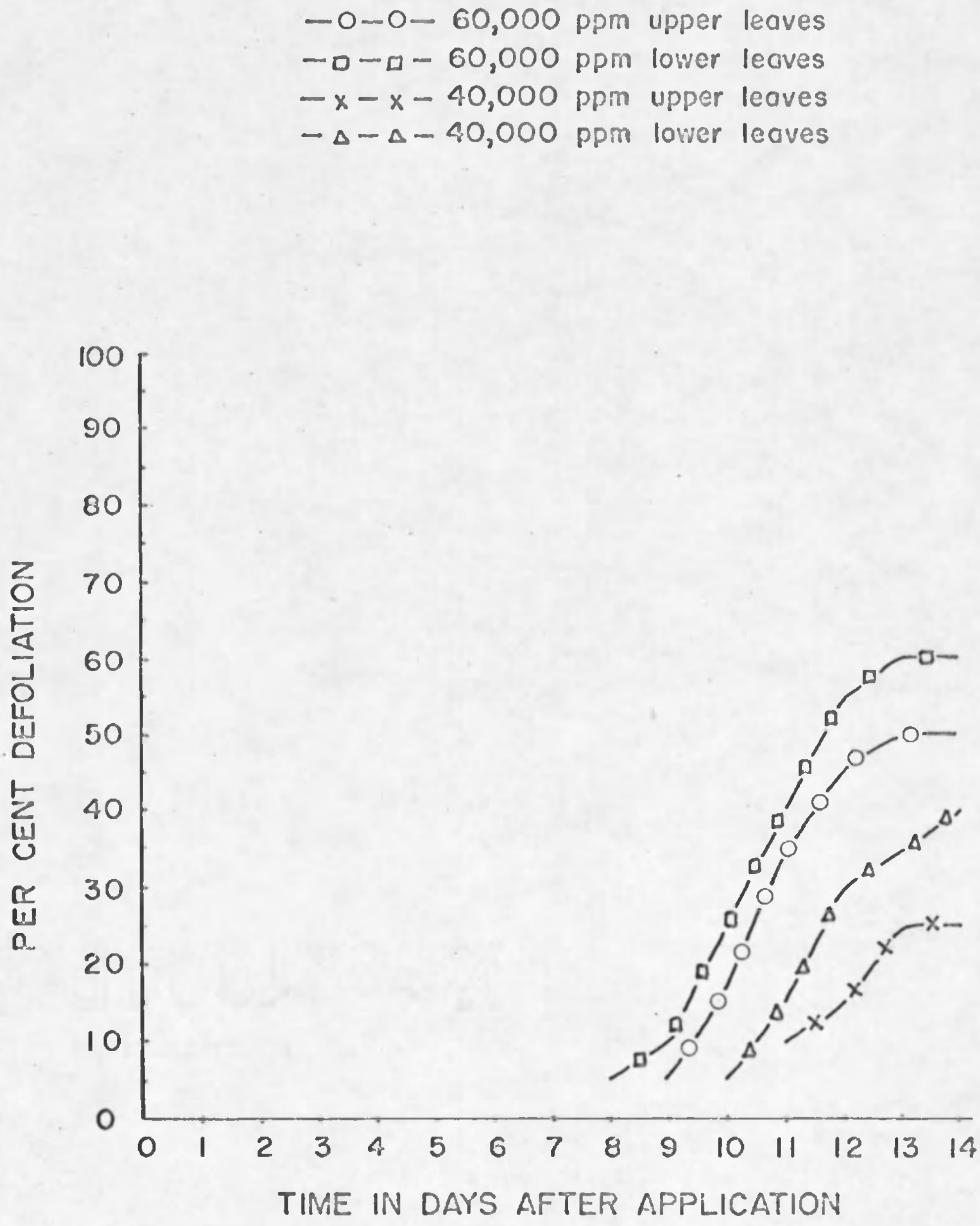

Figure 7. Per cent defoliation of Deltapine Smooth Leaf cotton plants obtained when two rates of anhydrous ammonia gas were applied on November 1, 1963.

40,000 ppm applied on October 1 would have been insufficient to induce adequate defoliation under normal conditions. Inadequate defoliation resulted from 20,000 ppm at all application dates.

Immediately following the injection of 60,000 ppm anhydrous ammonia gas into the chamber on September 1, the leaf color changed to a lighter green. Within 30 minutes following removal of the leaf from the chamber, leaf color changed to a very dark green and leaf texture became quite flaccid. Eighteen to 24 hours later, the leaves were dehydrated and brittle. Generally speaking, these color and texture changes following the applications were less striking as the concentration of anhydrous ammonia gas decreased and as the season advanced. These results do not agree with Johnson (16), who reported that chemicals causing mild injury to leaves were usually more effective defoliants than were very toxic chemicals which caused rapid chlorosis and dehydration of the leaves and prevented abscission.

The average per cent abscission of upper and lower leaves increased with increasing concentrations of anhydrous ammonia gas at all application dates. These results might be explained on the basis of Hall's (11) proposed auxin-ethylene hypothesis regarding injury to cotton leaves and subsequent abscission. It is the author's opinion that cotton leaves exposed to increased concentrations of anhydrous ammonia gas would have a greater portion of cells injured thereby accelerating the processes promoting abscission. Jackson, as reported by Hall (11), noted somewhat similar results by treating various portions of the upper surface of cotton leaves with a defoliant. His investigations indicated the rate of abscission was proportional to the leaf area treated.

For the September 1 and 15 and November 1 applications, lower leaves abscised sooner and had a higher per cent of abscission than upper leaves within 14 days after treatment regardless of the concentration of anhydrous ammonia gas used. These results agreed with those of Tharp (22) who noted that defoliation was directly and proportionately correlated with leaf maturity. However, for the October 1 and 15 applications, upper leaves abscised sooner and had a higher per cent abscission than lower leaves within 14 days after treatment except for the 60,000 ppm concentration on October 1. Apparently, the natural processes preceding abscission were induced by the severe grasshopper damage to the upper leaves before anhydrous ammonia gas treatments were applied. Injury to the upper leaves from both anhydrous ammonia gas and grasshoppers apparently had an accumulative effect on rate and per cent abscission.

Generally, time for defoliation to occur after treatment increased and the per cent defoliation decreased as the season advanced regardless of the concentration of anhydrous ammonia gas applied. These results were probably the natural effect of external factors such as photoperiodism, temperature and availability of water and nutrients.

Daily temperatures from September 1 through November 16 are presented in Table 1. The relationship of the average per cent abscission of upper and lower leaves, treated separately with three concentrations of anhydrous ammonia gas, to the mean temperature for 14 days following each application date is presented in Figure 8. The solid line represents the expected effects of temperature on per cent abscission according to Lane et al. (19) who reported that chemically induced abscission doubled with each 18 F increase in temperature from 59 to 95 F.

The average per cent abscission of upper and lower leaves induced with 60,000 ppm was in general agreement with the per cent abscission expected for an 18 F increase in mean temperature from 66.6 to 84.6 F. The 40,000 ppm concentration induced abscission in a similar pattern with mean temperatures above 79 F, but considerably less abscission than expected with mean temperatures below 79 F. The 20,000 ppm rate induced considerably less abscission than expected at any mean temperature. The average per cent abscission of upper and lower leaves was dependent upon both the mean temperature and concentration of anhydrous ammonia gas applied.

Table 1. Daily maximum, minimum, and mean air temperatures among cotton plants at a height of 30 inches above the soil surface for the period from September 1 to November 16, 1963; Campbell Avenue Farm, Tucson, Arizona.

	September			October			November		
	Temperature in F			Temperature in F			Temperature in F		
Date	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1	88	66	77.0	100	59	79.5	92	53	72.5
2	93	70	81.5	103	57	80.0	82	68	75.0
3	82	70	76.0	104	56	80.0	84	50	67.0
4	84	68	76.0	102	56	79.0	89	50	69.5
5	86	64	75.0	102	64	83.0	87	48	67.5
6	87	64	75.5	102	61	81.5	90	46	68.0
7	89	63	76.0	106	53	79.5	64	52	58.0
8	90	62	76.0	104	56	80.0	72	43	57.5
9	92	66	86.0	105	58	81.5	80	44	62.0
10	99	72	84.5	104	58	81.0	92	47	70.5
11	99	72	80.5	99	60	79.5	78	51	64.5
12	99	70	84.5	104	56	80.0	92	42	67.0
13	98	72	85.0	100	53	76.5	94	52	73.0
14	92	69	80.5	103	51	77.0	89	51	70.0
15	95	69	82.0	104	54	79.0	86	49	67.5
16	96	71	83.5	96	70	83.0	78	40	59.0
17	103	69	86.0	95	70	82.5			
18	99	78	88.5	a					
19	98	65	81.5						
20	95	69	82.0						
21	96	62	79.0	94	60	77.0			
22	102	65	83.5	94	60	77.0			
23	101	72	86.5	90	60	75.0			
24	104	70	85.5	91	59	75.0			
25	102	75	88.5	94	54	74.0			
26	101	70	85.5	94	54	74.0			
27	101	60	80.5	94	54	74.0			
28	100	60	80.0	96	58	77.0			
29	100	62	81.0	91	60	75.5			
30	100	60	80.0	94	58	76.0			
31				92	62	77.0			

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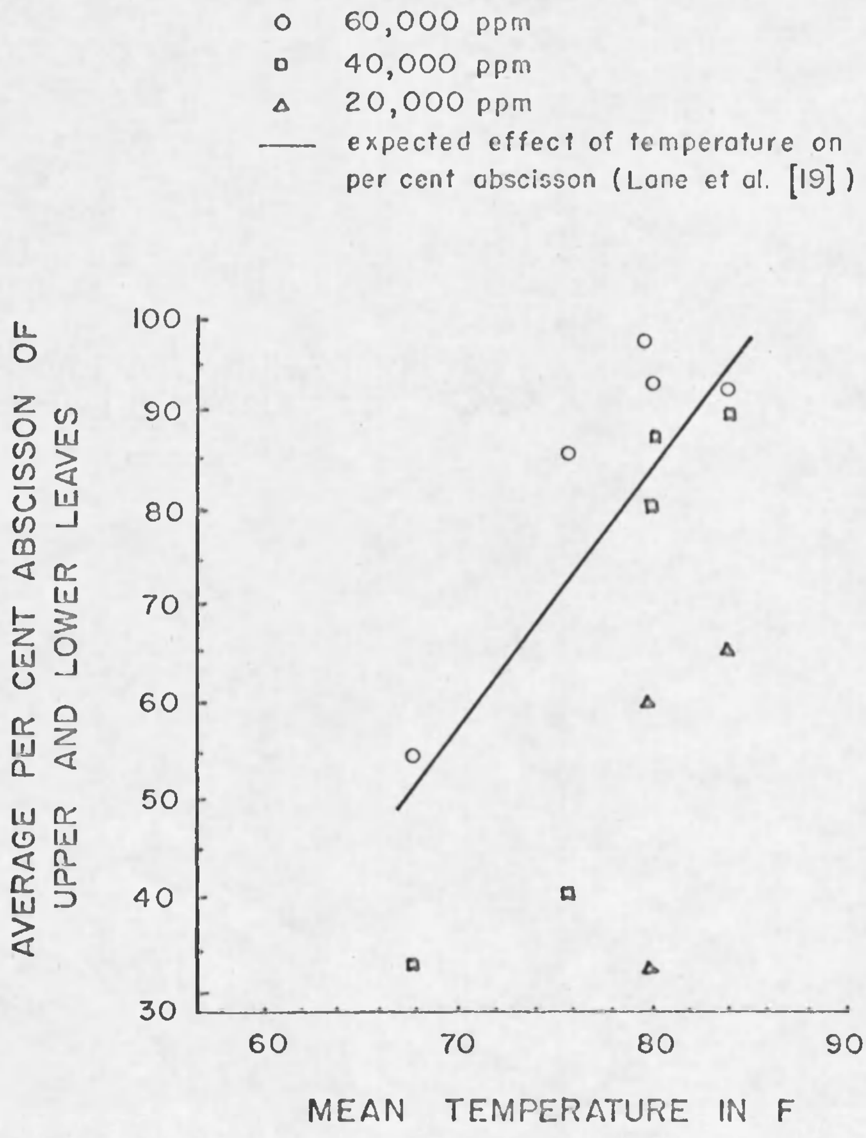

Figure 8. The relationship of average per cent abscission of upper and lower Deltapine Smooth Leaf cotton leaves treated with three concentrations of anhydrous ammonia gas to the mean air temperature for 14 days following applications compared to the expected effect of temperature on abscission.

Relative humidity during the 14 days following each application was not considered low enough to influence abscission (Table 2). With the exception of a few days following the September 15, October 1 and 15 applications, the daily mean relative humidity was 50 per cent or greater. Tharp (22) reported that the rate and per cent of abscission were best when the relative humidity was 50 per cent or greater.

Per cent of soil moisture, determined on a dry weight basis, for the first and second foot of soil at each application date are presented in Table 3. According to Hall (11), cotton grown without adequate soil moisture consistently resulted in less defoliation than cotton which received an adequate moisture supply. Hall (8) mentioned that a rapid decrease in soil moisture usually caused cotton plants to shed their basal leaves. Also, a gradual decrease in soil moisture, resulting in drought near the end of the season, made defoliation extremely difficult.

Relatively few irrigations were necessary throughout the growing season because of frequent summer precipitation and runoff water from other fields supplied adequate moisture. Even though the soil moisture condition during the October 15 application was approaching the wilting point for Gila sandy loam soil, moisture conditions throughout the growing season were considered adequate for good defoliation.

Table 2. Daily maximum, minimum, and mean relative humidity among cotton plants at a height of 30 inches above the soil surface for the period from September 1 to November 16, 1963; Campbell Avenue Farm, Tucson, Arizona.

	September			October			November		
	Relative Humidity			Relative Humidity			Relative Humidity		
Date	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
	%	%	%	%	%	%	%	%	%
1	88	42	65.0	94	20	57.0	99	20	59.5
2	90	32	61.0	97	10	53.5	72	30	51.0
3	92	50	71.0	80	8	44.0	95	21	58.0
4	90	50	70.0	58	10	34.0	99	20	59.5
5	90	42	66.0	80	20	50.0	96	20	58.0
6	90	40	65.0	94	12	53.0	99	11	55.0
7	92	38	65.0	88	10	49.0	98	50	74.0
8	88	35	61.5	82	10	46.0	97	36	66.5
9	88	35	61.5	80	12	46.0	95	28	61.5
10	94	30	62.0	78	14	46.0	96	18	57.0
11	93	30	61.5	80	18	49.0	96	20	58.0
12	92	34	63.0	90	14	52.0	100	15	57.5
13	88	22	55.0	94	11	52.5	94	12	53.0
14	89	32	60.5	84	11	47.5	94	14	54.0
15	90	30	60.0	83	14	48.5	92	15	53.5
16	88	24	56.0	72	30	51.0	98	18	58.0
17	94	24	59.0	70	26	48.0			
18	68	26	47.0	a					
19	90	28	59.0						
20	90	26	58.0						
21	92	28	60.0	90	20	55.0			
22	92	22	57.0	92	20	56.0			
23	88	32	60.0	94	25	59.5			
24	94	18	56.0	94	22	58.0			
25	45	15	30.0	93	14	53.5			
26	79	14	46.5	93	14	53.5			
27	86	13	49.5	95	14	54.5			
28	96	20	58.0	90	15	62.5			
29	88	16	52.0	93	20	56.5			
30	94	14	54.0	92	20	56.0			
31				93	22	57.5			

[a]Data missing.

Table 3. Per cent moisture for the 1st and 2nd foot of soil from September 1 to November 1, 1963, when occupied with mature cotton plants; Campbell Avenue Farm, Tucson, Arizona.

	Per cent soil moisture	
Date	1st foot	2nd foot
September 1	44.6	47.5
15	19.0	16.8
October 1	52.6	58.9
15	8.0	8.2
November 1	12.6	15.1

Data for the per cent nitrogen by weight in leaves which abscised following treatment with anhydrous ammonia gas on September 1, October 1, and November 1 compared to untreated checks collected at the respective times of application are shown in Figure 9. Treated leaves contained slightly more nitrogen when compared to untreated checks for the September 1 application only, with the exception of lower leaves treated with 20,000 ppm. Leaves which abscised following treatment with anhydrous ammonia gas on October 1 and November 1 contained less nitrogen than untreated checks collected at the respective dates of application. These results are not in agreement with Hawkes (15), who mentioned that ammonia retention by treated cotton leaves would be returned to the soil thereby increasing soil fertility. The reason for these results is not known. Further study on this phase appears warranted.

The economics associated with using anhydrous ammonia gas as a cotton defoliant are favorable. Application of 40,000 ppm with the experimental equipment of Chevron Chemical Company would require 82 pounds anhydrous ammonia per acre. Applying 60,000 ppm would require 123 pounds per acre. At present, material costs would be about $3.00 to $5.00 per acre.

The major problem with using anhydrous ammonia gas as a cotton defoliant is the cost and complexity of the

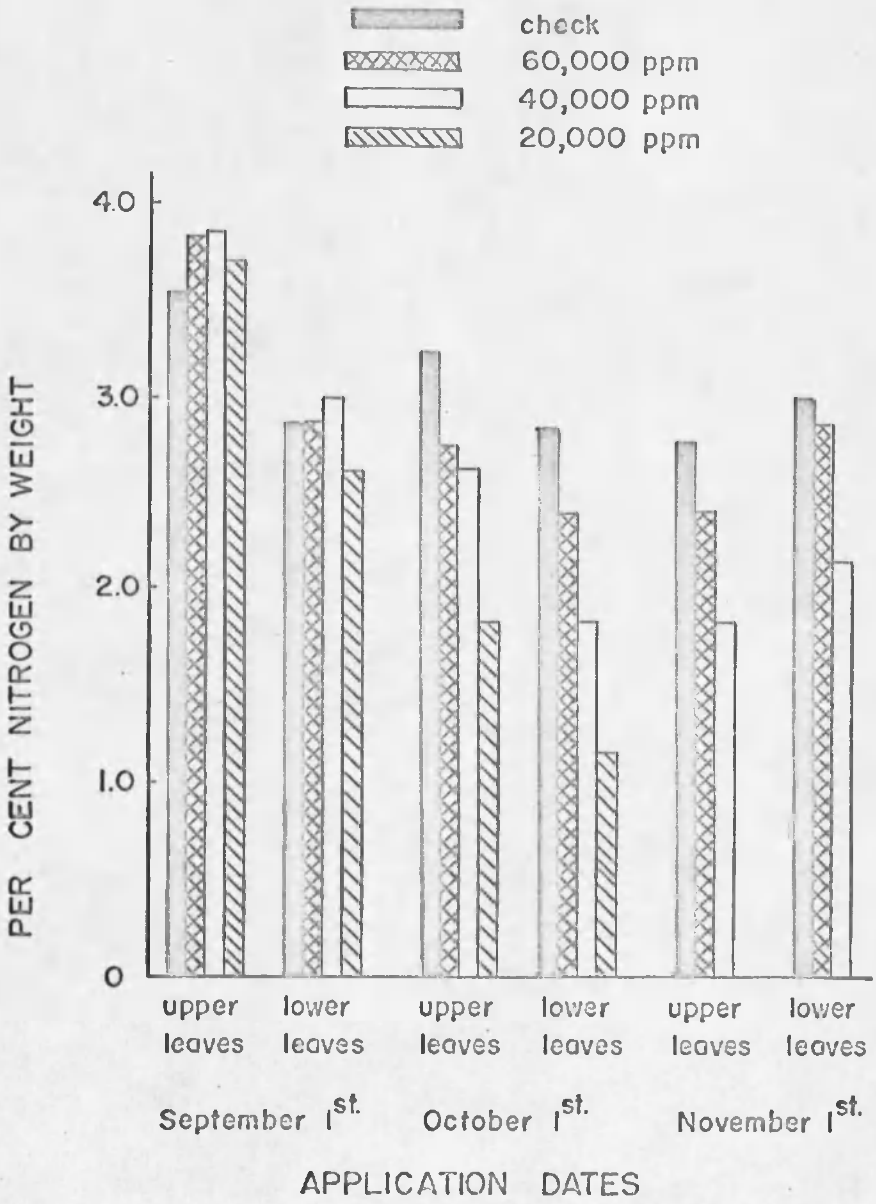

Figure 9. Per cent nitrogen, by Kjeldahl analysis, present in leaves which abscised following treatment with anhydrous ammonia gas at three dates compared to untreated checks collected at the respective times of application.

special equipment required for its application. The equipment evaluated was slow in terms of the number of acres treated per day. Movement through dense, rank cotton growth is difficult. Exposure of untreated cotton leaves to anhydrous ammonia vapor, downwind from the application equipment apparently reduces the stomatal opening. If application is made for the purpose of defoliation before this condition is reversed, resulting defoliation may be inadequate.

Adequate defoliation can be obtained with one application of anhydrous ammonia gas; whereas, many of the chemicals currently used as defoliants often require two or three applications to induce defoliation. Many of the defoliants used currently often require the removal of irrigation water as much as 4 to 6 weeks in advance of the proposed defoliation date to precondition the cotton for defoliation. Because anhydrous ammonia gas is effective on tall, rank, actively growing cotton, the possibility of extending the growing season as much as 4 to 6 weeks is an important consideration in terms of increased yields. Plant or soil residues from leaves treated with anhydrous ammonia gas are non-phytotoxic, while those from certain chemicals used for defoliation at present have been shown to be phytotoxic.

The results of this study indicate that on the basis of some criteria, anhydrous ammonia gas has the potential of becoming an important harvest-aid chemical for cotton defoliation.

SUMMARY AND CONCLUSIONS

A defoliation experiment with anhydrous ammonia gas was conducted under field conditions at the University of Arizona Campbell Avenue Farm, Tucson, Arizona, in 1963. The objectives were to: (a) determine the concentration of anhydrous ammonia gas required to induce adequate defoliation of Deltapine Smooth Leaf cotton; (b) determine the optimum date of application for adequate defoliation; (c) determine the effect of temperature, relative humidity, and soil moisture on defoliation; and (d) determine the per cent nitrogen present in treated and untreated leaves.

The average per cent abscission of upper and lower leaves increased with increasing concentrations of anhydrous ammonia gas at all application dates. The 60,000 ppm concentration induced adequate defoliation of upper and lower leaves at all application dates except November 1. The 40,000 ppm concentration induced adequate defoliation of upper and lower leaves at all application dates except October 15 and November 1. The 20,000 ppm rate failed to induce adequate defoliation at any application date.

With the exception of upper leaves which suffered severe grasshopper damage at the October 1 and 15 application dates, lower leaves abscised sooner and had a higher per cent abscission than upper leaves within 14 days after treatment regardless of the concentration of anhydrous ammonia gas applied.

Generally, time for defoliation increased and the per cent defoliation decreased as the season progressed regardless of the concentration of anhydrous ammonia.

The average per cent abscission of upper and lower leaves was dependent on the mean air temperature and concentration of anhydrous ammonia gas. When the concentration of anhydrous ammonia gas was sufficient to induce adequate abscission this process approximately doubled with an increase in mean air temperature of 18 F from 66.6 to 84.6 F.

The relative humidity and soil moisture present during all application dates were not considered to be limiting factors for adequate defoliation.

The per cent nitrogen by weight present in treated leaves which abscised following treatment compared to untreated leaves collected on the date of application was slightly higher in the September 1 application only, except for the 20,000 ppm rate applied to lower leaves. Treated leaves which abscised contained less nitrogen than untreated leaves collected on the application dates of October 1 and November 1.

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