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A study of the effect of gibberellic acid on the phytotoxicity of dalapon, on *Cynodon dactylon* Pers. (*Hariyali*) *

by

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Synopsis: The interaction and synergetic effects between gibberellic acid and dalapon (2, 2-dichloropropionic acid) have been studied. A prior application of gibberellic acid increases the efficacy of the above herbicide even at very low concentrations.

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 regulating substances has fostered a multimillion dollar business in U. S. A., particularly in the effective control of weeds. Among many herbicides appearing on the market, comparatively a few have been successful in the control or eradication of monocotyledonous plants, including grasses.

Gibberellic acid, a product of the Asian fungus *Gibberella fuzikuroi*, is claimed to possess remarkable growth promoting properties, and has been put to various uses in Agriculture. Gibberelin is a general term applied to any plant stimulating substance produced by the *Gibberella* fungus. The present investigation was designed to determine the effect of dalapon (2, 2-dichloropropionic acid) on *Cynodon dactylon* Pers. (*Hariyali*) after applications 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 that could be applied to control the above weed. 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 the herbicide.

Review of Literature: The research on gibberellin had its birth in Japan, in 1898 or so. This fungus caused a disease called 'Bakane' or foolish seedling in 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 were published by Kurosawa (1926), Yabuta and Hayashi (1939) and subsequently reviewed in full by Brian *et al.* (1955, 1958). Wittwer

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and Bukovac (1956, 1957 a, b, c & d, 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 Crucifers.

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 morphological and physiological effects of epicotyl dormancy of tree peony (*Pasonia 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 a & b) 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, gibbberellic acid action was more pronounced in lengthening internodes. The authors attempted to prove that there was a close relationship and inter-dependence between the action of gibberellic acid and indoleacetic acid in growing points. When decapitated shoots were applied with gibberellin, lengthening of internodes was not prominent. 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 *Lilium*, *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 colour. He discussed the possibility of spraying gibberellin on grape vines to prevent frost damage. At Dorris, 1000 acres of vineyard were successfully sprayed with gibberellin in 1958.

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

Hauser (1959 a and b) 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 and Wittwer (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 *(C. dactylon* Pers.), 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 (1957) reported that a rate of 10 to 15 pounds per acre in 50 gallons of water gave good control of common Bermudagrass. Swezy (1955) recorded that any disturbance by cultivation during or after application, minimised 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 *(Distichilis spicata)* and carizzo cane *(Phragmites communis)*.

Danielson *et al.* (1955) observed that a minimum rate of 4 pounds was necessary as pre-emergence treatment to control annual grasses. Corn and snap beans were tolerant upto 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 sugarcane 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. 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 the 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 Orsings and Guzman (1959). Two dalapon applications 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 and Thompson (1957) suggested that 2 repeated applications of dalapon at 5 pounds each appeared to be more effective than single application 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 5½ 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 b) 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 a) suggested that the best time of application was immediately after sprigging the Bermudagrass, but prior to emergence of weeds. The same authors (1955 b) worked on 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. Hauser and Thompson (1956 a) in another trial used single treatment at 0, 10, 15 or 20 pounds per acre and the plots were disked 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 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 two treatments of same concentration at intervals also resulted

FIG. 1

Method of making foliar application of gibberellic acid and dalapon by dipping the grass foliage for 30 seconds.

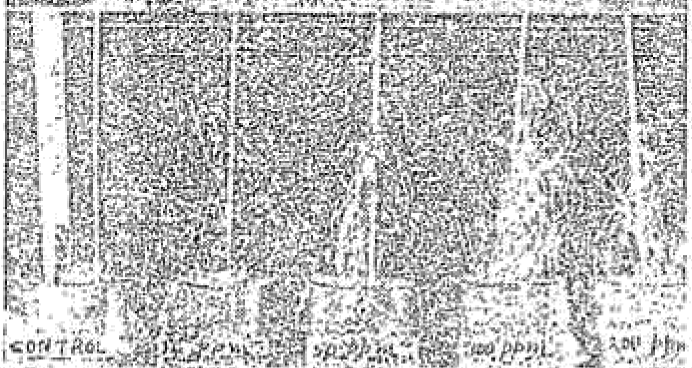

FIG. 2.

Plants of *C. dactylon* Pers. one week after application of several concentrations of gibberellic acid.

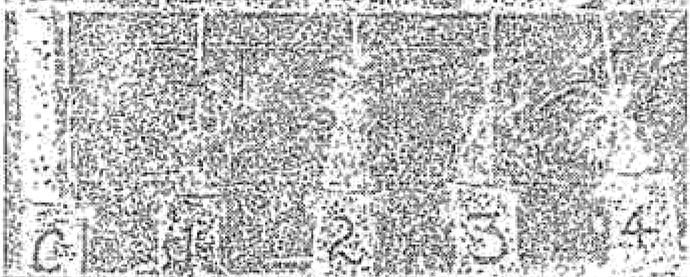

FIG. 3.

Plants of *C. dactylon* treated with one pound acid equivalent dalapon in 15 gallons of water one week after application of gibberellic acid at concentrations of 0 (C), 10 (1), 50 (2), 100 (3) and 200 ppm (4). Photograph taken two weeks after application of dalapon.

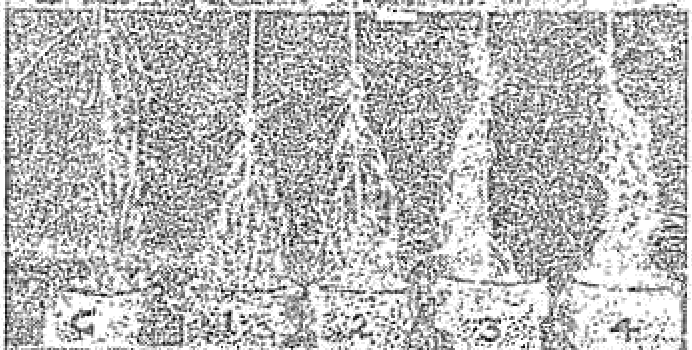

FIG. 4.

Plants of *C. dactylon* Pers. treated with one pound acid equivalent of dalapon in 15 gallons of water applied one week after application of gibberellic acid, applied as in figure 3. Photograph four weeks after application of dalapon.

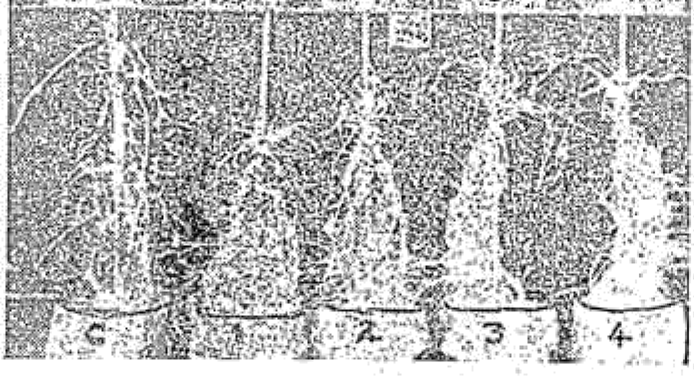

FIG. 5.

Same treatment as above and photographs taken 6 weeks after application of dalapon.

in high degree of rhizome kill. Swezy and Fisher (1955) showed that summer annual grasses such as crabgrass, lovegrass (*Eragrostis* sp.) and ticklegrass (*Agrostis seabra*) in cotton were controlled by directed spray of dalapon. While crabgras 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 Bohmont (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 *Phragmites* spp. at different stages of growth and different times of the year by Day and Swezy (1956). Complete top kills were obtained at all rates, at 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 sugarcane. 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 dalapon by aircraft spray 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 one 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.

Methods and materials: This investigation was carried out at the University of Tennessee during 1959–'60. Rhizomes of *C. dactylon* Pers. Bermudagrass - (*Hariyali*) were sprigged into greenhouse pots, each containing 4·2 kg. of Huntington silt loam soil with a pH of 6·0. Nitrogen at a rate of 200 pounds per acre, was applied to the soil to encourage rapid vegetative growth of the species. Pots were watered as and when necessary, to maintain adequate soil moisture. Greenhouse temperature was maintained above 65°F. After considerable growth all plants were cut back to one inch in height, to have uniform plants for the experiment. Regrowth of plants had reached a height of 9 inches when treatment was initiated.

The experimental work involved the treatment of the species with different strengths of gibberellic acid and subsequent application of dalapon. After preliminary observations it was seen that rates of 10, 50, 100 and 200 ppm gibberellic acid were optimum for inducing elongation of internodes.

Gibberellic acid (Potassium salt - Merck's Gibrel) and dalapon (2, 2-dichloropropionic acid) were applied as foliar applications. This was done by dipping the foliage of *C. dactylon* Pers. for 30 seconds in gibberellic acid or the herbicide (Fig. 1). The trial was conducted in four replications. The well grown plants were treated first with 10, 50, 100 and 200 ppm gibberellic acid and a week after, dalapon was applied at a rate of one pound per acre in 15 gallons of water. Observations were taken once a week on general symptoms, twisting, distorting, swelling of nodes and lengthening of internodes. Photographs were taken to show the differences and dry weight of plants were taken 16 weeks after starting of the trials.

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 c.m. 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 *hariyali*, one week after application is shown in figure 2. The shoot growth and development were 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.

Dalapon caused different degrees of injury to the species during the two 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 plants which had received 100 and 200 ppm no significant action of dalapon was noted during the first two weeks. The check which had 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 the grass at the end of two weeks after application of dalapon is shown in figure 3.

Three-weeks after the dalapon application, *hariyali* (Bermudagrass) showed different symptoms than those seen in the first two 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 pots which had received 50 ppm in which dalapon action had started in the first two 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 plants 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.

A complete kill of aerial and underground parts of the species 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 the plants would resprout. After 16 weeks, the Bermudagrass which had received gibberellic acid and dalapon did not sprout. New shoots were seen sprouting from the rhizomes of the control. The dry weights of all treatments after 16 weeks are presented in the Table.

TABLE: Average dry weights of entire plants of *C. dactylon* Pers. 16 weeks after treatments with various rates of gibberellic acid followed by dalapon.

Gibberellic acid - ppm.	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

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 (*C. dactylon* Pers.) 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 control which had received only dalapon did not show a complete kill of Bermudagrass. Synergetic effects of gibberellic acid and dalapon were obvious.

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