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To the Graduate Council:

I am submitting herewith a thesis written by Srinivasan Kannan entitled "Phytotoxicity of Dalapon on Bermudagrass as Influenced by Gibberellic Acid, Nitrogen and Surfactants." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science with a major in Agronomy.

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PHYTOTOXICITY OF DALAPON ON BERMUDAGRASS AS INFLUENCED BY GIBBERELLIC ACID, NITROGEN AND SURFACTANTS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Srinivasan Kannan

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CHAPTER I

INTRODUCTION

In the past numerous cultural and biological methods have been utilized for controlling perennial grasses. Chemical methods have also been employed for specific problems. These include soil sterilants, herbicidal oils and other contact herbicides for non-selective control of grasses. Each of these foregoing methods has distinct advantages and well recognized limitations. Among the several chemicals recently developed and utilized as possessing herbicidal properties for controlling perennial grasses, dalapon is a promising recent addition to the family of chloro-substituted alkane carboxylic acids. Dalapon, 2, 2-dichloro-propionic acid, exhibits a systemic action and is actively absorbed and translocated through the living grass foliage. Since its discovery in 1951, dalapon is proving to be unusually effective in controlling a wide range of grasses and several reports have appeared in the literature on the herbicidal action of this compound.

Although considerable practical information pertaining to the use of dalapon has been accumulated within a relatively short period, there is a paucity of fundamental work on the synergetic effects of dalapon with other agents. In this connection the role of surfactants and gibberellic acid in influencing the effectiveness of dalapon has been studied by only a relatively few workers. Whereas numerous and extensive reports indicate the growth promoting properties and functional aspects of gibberellic acid on several plants, knowledge of interaction between the chemical and herbicide is limited. Because of more wide-spread use

of dalapon in the control of grasses and the high cost of this herbicide, investigation of the effects of other chemicals and agents on the herbicidal behavior of dalapon is desirable in order to increase the efficiency of the material and reduce the per acre cost. The object of the present study is to determine the effectiveness of dalapon on common Bermudagrass (Cynodon dactylon) as influenced by gibberellic acid, nitrogen and surfactants.

CHAPTER II

REVIEW OF LITERATURE

DALAPON

Following the discovery of the herbicidal properties of 2-2-dichloropropionic acid in 1951, dalapon has become the outstanding herbicide for controlling perennial grasses such as quackgrass (Agropyron repens), Bermudagrass (Cynodon dactylon) and Johnsongrass (Sorghum halepense).

Wormley (1954) classifies dalapon as a partner to 2,4-D (2,4-dichlorophenoxy acetic acid) because dalapon is selective on grasses just as 2,4-D is on broadleaved plants. Using five different chemicals in different combinations in Louisiana sugarcane (Saccharum spp.) fields, Stamper (1957) indicated that 3, 4 and 6 pounds acid equivalent of dalapon per acre was effective on controlling Johnsongrass. He has further stated that a combination of dalapon and TCA (Trichloroacetic acid) showed better results than dalapon with amitrole (3-amino-1,2,4-triozole). Watson (1955) has demonstrated that a total of three applications of dalapon resulted in 95% to 98% control of established Johnsongrass in cotton (Gossypium hirsutum) fields. Similarly, Miller and Foy (1955) concluded from California tests that Johnsongrass may be controlled effectively by spot spraying with up to 4 applications of dalapon. The same authors in another study observed that four applications of dalapon at the rate of 5 pounds per acre was successful when made when the grass was from 1 to 5½ feet tall (Foy and Miller, 1956). Rea (1955) reported a 95% reduction of Johnsongrass with two spot treatments with a dalapon

in water spray in Texas. Hauser and Thompson (1956) also indicated that two repeated applications of dalapon at the rate of 5 pounds per acre each appeared more effective in controlling Johnsongrass than single application of 10, 15 or 20 pounds per acre. Likewise several studies have concluded that multiple applications are more effective than a single application of the same total amount of the chemical (Foy and Miller, 1955a; Hauser and Thompson, 1958; McHenry 1957; Santelmann and Meade, 1958).

As indicated earlier, dalapon is also effective in controlling Bermudagrass. In this connection, Westmoreland (1959) has reviewed the use of dalapon on Bermuda and Johnsongrasses. Searcy (1957) reported that a rate of 10 to 15 pounds per acre in 50 gallons of water gave good control of Bermudagrass. Hanson (1956) has obtained complete kill of Bermudagrass in sugarcane fields in Hawaii through split application of dalapon at $2\frac{1}{2}$ pounds per acre applied four times or two applications of 5 pounds each. He has further shown that dalapon with 2,4-D is also effective as a pre-emergence grass-killer in sugarcane lands.

Control of quackgrass was studied by Buchholtz and Peterson (1957) in Wisconsin. They concluded that an application of 5 pounds of dalapon per acre in the spring and 10 pounds in the fall is satisfactory. Working on the eradication of the perennial grass, Phragmites communis, Day and Swezey (1956) in California obtained complete kill of the grass using dalapon at rates of 15 to 30 pounds of acid equivalent per acre at different stages of growth and times of the year.

Studying the effect of the chemical on annual grasses, research personnel in Arizona, California, Missouri and Mississippi have reported

in 1953, directed basal sprays of dalapon to be effective in killing or severely stunting annual grass species (Dow Chemical Co. Bulletin 2). Foy and Miller (1955) observed that 3 to 6 pounds of dalapon per acre applied at midseason significantly delayed maturity and reduced cotton yields. The control of annual grasses in California cotton was obtained by Swezey and Fisher (1955). In 1953, the authors observed that an 8 pound treatment of dalapon as a directed spray at "lay-by" resulted in severe stunting of crabgrass. They concluded from 1952 and 1953 trials that directed spray of dalapon at 3 to 6 pounds per acre would effectively control young seedlings of other important summer growing annual grasses. Similarly Shear and Chappell (1955) also controlled crabgrass in corn (Zea mays) fields effectively with 5 to 10 pounds acid equivalent of dalapon with no injury to corn in 1953. In another experiment conducted in 1954, they reported that dalapon cannot be recommended as a directed spray for grass control in established corn when applied before flowering of corn. Orsingo and Guzman (1959) advocated two dalapon applications of 5 pounds each or three applications of 3, 5 or 6 pounds per acre for effective control of crabgrass and goosegrass (Eleusine indica). Using dalapon on legumes, Peters and Kerkin (1957) collected evidence to show that all rates of dalapon resulted in a marked reduction of the annual grass stand without any significant effect on the legumes. Danielson et al. (1955) observed that a minimum of 4 pounds was necessary as pre-emergence treatment to control annual grasses in a sandy clay loam soil. Corn and snap beans were tolerant up to 6 pounds per acre applied as a pre-emergence spray. Dalapon was so toxic to seedling tomato plants (Solanum lycopersicum) that it does not appear to have any possibility

of practical use at the seedling stage of growth.

The effect of dalapon on nutgrass (Cyperus rotundus) has also given promising results. Stamper and Melville (1956) conducted three field tests in 1955 using dalapon, amitrole and combination of both on areas heavily infested with nutgrass. Their conclusions indicated that dalapon at 12 and 24 pounds per acre gave much faster kill of nutgrass than amitrole or combination of the two herbicides.

Alley and Bohmount (1956) confirmed from experiments conducted in Wyoming, that at all comparable rates dalapon proved a better post-emergence chemical than a pre-emergence chemical, for control of grasses in sugar beets (Beta vulgaris).

In addition to the crops mentioned above, grass was controlled with dalapon in grapes (Vitis vinifera), potatoes (Solanum tuberosum), pineapples (Ananassa spp.), asparagus (Asparagus spp.) and under fruit trees of various kinds (Down to Earth Staff, 1957). In addition, dalapon was also used for lawn maintenance as reported by Westmoreland and Duncan (1958), by controlling Bermudagrass with 1 pound of dalapon in 5 gallons of water. Ball (1958) conducted trials by applying dalapon with aircraft against Typha species.

Working on the stability of dalapon in soils, Thiegs (1955) concluded that the disappearance of the herbicide was due mainly to soil microbial activity. Worsham and Griddens (1957) found generally that dalapon had no effect on soil microorganisms. However, the herbicide stimulated growth of the microorganisms in some cases.

Factors influencing dalapon activity were studied by some workers. For example, Swezy (1954) and Foy and Miller (1956) reported that poor

moisture conditions, insufficient vegetative growth, disking and senescence tend to reduce the effectiveness of dalapon on Johnsongrass. Deep plowing and mowing, under some conditions have increased the effectiveness (Watson, 1954; Foy and Miller, 1956; Barrows, 1957; Bachholtz and Peterson, 1957; Santelman and Meade, 1958). Some workers (Bachholtz and Peterson, 1957) advocated nitrogen fertilization to promote rapid and complete development of shoots prior to treatment. The slow growth of quackgrass in spring was improved by applying 50 pounds of nitrogen per acre in the late winter or early spring. Control of quackgrass obtained with dalapon on fertilized areas was frequently better than on unfertilized areas.

Light has been suggested as a factor in the action of dalapon by Olsson (1957). He obtained greater inhibiting action of dalapon in the light than in the dark. Wilkinson (1955); however, discounted the effect of light as a factor except as it influences translocation and therefore uptake of chemical from the soil.

The influences of varying weather conditions such as temperature, relative humidity, wind, etc. on the effectiveness of herbicides is a matter of common observation in the field; however, the individual factors have received very little critical study. Standifer and Ennis (1956) dealt with environmental effects on dalapon toxicity. Their observations on the effect of relative humidity on the efficiency of applied dalapon indicated that the compound was absorbed more readily or efficiently under conditions of high humidity than under low humidity.

Rain falling soon after spray application can wash off the herbicide before maximum absorption has occurred. This has been observed

in fields with a variety of compounds including dalapon. Hanson (1956) simulated rain fall after spraying with dalapon and found that if no rains fall for at least ½ hour following dalapon spraying, optimum effectiveness should result. Standifer and Ennis (1956) concluded that maximum absorption and translocation of dalapon required 24 hours or longer in young corn. Similarily Santelmann and Willard (1956) using the washing technique, found that although washing 5 minutes after treatment did not prevent severe damage to the treated leaf of quackgrass, longer exposures to the chemical were more injurious to the treated leaf and other plant parts.

Rao (1960) studied the effect of gibberellic acid on the phytotoxicity of dalapon on Bermudagrass. His findings indicated that the action of dalapon used at 1 pound acid equivalent in 15 gallons of water was more rapid when plants have received an initial application of 50 ppm. gibberellic acid. The check pot which had received only dalapon did not show complete kill of Bermudagrass.

GIBBERELLIC ACID

Gibberellic acid is produced by an Asian fungus Gibberella fujikuroi. The research history of gibberellic acid began in Japan as early as 1898 where scientists did pioneer work with gibberilla fungus for many years with slight recognition abroad. From these findings came the first knowledge of a stem-lengthening product of the fungus. It was in 1932, when Kurosawa reported that filtrates from the fungus which caused Bakanae-byo or "foolish seedling" disease in rice (Oryza spp.) produced the same growth stimulation as the disease. It was not until

1938; however, that Yabuta and Sumiki after years of intensive study at Tokyo, officially announced the discovery of gibberellic acid. Subsequently Yabuta and Hayashi (1939) published a report on the isolation and bio-chemical aspects of gibberellic acid. In 1955 Stodola et al. repeated certain phases of Japanese work and almost simultaneously isolated Gibberellin A.3. Since then the varied effects of gibberellic acid have been studied and applied in recent years by scientists in many countries.

Numerous reports have appeared in semi-popular and scientific journals relating to the hormone-like effects of this material, which include a general treatment of the discovery, important developments, properties and uses of the gibberellic acid (Brian et al., 1958; Childers, 1957; Kemp et al., 1957; Wittwer, 1957; ARS of U.S.D.A., 1958).

Among the more spectacular effects in responsive plants has been a greatly increased rate and amount of stem elongation. Marth et al. (1956) have recorded the growth responses of 49 plants to gibberellic acid, using different concentrations and methods. Brian et al. (1954) have indicated that wheat (Triticum spp.) seedlings grown in nutrient solutions containing 5 ppm.of gibberellic acid have increased in height due to increase in length of both stem and leaf. Other plants that responded to gibberellic acid were oats (Avena sativa), clover (Trifolium spp.) cucumber (Cucumis spp.,) tomato, linseed (Linum usitatissimum) dwarf bean (Phasiolus spp.) and pea seedlings (Pisum spp.). Testing five varieties of tomatoes Bukovac and Wittwer (1956 have obtained striking increase in height as a result of 2 treatments of gibberellic acid of 10 mg. each given at a weekly interval. In another study also, Wittwer

and Bukovac (1957) have reported the effects of gibberellic acid on many economic plants. They enumerated the general effects, growth responses and other effects. Similarily Marth et al. (1956a) have published reports on the effect of gibberellic acid on several plants such as soybean (Glycine max), peanut (Arachis hypogaea), eggplant (Solanum ovigerum) and corn, showing that the heights of these treated plants were doubled or tripled. According to Sachs and Lang (1950) gibberellin A3 causes a ten-fold increase in longitudinal cell divisions in the pith region within 24 hours when applied to unvernalized Hyoscyamus niger. Studying the effect of both indole acetic acid and gibberellic acid on cotton embroys, Dure and Jensen (1957) have shown that with gibberellic acid treatment there was rapid cell division and elongation. Vlitos and Mendt (1957) have recorded the response of pea seedlings to gibberellic acid only in the presence of indoleacetic acid. Similarily Brian and Hemming (1957) have demonstrated a highly significant interaction between gibberellic acid and indole acetic acid on dwarf peas. Gibberellic acid signifi-cantly increases extension of internodes in the presence of IAA in concentration as low as 0.1 ppm., but the greatest response is obtained in concentration of 10 ppm. According to Hillman (1957) gibberellic acid further promotes the growth of internode sections of pea seedlings from red light-treated plants at all levels of IAA. Vlitos and Mendt (1957) have shown that the response of gibberellic acid in red light on Alaska pea seedlings was more marked than the response of seedlings not exposed to red light.

Applications to stimulate the growth of turf grasses and forage crops have also received much attention. Leben and Barton (1957) have

reported an apparent effect of gibberellic acid on winter dormancy of Kentucky bluegrass (Poa pratensis). Wittwer and Bukovac (1957a) have noticed more growth in early spring on Poa species and Bermudagrass induced by gibberellic acid. Quantities of the active chemical approximated 0.1, 1 and 10 ounces per acre, with foliage growth roughly proportional to the amounts applied. The results further indicated that Poa species and Bermudagrass were most responsive. Frietas et al. (1958) have shown that gibberellic sprays applied on the winter growth of Brazillian pasture grass (Panicum maximum) at 1,000 ppm. increased the height of the plants in 10 days. Hauser (1959), using 10, 100, and 1,000 ppm. of gibberellic acid has indicated that gibberellic acid at high concentrations stimulated elongation of nutgrass. The same author has also studied the interaction of dalapon and gibberellic acid on nutgrass and determined that the phytotoxicity of dalapon was increased by the presence of gibberellic acid. Gibberellic acid at a concentration of 1,000 ppm. was applied before, after, and on the same day, as the herbicidal treatment. Two applications of gibberellic acid at a concentration of 1,000 ppm. applied 7 days apart, with 10 pounds of dalapon acid equivalent caused more injury to nutgrass shoots than dalapon alone. Rao (1960) studied the effect of gibberellic acid and dalapon on Bermudagrass. His results indicated that concentrations of 50 and 100 ppm. lengthened the internode and dalapon at 1 pound acid equivalent in 15 gallons of water successfully killed aerial and subterranean parts of Bermudagrass. This action was more rapid than the treatments which received 0 and 50 ppm. of gibberellic acid.

Breaking dormancy is an important effect of gibberellic acid.

Agricultural crops like cotton and grasses such as Bermudagrass do not grow well in cool weather. In such instances the application of gibberellic acid appears to overcome the growth inhibiting effect of low temperature (Lona and Borghi,1957; Rappaport, 1956; Wittwer and Bukovac, 1957). Dormancy in peach (Amygdalus spp.) (Donoho and Walker) summer dormancy in tomato (Johnson and Liverman, 1957), epicotyl dormancy in tree phoeny (Barton et al., 1957) and dormancy in potato tubers (Rappaport, 1956), may be broken with gibberellic acid. Barton (1956) in one report has indicated that the physiological dwarfism displayed by Malus arnoldiana was overcome by the gibberellic acid treatment. Similarily certain types of both genetic and physiological dwarfism in mutant Maize (Zea mays) are also overcome with gibberellic acid (Phinney, 1956). Working on dormancy some writers have established the correlation between light requirement and gibberellic acid response in bean seedlings and pea seedlings (Lockhart, 1956 and 1957).

In all these studies, however, gibberellic acid is found to stimulate only the short growth. Leaf areas are increased and stems lengthen. Roots are not affected. Several treatments reduced the fresh and dry weight of subterranean parts. This is shown in such studies as those made by Bukovac and Wittwer (1956), Hauser (1959) and Morgan and Mees (1956). Again the new growth promoted by gibberellic acid, while otherwise normal, is often pale green. This can be offset by maintaining high fertility levels.

SURFACTANTS

Surfactants usually enhance foliar penetration of herbicides.

Their actions in the external environment of plants have been specifically and critically studied in the past. A comprehensive review has appeared in the literature on the usefulness of spray additives in increasing the effectiveness of a number of herbicides (Currier and Dybing, 1959). Root absorption of dalapon was enhanced by the addition of a surfactant (Currier, 1954). Foy (1958) using both C^{14} and Cl^{36} labelled dalapon demonstrated the advantages of using wetting agents with dalapon. Recently Leasure (1961), has conducted a study to determine the effect of surfactants on the translocation of sodium dalapon into the rhizomes of quackgrass. Tests using 2-C^{14} labelled dalapon formulations with and without a non-ionic wetting agent resulted in a definite increase in the amount of dalapon-2-C^{14} recovered from rhizomes, untreated shoots and leaves when a wetting agent is included. Sixty-three surfactants of different classes were evaluated by Jansen et al. (1961) for effects on the herbicidal activity of water-soluable forms of dalapon, 2-4-D, D.N.B.P. (triethanolamine salt of 4,6-dinitro-o-sec butylphenol) and amitrole on soybeans and corn. Their findings indicated that progressive enhancement of herbicidal activity was obtained with increases in surfactant concentrations. Polymerized salts of alkylaryl sulfonic acids, however, brought about progressive suppression of the herbicidal activity and still others were ineffective in changing the level of activity attributable to the herbicide alone.

CHAPTER III

METHODS AND PROCEDURES

This experiment was carried out in the greenhouse during the spring and summer of 1961. The effects of gibberellic acid, nitrogen and surfactants on the phytotoxicity of dalapon on Bermudagrass were studied. The treatments are outlined in Table 1. Each of the 28 treatments was replicated three times.

Two inch plugs of common Bermudagrass were planted into 1 gallon cans each containing about 4.0 k.g. of a morrell fine sandy loam in a polyethylene bag. Pots were watered whenever necessary to maintain optimum soil moisture. After the plants were 12 inches tall, 84 pots with uniform plants were selected for the experiment.

On May 15, 1961, half the number of total experimental units, 42 pots, received an application of ammonium nitrate at the rate of 400 pounds of nitrogen per acre or 2.7 grams of the fertilizer per pot. A weighed amount of the fertilizer was dissolved in water and each pot received the required aliquot. This treatment was included in the experiment in order to determine whether it would increase the efficiency of dalapon in the control of Bermudagrass.

Application of an emulsion of the potassium salt of gibberellic acid was begun on May 20, 1961. Two different concentrations of gibberellic acid, 50 ppm. and 100 ppm., were applied to the plants at three different times, 3 weeks before, 2 weeks before and 1 week before the plants were treated with dalapon. In addition, an untreated check without gibberellic acid was also used.

Table 1.--Treatments with nitrogen, surfactants, gibberellic acid and time of application of gibberellic acid to Bermudagrass prior to dalapon application.

	No nitrogen													
	No surfactant							Surfactant						
Time of gibberellic acid application in weeks prior to dalapon		1		2		3			1		2		3	
Concentration of gibberellic acid in ppm.	0	50	100	50	100	50	100	0	50	100	50	100	50	100

Table 1.--Continued

	Nitrogen													
	No surfactant							Surfactant						
Time of gibberellic acid application in weeks prior to dalapon		1		2		3			1		2		3	
Concentration of gibberellic acid in ppm.	0	50	100	50	100	50	100	0	50	100	50	100	50	100

Finally the influence of surfactants on the behavior of the herbicide was also studied by treating the plants with dalapon with and without an adjuvant. A surfactant, containing alkylarylpolyoxyethylene glycols-free fatty acids-isopropanol, was mixed with dalapon at the rate of 1/4 gallon per 100 gallons of solution. Application of the herbicide was made on June 12 at the rate of 1 pound of acid equivalent of dalapon dissolved in 15 gallons of demineralized water. Those pots which were to receive dalapon without surfactant were treated first then the adjuvant was mixed with the dalapon solution thoroughly to treat the remaining pots.

Both the gibberellic acid and dalapon were applied as foliar application. This was done by dipping the aerial portion of Bermuda-grass in the respective chemical solutions for 30 seconds (Figure 1). All the leaves were completely immersed to give a uniform application. Observations were made regularly on the general symptoms after the application of dalapon and photographs taken to record the differences between treatments. Green weights of the foliage were recorded.



Figure 1-Method of making foliar application of gibberellic acid and dalapon by dipping Bermudagrass foliage in the proper solution for 30 seconds.

CHAPTER IV

RESULTS AND DISCUSSION

The response of Bermudagrass to gibberellic acid was visible within 2 days after application. Gibberellic acid at both concentrations stimulated elongation of stem internodes of the grass. Although gibberellic acid at 50 ppm. appeared to stimulate more growth than did the 100 ppm. concentration there was no marked difference between the effects produced by the two concentrations. No severe injury to the plants was caused by this treatment although a few leaves were necrotic. All the plants treated with gibberellic acid were characterized by faster growth. During the 3 week period after application, the growth rate of the foliage was accelerated. The growth responses of Bermudagrass to gibberellic acid at 1 week, 2 weeks and 3 weeks after application are shown in Figures 2, 3 and 4. The new growth promoted by gibberellic acid was pale green, particularly in plants not receiving nitrogen.

The effect of nitrogen was seen 1 week after treatment. All the treated plants produced profuse vegetative growth as a result of the heavy application of nitrogen. The combined effect of nitrogen and gibberellic acid on foliage growth was greater than any other combination of treatments and slightly greater than nitrogen alone. The amount of foliage produced by these plants was tripled those of the untreated plants. The green weights of Bermudagrass, taken 8 weeks after treatment with dalapon are shown in Table 2. All the plants treated with nitrogen have shown increased green weight as compared to those not receiving nitrogen. The mean weight of the foliage which did not receive any nitrogen is only



Figure 2-Bermudagrass plants 1 week after application of gibberellic acid at concentrations of 0 ppm. (check),50 ppm. (1) and 100 ppm. (2).



Figure 3-Bermudagrass plants 2 weeks after application of gibberellic acid at concentrations of 0 ppm. (check), 50 ppm. (1) and 100 ppm. (2).



Figure 4-Bermudagrass plants 3 weeks after application of gibberellic acid at concentrations of 0 ppm. (check), 50 ppm. (1) and 100 ppm. (2).

Table 2.--Green weights in grams of Bermudagrass foliage 8 weeks after treatment with dalapon

(average of three replications)

	No nitrogen													
	No surfactant							Surfactant						
Time of gibberellic acid application in weeks prior to dalapon		1		2		3			1		2		3	
Concentration of gibberellic acid in ppm.	0	50	100	50	100	50	100	0	50	100	50	100	50	100
Green weight in grams	2.14	1.47	1.33	1.87	1.47	1.53	1.73	1.93	1.80	1.87	2.60	2.27	2.40	2.20

Table 2.--Continued

	Nitrogen													
	No surfactant							Surfactant						
Time of gibberellic acid application in weeks prior to dalapon		1		2		3			1		2		3	
Concentration of gibberellic acid in ppm.	0	50	100	50	100	50	100	0	50	100	50	100	50	100
Green weight in grams	10.4	4.6	5.33	5.47	4.47	6.73	6.83	9.47	7.2	3.73	8.13	8.4	10.73	9.07

1.9 grams whereas the weight of the nitrogen-treated foliage is 7.18 grams.

Bermudagrass was growing rapidly as a result of different treatments when application of dalapon was made. Dalapon caused some injury to the grass at varying degrees during the third week after application. All the dalapon-treated plants started showing signs of injury in the terminal leaves. For the first 4 weeks the action of dalapon on the plants was slow and no appreciable differences in injury was indicated between treatments. During the fifth week the toxic action of dalapon was rapid on all the nitrogen-treated plants resulting in death of the entire plant at the end of 6 weeks. Only a few leaves of the plants that did not receive nitrogen were affected (Figure 5). This clearly shows the influence of nitrogen in increasing the effectiveness of dalapon on Bermudagrass. Nitrogen produces more vegetative growth. The cells elongated resulting in thinner leaves and longer stems. This aids the penetration of dalapon into the grass foliage leading to more rapid absorption and translocation of the herbicide as well as more surface area for absorption. The results of the experiment have further shown that nitrogen had more pronounced effect on the action of dalapon than gibberellic acid though the latter also possesses stem-lengthening properties. No difference was shown in the response of the plants to dalapon between the two concentrations of gibberellic acid, 50 ppm. and 100 ppm., either among the plants not receiving nitrogen or among the nitrogen-treated plants (Figure 6). Also the surfactant used in the study did not appear to influence the effectiveness of dalapon on the grass under any treatment during the period of observation (Figure 7). The herbicide was well retained on the foliage when the plant was immersed in the solution containing the adjuvant.



Figure 5-Effect of nitrogen in increasing the toxic action of dalapon on Bermudagrass. (1) no nitrogen; (2) 400 pounds nitrogen per acre. Photograph taken 5 weeks after application of dalapon.



Figure 6-Bermudagrass plants 6 weeks after treatment with dalapon. (1) no nitrogen and 50 ppm. gibberellic acid; (2) no nitrogen and 100 ppm. gibberellic acid; (3) nitrogen and 50 ppm. gibberellic acid; (4) nitrogen and 100 ppm. gibberellic acid.



Figure 7-Bermudagrass plants 6 weeks after treatment with dalapon. (1) no nitrogen and no surfactant; (2) no nitrogen and surfactant; (3) nitrogen and no surfactant; (4) nitrogen and surfactant.

Observations also indicated that although all the nitrogen-treated plants were necrotic by the sixth week, plants treated with nitrogen as well as gibberellic acid, applied 2 weeks and 3 weeks before dalapon, died first. Plants receiving nitrogen alone and those with both nitrogen and gibberellic acid applied 1 week prior to dalapon were less responsive than the remaining ones under the main treatment of nitrogen (Figure 8). Death did not occur during the fifth week under these two treatments, nitrogen with gibberellic acid applied 1 week before dalapon and nitrogen alone. The remaining nitrogen-treated plants were necrotic at this time.

Observations made during the seventh week on the plants not receiving nitrogen did not indicate any apparent difference in injury due to dalapon. Dalapon was equally toxic to all the plants and death was slow (Figure 9). Even at the end of 7 weeks only 60% of the foliage was dead. This indicates that under the conditions of the experiment, gibberellic acid did not promote the phytotoxicity of dalapon on Bermudagrass if the plants were not treated with nitrogen. In most of the plants not receiving nitrogen, regrowth appeared at the base, whereas the nitrogen-treated plants did not show any sign of new shoots from the rhizome. Rao (1960) has reported that toxicity of dalapon on Bermudagrass was influenced by gibberellic acid at 50 ppm. Since he applied 200 pounds of nitrogen to all the treatments, his results refer only to the combined effect of nitrogen and gibberellic acid. In this respect the observation made in the present study that nitrogen in combination with gibberellic acid is better than nitrogen alone, in influencing the effectiveness of dalapon, is consistent with Rao's findings.

These findings appear to suggest that for hastening the phytotoxicity



Figure 8-Nitrogen-treated plants showing that nitrogen alone (check) and nitrogen and gibberellic acid, 50 ppm. (1) and 100 ppm. (2), applied 1 week before dalapon, are less responsive to dalapon than nitrogen and gibberellic acid, 50 ppm. (3) and 100 ppm. (4), applied 2 weeks before and nitrogen and gibberellic acid, 50 ppm. (5) and 100 ppm. (6), applied 3 weeks before dalapon. Photograph taken 5 weeks after treatment with dalapon.



Figure 9-Treatments not receiving nitrogen, showing that dalapon is equally effective on all the plants. Concentration of gibberellic acid: 0 ppm. (check); 50 ppm. (2) and 100 ppm. (3)-applied 1 week before dalapon; 50 ppm. (3) and 100 ppm. (4)-applied 2 weeks before dalapon; 50 ppm. (5) and 100 ppm. (6)-applied 3 weeks before dalapon. Photograph taken 6 weeks after application of dalapon.

of dalapon on Bermudagrass (1) nitrogen in combination with gibberellic acid is better than nitrogen alone and (2) the best time of application of gibberellic acid to nitrogen-treated plants is 2 weeks or 3 weeks prior to dalapon application.

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CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted to determine the effects of nitrogen, gibberellic acid and surfactants on the phytotoxicity of dalapon on Bermudagrass. Gibberellic acid at concentrations of 50 ppm. and 100 ppm. stimulated growth and the heavy application of 400 pounds of nitrogen per acre resulted in profuse vegetative growth of the grass.

The results of the experiment indicated that at the end of 6 weeks after treatment with dalapon, complete necrosis was recorded on all the nitrogen-treated plants. Neither the two concentrations of gibberellic acid used nor the time of application had any influence on dalapon activity in plants not receiving nitrogen. Observations also showed that nitrogen in combination with gibberellic acid (50 ppm. or 100 ppm.) applied either 2 weeks or 3 weeks before treatment with dalapon, caused more injury to the plants, than nitrogen alone. The effectiveness of dalapon was not increased by the surfactant added.

In conclusion, this study indicated that nitrogen is the most important factor studied in influencing the action of dalapon on Bermudagrass. Since nitrogen is less expensive at the rate used than gibberellic acid, the merit of this finding has a practical approach in achieving more effective control of Bermudagrass with dalapon.

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