March 12, 1960

To the Graduate Council:

I am submitting herewith a thesis written by Jivanna Sakharam Rao entitled "A Study of the Effect of Gibberellic Acid on the Phytotoxicity of Dalapon or Simazin on Bermudagrass." 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.

Henry Andrews
Major Professor

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A STUDY OF THE EFFECT OF GIBBERELLIC ACID ON THE PHYTOTOXICITY OF DALAPON OR SIMAZIN ON BERMUDAGRASS

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

Jivanna Sakharam Rao

March 1960

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33

ACKNOWLEDGEMENT

I have great pleasure in expressing my sincere thanks to: Mr. Henry Andrews for suggesting the problem, for his lavish encouragement and continued interest in the investigation; Dr. L. H. Dickson and Dr. G. E. Hunt for going through the thesis and making suitable comments; Professor L. H. Skold for his valuable suggestions; Mrs. Adina Smith for her neat execution in typing which speaks for itself.

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CHAPTER I

INTRODUCTION

The growth regulating substances having the capacity to act on the plant metabolism have gained extensive use as herbicides in recent years. Large scale use of these growth regulators has fostered a multimillion-dollar business in the United States of America, particularly in the effective control of weeds. Among many herbicides appearing on the market, comparatively few have been successful in the control or eradication of monocotyledonous plants including grasses.

Gibberellic acid, a product of the Asian fungus Gibberella fujikuroi, is claimed to possess remarkable growth promoting properties, and has been put to various uses in agriculture. Gibberellin is a general term applied to any plant stimulating substance produced by the Gibberella fungus. The present investigation was designed to determine the effect on Bermudagrass of dalapon (2,2-dichloropropionic acid) and of simazin (2-chloro-4,6-bis-ethylamino-S-triazine), after application of different concentrations of gibberellic acid. The object was to study the interaction and synergetic effects, if any, in order to determine the lowest and most economical rates of dalapon or simazin that could be applied, to control Bermudagrass. Gibberellic acid with its unique property of inducing rapid cell elongation in plant tissues was used to determine if it would increase the efficiency of either of these herbicides.

CHAPTER II

REVIEW OF LITERATURE

The research on gibberellin had its birth in Japan, in 1898. This fungus caused a disease called "bakanae" or foolish seedling of rice. Pure crystals of gibberellin, isolated in 1934, had the capacity to lengthen the internodes in plants. The interesting feature was that even very small quantities of the chemical lengthened plant stems appreciably.

Comprehensive reports on the history and early research on the hormone was published by Kurosawa (1926), Yabuta and Hayashi (1939) and subsequently reviewed in full by Brian et al. (1955, 1958). Wittwer and Bukovac (1956, 1957, 1958) reported the effect of gibberellic acid on many economic plants. They enumerated the general effects, growth responses, flowering responses and other effects. They concluded that important benefits were apparent in its use in celery production, and seed production in radish and other annual Cruciferæ.

Barton (1958) working with gibberellin stated that possibilities with gibberellin are great in making pollen grains compatible. The Agricultural Research Service of the United States Department of Agriculture (1958) published a detailed report on the properties of gibberellic acid. The report indicated that the chemical was not successful in speeding up the germination of bluegrass, as far as the grasses were concerned.

Barton and Fine (1957) recorded that gibberellic acid can be used with fungicides and bactericides without any interference with disease control. Barton and Chandler (1957) showed in great detail the morpho-

logical and physiological effects of epicotyl dormancy of tree peony (Paeonia suffruticosa). The elongation of hypocotyl and internal tissues was obvious. Barton (1956) further stated that gibberellic acid eliminated dwarf condition in Morus arnoldiana.

Marth et al. (1956) made a detailed study of responses of several species to gibberellic acid, using different concentrations and methods. Well marked responses were noticed in pinto beans (Phaseolus vulgaris), Virginia pine (Pinus virginiana), white pine (P. strobus)and white spruce (Picea glauca). The lengthening of internodes was consistently characteristic and leaves underwent a temporary chlorosis. The measurements of roots indicated that they were inversely proportional to stem elongation.

Vlitos and Mendt (1957) recorded that in the presence of indoleacetic acid, gibberellic acid action was more pronounced in lengthening internodes. The authors attempted to prove that there was a close relationship and interdependence between the action of gibberellic acid and indoleacetic acid in growing points. When decapitated shoots were applied with gibberellin, lengthening of internodes was not preminant. Chandler (1957) proved that the addition of gibberellic acid at the rate of 31.25 to 1000 mg., gave considerable increase in pollen tube germination in species of Lilum, Delphinium and Lobelia. Florence (1959) recently reported that a combination of gibberellic acid and light treatment resulted in overcoming etiolation effects.

Lert (1959) recently stated that potassium gibberellate can be economically used in Chrysanthemum production. This resulted in significantly longer stalks and often eliminated "pompon clustering" in this

species. However it was not beneficial in improving the keeping quality or advancing the date of flowering of Chrysanthemum varieties.

Weaver (1959) in California, used gibberellin at a rate of 2.5 to 100 ppm to produce a good set of large berries in varieties of grapes such as Black Cornith, Thompson seedless and Zinfandel. Prebloom sprays did hasten flowering, ripening and improving color. He discussed the possibility of spraying gibberellin on grape vines to prevent frost damage. At Derris, 1000 acres of vineyard were successfully sprayed with gibberellin in 1958.

Freitas (1958) studied the stimulating effect of gibberellic acid on winter growth of a Brazilian pasture grass, with the possibility of improving pasture during cool, dry winter months. Application of 1000 ppm of gibberellic acid increased the height of coloniacgrass (Panicum maximum) in ten days, indicating that gibberellic acid has the capacity to break dormancy.

Hauser (1959) studied in detail the responses of nutgrass (Cyperus rotundus) to the potassium salt of gibberellic acid, using three concentrations, 10, 100 and 1000 ppm applied with an atomizer. His studies indicated that gibberellic acid with higher concentrations stimulated elongation of nutgrass foliage. The weight of the leaves increased or decreased according to the treatment. The interaction of 2,4-D or dalapon was tried after spraying with gibberellic acid. It was determined that phytotoxicity of dalapon was increased by the presence of gibberellic acid. Two applications of gibberellic acid (1000 ppm) with 10 pounds of dalapon acid equivalent caused visual symptoms of toxicity on the third day of application. Bukovac (1957) studied the effect of gibberellic

acid on the induction of flowering in biennials. The Merck Company issued a comprehensive technical bulletin listing a complete bibliography on the work done with gibberellic acid. The research projects with gibberellin in the past few years proved that it is team work of four related hormonic compounds A_1, A_2, A_3 and A_4.

Dalapon is one of the latest successful herbicides recommended for the control and eradication of grassy weeds. Many preliminary and detailed investigations have been conducted with dalapon on noxious grassy weeds such as Johnsongrass and Bermudagrass, resulting in complete control in cotton fields.

Watson (1955, 1956) investigated the possibility of controlling Johnsongrass and concluded that dalapon sodium salt gave excellent control. Working with Bermudagrass, Searcy (1951) reported that a rate of 10 to 15 pounds per acre in 50 gallons of water gave good control of common Bermudagrass. Sweay (1953) recorded that any disturbance by cultivation during or after application, minimized the effects of dalapon. He further suggested that using other combinations of herbicides such as oil and dinitrophenols interferred with the absorption and translocation of the chemical. Availability of moisture for active growth of Bermudagrass was an important factor for effective action of dalapon. Application of dalapon to dormant Bermudagrass was not successful. The other grasses which were brought under control by using dalapon were saltgrass (Distichlis spicata) and carisso cane (Phragmites communis).

Danielsen et al. (1955) observed that a minimum of 4 pounds were necessary as pre-emergence treatment to control annual grasses. Corn and snap beans were tolerant up to a 6 pounds per acre rate of dalapon,

as a pre-emergence spray. Dalapon is toxic to young tomato plants; therefore, it is of no use in fields of transplanted tomato.

Stamper (1957) working with dalapon in sugar cane fields of Louisiana, indicated that 3, 4 and 6 pounds per acre were effective on Johnsongrass. He also observed that dalapon with TCA (Trichloroacetic acid) was effective on Johnsongrass.

Some anatomical changes induced by dalapon were studied by Davis (1957) in Arkansas. A pre-emergence rates of 3, 5, 16, 32, 48 and 64 pounds were made on cotton and morning glory (Ipomoea purpurea). The cotyledonary nodes were studied 6 weeks after application. Dalapon hindered with normal development of terminal meristems. The terminal tissue is either killed or suppressed. After necrosis of meristematic tissue, a band of cork-like tissue was formed. The secondary terminals were short and deformed, and unless the tertiary meristems developed, the plant became necrotic.

Bingham and McWhorter (1959) reported 95% control over grass weeds and 100% control over broad-leaved weeds, using 4 and 8 pounds per acre. This resulted in little injury to cotton and corn, but moderate injury to soybeans.

The effects of rate and time of application of dalapon on grass weeds in organic soils were investigated by Orsenigo and Guzman (1959). Two dalapon application of 5 pounds per acre or 3 applications of 3, 4, and 5 pounds per acre controlled goosegrass (Eleusine indica) and crabgrass (Digitaria sanguinalis). Westmoreland (1959) in his trials with dalapon on Bermudagrass, reported that the herbicide controlled the grass

over a wide range of soil and weather conditions.

The responses of cotton to rates of 3 and 6 pounds per acre of dalapon, were measured by Foy and Miller (1955). They were of opinion that the above rates when applied in mid-season, delayed both maturity and yield of cotton. Shear and Chappell (1955) indicated in their study that dalapon cannot be recommended as a direct spray in established corn fields. Rea (1955) recorded that a foliar application of dalapon at 6 pounds per acre in 40 gallons of water did not control annual grasses. Worsham and Giddens (1957) remarked that dalapon had no effect on soil micro-organisms; however, in some cases the herbicide stimulated growth of the micro-organisms. The Dow Chemical Company's Bulletin No. 2 (1953) recorded a comprehensive review and account of the trials with dalapon in several states on Johnsongrass, Bermudagrass and quackgrass.

The use of dalapon for pre-planting control of Johnsongrass appeared to be a feasible method of application, achieving 80% to 90% control in cotton. There was no noticeable injury to cotton at a rate of 8 pounds per acre and higher rates had no advantage. Hauser et al. (1957) suggested that 2 repeated applications of dalapon at 5 pounds each appeared to be more effective than single applications of 10, 15 or 20 pounds per acre on non-crop areas, in April and July. There was no marked difference between April and July treatments. Under 1955, weather conditions, 10 or 15 pounds per acre of dalapon gave over 90% control of Johnsongrass with minor temporary injury to corn and no injury to cotton. Foy and Miller (1956) believed that a rate of 20 pounds of dalapon per acre, applied to vigorously growing Johnsongrass (1 to 5 1/2 feet height) gave best results. Poor moisture conditions, insufficient vegetative

growth, disking or burning subsequent to treatment tended to reduce its effectiveness. Hauser and Thompson (1956) reported that Cyperus rotundus was more responsive to dalapon and 2, 4-D, than C. esculentus. Similarly working with nutgrass, Stamper and Melville (1956) reported that dalapon at 12 and 24 pounds per acre gave a faster top kill than any other herbicide or combination. Hauser et al. (1955) suggested that the best time of application was immediately after sprigging the Bermudagrass, but prior to emergence of weeds. The same authors (1955) worked the effects of dalapon on the control of Johnsongrass and nutgrass, with and without disking. Their observation was that dalapon at 10 pounds per acre in one application gave 80% and 78% reduction in stand, with and without disking respectively. The same authors (1956) in another trial used single treatments at 0, 10, 15 or 20 pounds per acre and the plots were disked after 2, 3 or 4 weeks, after the initial herbicide application. There was no significant difference in Johnsongrass control, all rates giving around 90% control.

The stability of dalapon in soils was studied by Thiegs (1955). The disappearance of the herbicide in the soil was mainly due to soil microbial activity; a bacterial population capable of utilising the compound was built up.

Watson (1955, 1956) recorded 95 to 98% top kill of Johnsongrass using 85% sodium salt of dalapon at a concentration of 1/5 pound per gallon of water. This was possible when the grass was 6 to 8 inches in height and subsequent 2 treatments of same concentration at intervals also resulted in high degree of rhizome kill.

Sweny and Fisher (1955) showed that summer annual grasses such as crabgrass, lovegrass (Eragrostis Sp.) and ticklegrass (Agrostis scabra) in cotton were controlled by directed spray of dalapon. While crabgrass responded to 12 pounds of dalapon per acre, the other grasses were controlled at rates of 3 to 6 pounds, per acre.

In sugarbeets, Alley and Belmont (1956) showed that dalapon at 6 pounds per acre proved to be a better post-emergence chemical than a pre-emergence chemical. This gave 84% control without reducing sugarbeet yields, while a rate of 10 pounds affected the yield adversely. Different rates of dalapon from 15 to 60 pounds acid equivalent per acre were applied to foliage of common weed (Phragmites spp.) at different stages of growth and different times of the year by Day (1956). Complete top kills were obtained at all rates, all stages of growth and when applied at all times of the year. Rhizomes were not killed by dalapon.

Hanson (1956) studied the effects of dalapon on Bermudagrass in sugar cane. He used 10 pounds acid equivalent in 200 gallons of water per acre, which gave control of Bermudagrass in 89 days. The author stated that the same amount in high or low gallonage per acre had the same effect. Buchholtz and Peterson (1957) noted that application of dalapon at 5 pounds per acre as spring treatment on quackgrass enabled them to reduce their competition to crop plants. A rate of 10 pounds per acre as a fall treatment gave control but not eradication. Ball (1958) tried applying dalapon by aircraft at 20 pounds in 11 gallons of water per acre on Typha spp., and Panicum hemitomon. In the former it gave 95 to 100% control, while in the latter the control was at least 95%.

Studying the effect of dalapon in lawns, Westmoreland and Duncan

(1959) reported that 1 pound in 5 gallons of water gave satisfactory control over common Bermudagrass and Zoysia when they were growing on side walks.

Autoradiography of radioactive dalapon was studied by Crafts and Foy (1959). They recorded that dalapon moves readily from treated leaves to roots. It circulates through both phloem and xylem. Dalapon was readily absorbed through the roots and rapidly swept into transpiration stream. Rate of absorption was related to root spread and leaf area. Foliar absorption was through both the stomata and cuticle. The nature of cuticle constituted one of the limiting factors. Standifer and Ennis (1956) suggested that maximum amount of absorption and translocation did not occur until 24 hours or longer after application. This compound was absorbed more effectively or rapidly under conditions of high humidity. Foy (1958) elucidated the mechanisms of absorption, distribution and metabolism of dalapon. He observed that some dalapon was retained along the transport path. Some leakage of foliar-applied dalapon occurred from roots. Dalapon stimulus was traced through three generations of wheat. It was confirmed that dalapon enters through roots and leaves. Some dalapon was retained along the transport path.

Simazin, a new herbicide with great possibilities, was introduced in the United States in 1955. Outstanding results have been reported by using the chemical particularly in controlling the annual grassy weeds and broad leaved weeds. It is a wettable powder that remains in the upper layers of the soil and gains entry through the plant roots and kills young germinating seedlings. Chlorosis is the early visual symptoms, and

ultimately the death of the plant ensues. It is expected that simazin will be very useful as a pre-emergence herbicide for annual grasses and broad leaved weeds. Many crop plants such as corn, apple, citrus, and others are tolerant to the chemical.

Roberts (1957) tried simazin with 2, 4-D and dinitro amine as pre- and post-emergence herbicide in corn. After 19 days it was noted that simazin at a rate of 8 pounds was outstanding in killing all broad leaved annuals without injuring corn.

Trevett and Burton (1957, 1958) compared simazin with other herbicides in pre-emergence treatments in corn. Four pounds per acre proved successful in controlling annual weeds. He added that a combination treatment of 3 pounds per acre DNBP (Dinitro-O-sec-butyl-phenol) and 1 pound per acre of simazin gave good control over grassy weeds.

Davis et al. (1959) studied the absorption and translocation of radioactive simazin in corn, cotton and cucumber. Cucumber was affected in 4 days, cotton in 6 days, and corn in 15 days. The distribution pattern of absorption and translocation was studied. In cucumber simazin moved in less than 12 minutes from roots to leaves. It appeared first in the veins thereafter moved to the leaf blade. He observed that there was no movement through leaves except where cuticle was broken.

CHAPTER III

METHODS AND PROCEDURES

This investigation was carried out in the greenhouse of University of Tennessee, College of Agriculture, Knoxville, during the fall 1959, and winter of 1960. Rhizomes of Bermudagrass were sprigged into greenhouse pots, each containing 4.2 kg. of Huntington silt loam soil with a pH of 6.0. Nitrogen at the rate of 200 pounds per acre, was applied to the soil to encourage rapid vegetative growth of the Bermudagrass. Pots were watered as necessary to maintain approximate optimum soil moisture. Greenhouse temperature was maintained above 65° F. After considerable growth had been made all plants were cut back to 1 inch in height to establish uniform plants for the experiment. Regrowth of plants had reached a height of 9 inches when the treatments had initiated.

The experimental work involved the treatment of Bermudagrass with gibberellic acid and subsequent treatment with dalapon or with simazin to determine the effects of the chemical on the growth of the plants. Experimental work was initiated on September 18, 1959 and four trials were conducted. Trials I and II replicated four times, trial III three times and IV twice. Several concentrations of gibberellic acid (10, 50, 100, 200, 500 and 1000 ppm) were applied to Bermudagrass, to determine the optimum concentration. Concentrations above 200 ppm caused injury to the Bermudagrass. The above preliminary observations indicated that rates of 10, 50, 100 and 200 ppm, were optimum for inducing elongation of internodes.

Gibberellic acid[1] (potassium salt) and dalapon were applied as foliar applications. This was done by dipping the aerial portion of Bermudagrass in the respective chemical solutions for 30 seconds (figure 1). All the leaves were immersed to give uniform application. For each of the four trials Bermudagrass had been treated with 10, 50, 100 and 200 ppm of gibberellic acid and in addition an untreated check was used. In trial I 4 pots of each of the above were treated with dalapon at 1 pound acid equivalent per acre in 15 gallons of water. In the case of trial II dalapon at the same rate in 30 gallons of water was applied to the Bermudagrass. In trial III simazin at 20 pounds active ingredient per acre was applied to the soil. In the fourth trial, dalapon at a concentration of 1 pound in 30 and 60 gallons of water was applied and then washed following different intervals of time. The details of this treatment are outlined in table 1. Observations were taken once a week on the general symptoms, twisting, disterting, swelling of nodes and lengthening of internodes. Photographs were taken every 2 weeks, to record the differences between treatments in trial. Dry weights of the plants were taken 16 weeks after starting of the trial.

1/The chemical used was "Gibrel" an emulsion manufactured by Merck and Company.



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

Table 1.—Rates of application of gibberellic acid and dalapon on Bermudagrass, with method of treatment.

Treatment No.	ppm Gibberellic acid	Pounds of dalapon in 30 gallons of water	Time elapsed before washing
1 (check)	0	0	no washing
2	0	1	no washing
3	100	1	15 mts.
4	100	1	30 mts.
5	100	1	1 hour
6	100	1	6 hours
7	100	1/2	30 mts.
8	100	1/2	1 hour
9	100	1/2	no washing

CHAPTER IV

RESULTS AND DISCUSSION

Preliminary observations indicated that treatment with any concentration of gibberellic acid above 200 ppm caused considerable injury to Bermudagrass. At a concentration of 10 ppm the action of gibberellic acid was manifested in visible lengthening of the internodes. Concentrations of 50 and 100 ppm resulted in a lengthening of stem internodes, the fifth internode from the apex being 0.5 cm longer than that of the untreated check. Gibberellic acid at 200 ppm caused some injury to the leaves visible 3 days after application. At all concentrations used, response of Bermudagrass to gibberellic acid was visible within 48 to 60 hours. The effect of four concentrations of gibberellic acid on Bermudagrass, 1 week after application is shown in figure 2. The shoot growth and development was greater than root development. The maximum root development was in the untreated check and was less with higher concentrations of gibberellic acid. The pots which received 200 ppm gibberellic acid had a few roots, only 1 to 2 inches long.

Trial I

Dalapon caused different degrees of injury to Bermudagrass during the 2 weeks after application. During this period, maximum visible injury occurred where 50 ppm gibberellic acid had been applied. In the treatments which received 10,100 and 200 ppm only a few leaves were affected. In the case of Bermudagrass which had received 100 and 200 ppm, no significant action of dalapon was noted during the first 2 weeks. The check which had

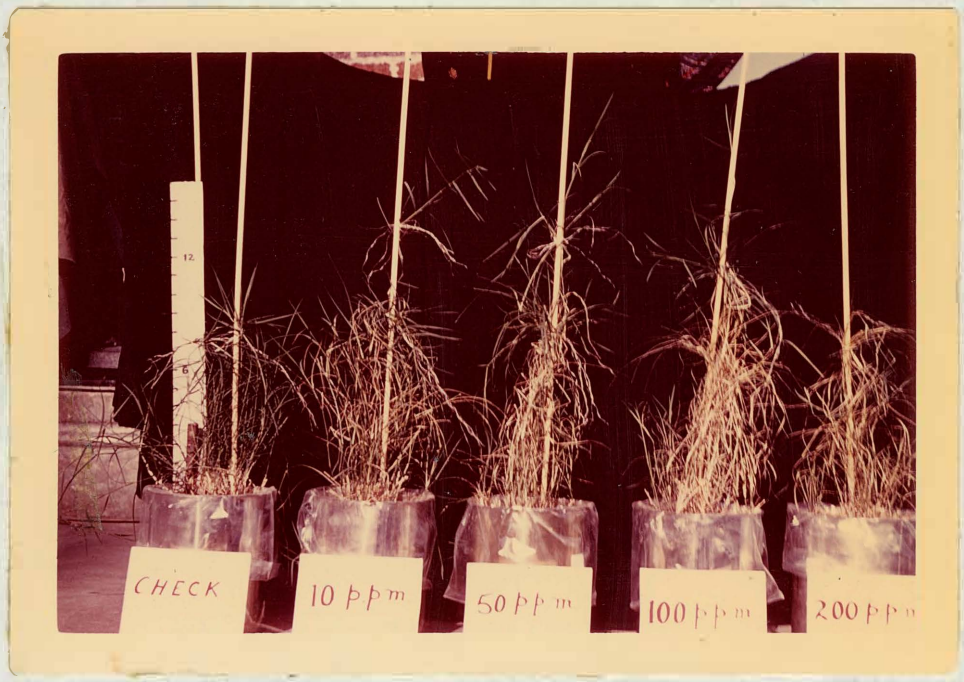


Figure 2--Bermudagrass plants 1 week after application of several concentrations of gibberellic acid.

received dalapon alone, did not show any injury during this period. This indicated that the dalapon action was rapid in the presence of 50 ppm gibberellic acid. The response of Bermudagrass at the end of 2 weeks after application of dalapon is shown in figure 3.

Three weeks after the dalapon application, Bermudagrass showed different symptoms than those seen in the first 2 weeks (Figure 4). The pots which had received 100 and 200 ppm gibberellic acid showed remarkable degree of injury during this period. There was burning of 80 to 85% of the leaves and aerial shoots. The action of dalapon was delayed, but once the action had started the injury was rapid and obvious. The grass which had received 50 ppm, in which dalapon action had started in the first 2 weeks, did not show additional injury during this period. This indicated that a prior application of 50 ppm gibberellic acid induced quicker action of dalapon, but subsequently the action was slowed down. The Bermudagrass which had received only dalapon, started showing signs of injury in the terminal leaves of lower branches.

Figure 5 shows the action of dalapon in the fifth and sixth weeks after application. Almost a complete kill of the aerial portions was observed in the pots which had received 100 and 200 ppm of gibberellic acid. In the above treatments there was no sign of any new shoots sprouting from the rhizome, indicating that dalapon also had acted on the underground parts of the plant. The treatments which had received 10 and 50 ppm showed about 50% kill of the aerial portions. In the check pot which had not received gibberellic acid, dalapon showed 30 to 35% injury during this period.



Figure 3--Bermudagrass plants treated with 1 pound acid equivalent dalapon in 15 gallons water 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 2 weeks after application of dalapon.



Figure 4--Bermudagrass plants treated with 1 pound acid equivalent of dalapon in 15 gallons of water applied 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 4 weeks after application of dalapon.



Figure 5--Bermudagrass plants treated with 1 pound acid equivalent of dalapon in 15 gallons of water applied 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 6 weeks after application of dalapon.

A complete kill of aerial and underground parts of Bermudagrass was achieved during the seventh and eighth week after application of dalapon. The Bermudagrass in the check pot did not show complete injury, but there was 75% kill of the aerial portion. Subsequent watering for 10 additional weeks was done to see whether Bermudagrass would resprout. After 16 weeks, the Bermudagrass which had received gibberellic acid and dalapon did not sprout. No new shoots were seen sprouting from the rhizomes of the control. The dry weights of all treatments after 16 weeks are presented in table 2.

Trial II

The action of simazin was initially well marked on the Bermudagrass which had an application of 50 ppm gibberellic acid. In the pots which had received 10, 100 and 200 ppm gibberellic acid there was a 20 to 40% kill of the leaves in the first 2 weeks. Only a few leaves in the check pot indicated injury (figure 6).

In the third and fourth week, after treatment there was rapid action of simazin in pots which received gibberellic acid. Bermudagrass which received 50 ppm gibberellic acid showed maximum injury. There was an increase in foliage kill during this period in the case of Bermudagrass that had received the 10 ppm, 100 ppm and 200 ppm rates (figure 7). The check pot which received only simazin had some injury to the terminal leaves of lower branches, indicating that simazin by itself caused only slight injury.

During the fifth and sixth weeks of the trial, the action of

Table 2--Average dry weights of entire Bermudagrass plants, 16 weeks after treatments with various rates of gibberellic acid followed by dalapon.

ppm Gibberellic acid	Pounds of dalapon in 15 gallons of water	Plant weight in grams
0	0	45.6
0	1	23.6
10	1	20.6
50	1	16.0
100	1	21.3
200	1	10.7



Figure 6--Bermudagrass plants treated with 20 pounds active ingredient per acre of simazin applied 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 2 weeks after application of simazin.



Figure 7--Bermudagrass plants treated with 20 pounds active ingredient per acre of simazin applied 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 4 weeks after application of simazin.

simazin was more pronounced than during the previous weeks. With the exception of the treatments which had received 10 ppm gibberellic acid and the check, all other treatments showed 80 to 85% kill of the aerial portion. A few side shoots were developing from the rhizome during this period. The check treatment and the grass which had received 10 ppm gibberellic acid, resulted in about 50% kill of the aerial portion (figure 8).

After 6 weeks it appeared that the phytotoxicity of simazin was over. The injured aerial portions did not recover but new shoots sprouted in quick succession from the rhizomiferous stems. A few dicotyledenous weeds as well as monocot seedlings were seen in the pots. This indicated that simazin in the presence of gibberellic acid could achieve a complete kill of only the aerial portion, rhizomes not being affected. Therefore simazin can not be used for eradicating Bermudagrass. The dry weights of Bermudagrass plants at the end of 16 weeks are presented in table 3.

Trial III

Dalapon at a concentration of 1 pound acid equivalent in 30 gallons of water with any combination of gibberellic acid was not successful in killing Bermudagrass. During the first 2 weeks after application of dalapon (figure 9) plants which had received 50, 100 and 200 ppm of gibberellic acid showed signs of injury. The control treatment and the one which had received 10 ppm gibberellic acid prior to the application of dalapon, did not show any injury during this period.

In the third and fourth weeks of the trial, Bermudagrass continued



Figure 8—Bermudagrass plants treated with 20 pounds active ingredient per acre of simazin 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 6 weeks after application of simazin.

Table 3.—Average dry weights of entire Bermudagrass plants, 16 weeks after treatment with various rates of gibberellic acid followed by simazin.

PPM Gibberellic acid	Pounds active ingredient per acre of simazin	Plant weight in grams
0	0	45.6
0	20	35.8
10	20	24.7
50	20	28.6
100	20	28.1
200	20	27.9



Figure 9--Bermudagrass plants treated with 1 pound acid equivalent of dalapon in 30 gallons of water applied after 1 week after application of gibberellic acid, which was applied at concentrations of 0(0), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 2 weeks after application of dalapon.

to grow. The check which had received only dalapon and the Bermudagrass which had 10 ppm gibberellic acid application, showed minor symptoms of dalapon injury (figure 10).

During the fifth and sixth weeks after the application of dalapon, all the plants exhibited 40 to 50% injury irrespective of the difference in concentration of the gibberellic acid. The visual appearance of the control plants had the same degree of injury as the Bermudagrass which had received 10 ppm gibberellic acid. The uninjured apical shoots were continuing to grow. A few new shoots were sprouting from the rhizomiferous stem (figure 11).

After 6 weeks the degree of injury caused was the same, irrespective of the earlier application of different concentrations of gibberellic acid. Development of new shoots and leaves was obvious. This indicated that dalapon at 1 pound in 30 gallons of water, involved a delayed and ineffective action. The different concentrations of gibberellic acid had some initial effects in inducing rapid action of dalapon. A prior application of 50 ppm and 100 ppm was successful in speeding up the dalapon action. Continuous watering revealed that Bermudagrass could recover after some time. The dry weights of entire plants 16 weeks after treatment are presented in table 4.

Trial IV

Dalapon at the rate of 1 pound acid equivalent in 30 gallons of water did not cause more than 20 to 25% injury to Bermudagrass at the end of 3 weeks. The above rate after the application of 100 ppm of



Figure 10--Bermudagrass treated with 1 pound acid equivalent of dalapon in 30 gallons of water applied after 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 4 weeks after application of dalapon.



Figure 11-Bermudagrass plants treated with 1 pound acid equivalent of dalapon in 30 gallons of water applied 1 week after application of gibberellic acid, which was applied at concentrations of 0(C), 10(1), 50(2), 100(3) and 200 ppm (4). Photograph taken 6 weeks after application of dalapon.

Table 4--Average dry weights of Bermudagrass plants, 16 weeks after treatment with various rates of gibberellic acid followed by dalapon.

ppm Gibberellic acid	Pounds of dalapon in 30 gallons of water	Plant weight in grams
0	0	45.6
0	1	22.6
10	1	15.8
50	1	18.8
100	1	18.6
200	1	17.9

gibberellic acid resulted in 40 to 45% injury, when dalapon was washed 15 or 30 minutes after application. Similarly when dalapon was washed after 1 or 6 hours after application, the injury was 60 to 65% when the Bermudagrass had a prior application of 100 ppm of gibberellic acid.

With 1 pound acid equivalent of dalapon in 60 gallons of water applied after application of 100 ppm of gibberellic acid, a 40% kill of aerial portion was achieved. However the unaffected shoots sprouted after 2 weeks. The above rate of dalapon with 100 ppm of gibberellic acid gave 20 to 30% aerial kill, when washed after 1/2 or 1 hour. New shoots developed after 2 weeks.

The above trial showed that the action of dalapon could be activated immediately in the presence of gibberellic acid. In the absence of gibberellic acid the action of dalapon was not only delayed but also less effective. A complete kill of Bermudagrass was not achieved in all cases.

CHAPTER V

SUMMARY AND CONCLUSIONS

Any concentration of gibberellic acid above 200 ppm caused considerable injury to Bermudagrass. Concentrations of 50 and 100 ppm lengthened the fifth internode from the apices by 0.5 cm over the check. Root development in the control treatment was the maximum and as the concentration of gibberellic acid increased, the root development was correspondingly reduced.

Dalapon at 1 pound acid equivalent in 15 gallons of water successfully killed the aerial and subterranean parts of Bermudagrass when used in combination with any of the concentrations of gibberellic acid used. The action of dalapon was most rapid in the treatment which had received an initial application of 50 ppm gibberellic acid. The check pot which had received only dalapon, did not show complete kill of Bermudagrass. Synergetic effects of gibberellic acid and dalapon were obvious.

Dalapon 1 pound acid equivalent in 30 gallons of water with any concentration of gibberellic acid used was not successful in killing Bermudagrass. The different concentrations of gibberellic acid had some effects in speeding up dalapon action, particularly 50 and 100 ppm. Some injury to Bermudagrass was visible but a complete kill of the aerial portion or the rhizome was not possible with dalapon at this rate. The phytotoxicity was terminated in 6 to 8 weeks and Bermudagrass sprouted from rhizomes and uninjured aerial shoots.

Simazin at 20 pounds active ingredient per acre in combination with 4 concentrations of gibberellic acid, did not achieve a complete kill of

Bermudagrass. A prior concentration of 50 ppm gibberellic acid helped in speeding up the action of simazin, but the phytotoxicity of simazin stopped after 6 weeks. The aerial portions were killed by simazin with all concentrations of gibberellic acid, but it was apparent that the rhizomes were not affected by simazin in the presence or absence of gibberellic acid. Therefore simazin cannot be used for eradication of Bermudagrass. The toxicity of simazin terminated at the end of 6 weeks and other weed seeds in the pots started germinating.

Dalapon at 1 pound acid equivalent per acre, in 30 or 60 gallons of water, caused 60 to 65% injury to Bermudagrass in the presence of 100 ppm of gibberellic acid, even when washed after 1 or 6 hours after application.

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