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Chemical Defoliation and Regrowth Inhibition in Cotton

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DIGEST

Tests were conducted during 1950, 1951 and 1952 on the feasibility of employing growth regulators and other chemicals to inhibit secondary growth following the chemical defoliation of cotton.

In the 1950-51 experiments, sucrose was added to the defoliant sprays. It significantly increased the amount of defoliation of the winter-grown plants but its effect was not pronounced in the spring-summer-grown plants, although defoliation was increased slightly. The addition of sugar also increased the amount of regrowth in most cases.

Maleic hydrazide (MH) increased the amount of defoliation in 1950-51, particularly when applied 2 weeks ahead of the defoliant. MH was effective in reducing regrowth at concentrations above 3,000 parts per million (p.p.m.) but stimulated secondary growth at lower concentrations.

Analyses of the leaf blades of the spring-summer 1951 plants showed that Shed-A-Leaf reduced the total carbohydrate content by 5 percent 72 hours following application. Over the same period of time, MH at 1,500, 3,000 and 4,500 p.p.m. induced a progressive buildup in the leaf carbohydrates. The most marked carbohydrate accumulation was obtained by pre-spraying with MH 2 weeks before the other treatments.

In 1952, the effects of MH on defoliation and regrowth inhibition were compared with those of various growth regulators and inhibitors. MH was more effective in increasing defoliation than any of the other growth regulators tested; in fact, in the spring 1952 experiments, the chlorphenoxypropionic materials severely reduced defoliation. When the synthetic auxins were combined with MH, there also was decreased defoliation.

In 1952, MH and other growth regulators applied 3 weeks before the defoliant were not as effective in checking regrowth as they were when applied with the defoliant. In most cases, they stimulated regrowth when applied 3 weeks before the defoliant.

In the spring 1952 greenhouse experiment, coumarin and amino triazole showed promise as practical regrowth inhibitors; this was confirmed in the 1952 field tests.

The amine salt of alpha-O-CPA and all MH treatments applied 3 weeks before the defoliant substantially reduced both seed germination and seedling survival. In some cases, other materials reduced germination, but it is questionable whether this was solely due to the chemicals.

With one exception, seed cotton production was not significantly affected by any of the materials.

The results of these experiments, although far from conclusive, appear to support the inhibitor hypothesis of lateral bud suppression.

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Chemical Defoliation and Regrowth Inhibition in Cotton

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REMOVAL OF COTTON LEAVES with chemical defoliants is desirable if mechanical harvesting is to be done before frost. Following defoliation, the axillary buds often are activated and new foliage or secondary growth appears. This becomes a serious problem, particularly if the grower is delayed in getting into his field with the harvester following defoliation. The new growth not only stains the lint and clogs the machine, but is very unresponsive to a second applicant of defoliant.

Experiments were conducted by the Texas Agricultural Experiment Station during 1950, 1951 and 1952 on the feasibility of employing growth regulators and other chemicals to inhibit or suppress secondary growth. This bulletin gives a summary of the results obtained.

REVIEW OF LITERATURE

Historical

In cotton, as with other dicotyledonous plants, the stem apex is a terminal bud. This bud normally produces auxin, mainly from the young developing leaves, but also to some extent from the stem apex itself (18). As long as the terminal bud is present and actively growing, it prevents the development of the lateral or axillary buds below it. This inhibition of lateral bud growth by the terminal bud is known as apical dominance.

In 1925, Snow (22) demonstrated that bud inhibition in horse bean was due to a diffusible substance originating from the terminal bud. Thimann and Skoog (28) confirmed Snow's finding and identified the inhibiting substance as auxin. They showed in their experiments that if the terminal buds were removed and replaced with agar blocks containing auxin, the axillary buds remained dormant as though the apical buds

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were intact. This type of experiment has since been extended to innumerable species of plants and the results support the original discovery of Thimann and Skoog with horse bean. Dostál (2) pointed out that leaves also exert a suppression on lateral bud growth. In the case of guayule, Smith (24) reported that mature leaves inhibit the buds in their axils more strongly than does the terminal bud itself.

Theories on Bud Inhibition

The mechanism of lateral bud inhibition by the terminal meristem is still an enigma, although several hypotheses have been proposed. One of the early explanations was that auxin at the apex, either naturally produced by the bud or artificially supplied after decapitation, in some way monopolized the available metabolites necessary for bud growth (13, 31). The axillary buds thus remained inactive because of the lack of essential nutrients or other growth factors. A slight modification of this view is the suggestion by Ferman (4) that the apical bud diverts to itself the supply of auxin precursor to the extent that the laterals are prevented from producing auxin. The work of Thimann (29), Skoog (20) and others (12) show, however, that the effect of applying auxin directly to the laterals is primarily local and does not lend much support to the above hypothesis.

Another suggested explanation is that the apical bud is able to grow at higher concentrations of auxin than the laterals. The commonly cited evidence offered in support of this idea is that the greater the distance from the terminal bud the less inhibition it has on the laterals. This effect is particularly noticeable in the growth of certain conifers and other plants which show a triangular growth habit.

Later work suggests the possible role of inhibitors in causing lateral bud inhibition. Many workers (8, 9, 15, 27, 30) have demonstrated the presence of unidentified growth-inhibiting substances in tissues of diverse plant species. Chemicals such as parasorbic acid and unsaturated lactones have been shown to have similar effects. Several workers (23, 27) have suggested the possibility that a special inhibiting substance is produced in some way, from or by auxin, in the laterals. The critical experiment to demonstrate this conclusively however, still remains, to be performed.

In reviewing our knowledge of the mechanism of bud inhibition, Thimann (18) summarized the present status quite adequately when stating, "Most of the data point to bud in-

hibition as due to auxin directly, with the mechanism probably involving the formation of an inhibitor by or under the influence of auxin."

Tissue Culture Work

An approach, which has shed some light on the problem of bud inhibition, has developed through studies of the factors necessary for the formation of buds in plant tissues. This has been the objective of the tissue culture work of Skoog and his co-workers at Wisconsin and their results are summarized in a recent paper (21). They noted that the application of indoleacetic or naphthaleneacetic acid leads to root formation with the suppression of bud formation; whereas, the application of adenine leads to bud formation. The inhibiting effect of auxin on bud formation was reversed by the addition of adenine or adenosine and phosphate. They concluded that these substances are not specific for either the formation or growth of particular organs as buds, but both are required for all types of growth. Their work indicated the interaction of auxin and adenine and other components of the nucleotides in phosphorylation systems as mediators of energy transfer reactions.

Practical Application of Bud Inhibitors

The literature concerning the control of axillary bud growth by chemicals in practical agriculture is not voluminous. In fact, most of the published reports of the applied uses of growth regulators to specifically suppress lateral bud growth have appeared mainly during the past decade. In 1947, Steinberg (25) investigated the use of synthetic auxins to inhibit axillary growth to tobacco plants following topping. He continued this work in the greenhouse and published his results in 1950 (26). His data showed that branching of plants could be completely suppressed for 28 days following the application of the growth regulators as a powder or liquid to the decapitated stem. Among the compounds included in his tests were indolebutyric acid, naphthaleneacetic acid, 2,4-dichlorophenoxyacetic acid and their derivatives. Scofield and Anderson (19) reported the successful use of white mineral oils to inhibit "suckers" of flue-cured tobacco varieties when the oil was applied at the time of terminal bud removal. Maleic hydrazide was employed successfully by Naylor and Davis (14) to inhibit axillary bud development of Turkish tobacco in greenhouse experiments in 1950. Petersen (17) extended the use of maleic hydrazide to topped Havana seed-tobacco grown in the field.

Maleic hydrazide and other growth regulators also have been utilized as a pre-harvest foliage spray to prevent sprouting of onions, potatoes, sugar beets, carrots and other root crops during storage (11, 16, 32, 33). Hall (5), in greenhouse experiments, reported increased defoliation and inhibition of secondary growth of cotton by 0.48 percent maleic hydrazide included in the defoliant sprays; whereas, Burleson and Hubbard (1) noted that only the higher dosages (0.75-1 percent) of maleic hydrazide were effective in reducing regrowth in irrigated field-grown cotton.

EXPERIMENTAL METHODS AND PROCEDURES

1950 and 1951 Experiments

Two greenhouse experiments were conducted by the Texas Station to study the effects and possible interaction of

Table 1. Effect of defoliants, sucrose and maleic hydrazide, singly and in combination, on percentage defoliation and inhibition of second growth in Stoneville 2B cotton grown in 3-gallon jars in greenhouse, winter-spring 1951[1]

Treatment	Average % defoliation	Relative amount of second growth renewal (%)	Remarks
Control	0.0	100	No remarks
5% sucrose	0.0	110	"
4800 p.p.m. maleic hydrazide	2.8	0	Stopped plant growth
2% Endothal	42.5	90	Toxic. Heavy top growth
2% Endothal + 5% sucrose	94.3	100	Heavy top and basal growth
2% Endothal + 4800 p.p.m. maleic hydrazide (1 wk. ahead of defoliant)	66.8	10	Few sparse leaves at top of plant
2% Endothal + 4800 p.p.m. maleic hydrazide (simultaneously)	64.00	10	"
2% Endothal + 5% sucrose + 4800 p.p.m. maleic hydrazide (1 wk. ahead defoliant-sugar)	88.0	20	Sucrose alleviated toxic "burning"
2% Endothal + 5% sucrose + 4800 p.p.m. maleic hydrazide (simultaneously)	81.8	10	"
2% Shed-A-Leaf	83.6	70	Heavy top growth
2% Shed-A-Leaf + 5% sucrose	94.4	90	Both top and basal growth
2% Shed-A-Leaf + 4800 p.p.m. maleic hydrazide (1 wk. ahead defoliant)	89.2	10	Some basal growth
2% Shed-A-Leaf + 4800 p.p.m. maleic hydrazide (simultaneously)	86.6	10	"
2% Shed-A-Leaf + 5% sucrose + 4800 p.p.m. maleic hydrazide (1 wk. ahead defoliant-sugar)	94.6	10	Early defoliation
2% Shed-A-Leaf + 5% sucrose + 4800 p.p.m. maleic hydrazide (simultaneously)	89.6	10	"

[1]Average of 8 plants per treatment.

maleic hydrazide (MH), sucrose, Shed-A-Leaf [SAL] (sodium chlorate-pentaborate) and Endothal (disodium 3,6-endoxohexahydrophthalate), when applied singly and in combination, upon defoliation and inhibition of second growth of cotton.

The first lot of 120 Stoneville 2B plants was grown during the winter-spring of 1950-51 in manured Houston Black clay in 3-gallon jars. At the open boll stage, the plants were divided into 15 spray treatments of 8 plants each (Table 1). The spray materials were applied by means of a power sprayer until the foliage was wet. Eight days after application the amount of defoliation was determined and all unabscised leaves removed from the plants. The plants were then continued in the greenhouse for 5 additional weeks to observe the extent of secondary growth. At the end of this period, the amount of regrowth initiated was determined by a relative scale of comparison which arbitrarily rated the amount of secondary

Table 2. Effect of Shed-A-Leaf, sucrose and maleic hydrazide, singly and in combination, on percentage defoliation and inhibition of second growth in Stoneville 2B cotton grown in 3-gallon jars during spring-summer 1951[1]

Treatment	Average % defoliation	Average weight of new growth in grams per plant
Control	0.0	4.78
2% Shed-A-Leaf	86.5	3.64
2.5% sucrose	0.0	3.42
2% Shed-A-Leaf + 2.5% sucrose (simultaneously)	87.0	4.70
1500 p.p.m. maleic hydrazide	0.0	4.97
1500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf (2 wks. ahead defoliant)	100.0	4.32
1500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf (simultaneously)	90.0	3.41
1500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf + 2.5% sucrose (2 wks. ahead defoliant-sugar)	92.5	2.75
1500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf + 2.5% sucrose (simultaneously)	93.0	3.30
3000 p.p.m. maleic hydrazide	0.0	1.80
3000 p.p.m. maleic hydrazide + 2% Shed-A-Leaf (2 wks. ahead defoliant)	91.5	0.42
3000 p.p.m. maleic hydrazide + 2% Shed-A-Leaf (simultaneously)	91.0	2.44
3000 p.p.m. maleic hydrazide + 2% Shed-A-Leaf + 2.5% sucrose (2 wks. ahead defoliant-sugar)	97.5	3.76
3000 p.p.m. maleic hydrazide + 2% Shed-A-Leaf + 2.5% sucrose (simultaneously)	95.0	1.55
4500 p.p.m. maleic hydrazide	0.0	0.38
4500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf (2 wks. ahead defoliant)	94.0	0.20
4500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf (simultaneously)	85.0	0.87
4500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf + 2.5% sucrose (2 wks. ahead defoliant-sugar)	84.0	1.64
4500 p.p.m. maleic hydrazide + 2% Shed-A-Leaf + 2.5% sucrose (simultaneously)	82.0	1.16

[1]Average of 8 plants per treatment.

Table 3. Carbohydrate content of cotton leaf blades as percentage dry weight, spring-summer 1951

Treatment and sample	Reducing sugars	Sucrose	Starch	Hemi-cellu-lose	Total
2 % SAL					
0-hour	3.20	1.70	4.65	5.83	15.38
24-hour	3.43	1.64	3.75	5.04	13.86
72-hour	2.87	0.35	2.98	4.11	10.31
1500 p.p.m. MH					
0-hour	1.02	1.25	3.46	4.90	10.63
24-hour	1.33	0.63	4.00	5.73	11.69
72-hour	1.00	1.20	4.68	6.53	13.41
1500 p.p.m.—2 wks. before 2% SAL					
24-hour	4.14	1.03	6.49	4.77	16.43
72-hour	2.39	3.89	7.00	6.80	20.08
1500 p.p.m. MH with 2% SAL					
24-hour	3.49	0.59	4.82	5.17	14.07
72-hour	4.60	1.64	3.65	4.90	14.79
1500 p.p.m. MH with 2% SAL + 2.5% sucrose					
24-hour	2.94	0.10	1.55	4.24	8.83
72-hour	3.70	2.02	4.36	4.90	14.98
1500 p.p.m. MH 2 wks. before 2% SAL + 2.5% sucrose					
24-hour	4.03	0.71	5.15	5.31	15.20
72-hour	5.45	2.28	5.20	5.17	18.10
3000 p.p.m. MH					
0-hour	1.22	0.63	6.13	5.70	13.68
24-hour	1.32	0.70	5.15	6.13	13.30
72-hour	1.43	0.75	6.66	5.60	14.44
3000 p.p.m. MH 2 wks. before 2% SAL					
24-hour	4.27	1.05	3.65	4.07	13.04
72-hour	3.81	2.38	1.55	6.00	13.74
3000 p.p.m. MH with 2% SAL					
24-hour	4.27	1.05	5.32	4.90	13.54
72-hour	4.83	1.40	6.66	5.73	18.62
3000 p.p.m. MH with 2% SAL + 2.5% sucrose					
24-hour	5.05	1.15	4.00	5.85	16.06
72-hour	4.94	1.31	8.60	5.17	20.02
3000 p.p.m. MH 2 wks. before 2% SAL + 2.5% sucrose					
24-hour	4.94	0.49	6.66	6.26	18.35
72-hour	4.35	1.33	5.59	5.31	16.58
4500 p.p.m. MH					
0-hour	1.32	0.73	4.00	4.90	10.95
24-hour	1.32	0.73	5.77	5.17	12.99
72-hour	0.91	0.48	6.13	5.10	12.62
4500 p.p.m. MH 2 wks. before 2% SAL					
24-hour	4.60	0.76	5.32	6.13	16.81
72-hour	3.60	Trace	5.30	5.04	13.94
4500 p.p.m. MH with 2% SAL					
24-hour	4.03	1.12	5.48	4.64	15.27
72-hour	5.38	2.30	8.60	5.31	21.59
4500 p.p.m. MH with 2% SAL + 2.5% sucrose					
24-hour	4.04	0.49	4.98	6.40	15.91
72-hour	2.50	1.14	3.46	5.44	12.54
4500 p.p.m. MH 2 wks. before 2% SAL + 2.5% sucrose					
24-hour	5.72	0.57	4.54	6.26	17.09
72-hour	3.16	3.42	6.49	6.40	19.47

growth produced by the controls as 100 percent. The amount of new growth in the other treatments was then assessed as percentage of that in the controls.

The second lot of 152 Stoneville 2B plants was grown during the spring and summer of 1951 and was cultured under the same conditions as the winter-spring series except that the plants were moved outside when the weather permitted. The treatments summarized in Table 2 were initiated when the bolls were starting to open and were completed 2 weeks later. Leaf-blade samples from representative plants treated with 1,500, 3,000 and 4,500 p.p.m. MH, or with 2 percent SAL, were collected just prior to application, and at 24 and 72 hours after application (Table 3). Leaf-blade samples were collected in the other treatments only at 24 and 72 hours after application, as indicated. These samples were analyzed for carbohydrate fractions according to methods previously reported (6). The amount of leaf-fall in the remaining plants was

Table 4. Effects of various growth regulators on chemical defoliation and inhibition of second growth when applied before and with a uniform concentration of monosodium cyanamide (X-5), 1951-1952

Treatment	Average percentage defoliation	Average weight of regrowth, grams
2% sodium cyanamide	77.2	15.0
2% sodium cyanamide + 4000 p.p.m. maleic hydrazide (together)	69.2	7.6
2% sodium cyanamide + 4000 p.p.m. maleic hydrazide (3 wks. before def.)	81.5	28.0
2% sodium cyanamide + 2000 p.p.m. naphthaleneacetic acid (together)	58.8	7.9
2% sodium cyanamide + 2000 p.p.m. naphthaleneacetic acid (3 wks. before def.)	80.9	10.9
2% sodium cyanamide + 2000 p.p.m. naphthaleneacetic acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. before def. + NAA)	70.3	22.1
2% sodium cyanamide + 2000 p.p.m. indolebutyric acid (together)	59.7	12.1
2% sodium cyanamide + 2000 p.p.m. indolebutyric acid (3 wks. before def.)	81.6	17.6
2% sodium cyanamide + 2000 p.p.m. indolebutyric acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. before def. + IBA)	72.0	29.4
2% sodium cyanamide + 500 p.p.m. amine salt, alpha-o-chlorophenoxypropionic acid (together)	64.5	12.0
2% sodium cyanamide + 500 p.p.m. amine salt, alpha-o-chlorophenoxypropionic acid (3 wks. before def.)	46.8	9.7
2% sodium cyanamide + 500 p.p.m. amine salt, alpha-o-chlorophenoxypropionic acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. before def. + CPA)	78.7	16.3
2% sodium cyanamide + 2000 p.p.m. pentachlorobenzoic acid (together)	63.0	16.9
2% sodium cyanamide + 2000 p.p.m. pentachlorobenzoic acid (3 wks. before def.)	87.3	20.0
2% sodium cyanamide + 2000 p.p.m. pentachlorobenzoic acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. before def. + PCBA)	65.8	23.3

determined 9 days after the last spray application, and the unabscised leaves were removed from all plants as before. The plants were then continued for 4 weeks under the usual conditions to determine regrowth. This was determined by removing all of the new growth in each treatment, weighing and calculating the average weight per plant (Table 2).

Field experiments were conducted during the summer of 1951 in which MH was combined with SAL. In general, due to the severe drouth, defoliation and regrowth inhibition were extremely erratic and no data are presented.

Table 5. Effects of various growth regulators upon cotton production and seed germination when applied before and with monosodium cyanamide (X-5), 1952

Treatment	Lint and seed, gms. per plant			% germination	% survival of healthy seedling
	Lint	Seed	Total		
2% sodium cyanamide	5.5	10.0	15.5	80	78
2% sodium cyanamide + 4000 p.p.m. maleic hydrazide (together)	4.1	8.5	12.6	72	64
2% sodium cyanamide + 4000 p.p.m. maleic hydrazide (MH 3 wks. ahead defol.)	6.0	11.2	17.2	97	37
2% sodium cyanamide + 2000 p.p.m. naphthaleneacetic acid (together)	3.8	6.6	10.4	85	83
2% sodium cyanamide + 2000 p.p.m. naphthaleneacetic acid (3 wks. ahead defol.)	5.6	11.6	17.2	90	90
2% sodium cyanamide + 2000 p.p.m. naphthaleneacetic acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. ahead def. + NAA)	4.5	8.5	13.0	89	38
2% sodium cyanamide + 2000 p.p.m. indolebutyric acid (together)	4.6	9.3	13.9	75	74
2% sodium cyanamide + 2000 p.p.m. indolebutyric acid (3 wks. ahead def.)	6.6	11.4	17.5	93	90
2% sodium cyanamide + 2000 p.p.m. indolebutyric acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. ahead def. + IBA)	5.6	11.5	17.1	88	44
2% sodium cyanamide + 500 p.p.m. amine salt, alpha-o-chlorophenoxy-propionic acid (together)	7.0	11.7	18.7	80	79
2% sodium cyanamide + 2000 p.p.m. amine salt, alpha-o-chlorophenoxy-propionic acid (3 wks. ahead def.)	3.0	6.0	9.0	40	28
2% sodium cyanamide + 500 p.p.m. amine salt, alpha-o-chlorophenoxy-propionic acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. ahead def. + CPA)	6.0	12.3	18.3	98	42
2% sodium cyanamide + 2000 p.p.m. pentachlorobenzoic acid (together)	5.4	11.3	16.7	81	81
2% sodium cyanamide + 2000 p.p.m. pentachlorobenzoic acid (3 wks. ahead def.)	5.4	9.6	15.0	86	81
2% sodium cyanamide + 2000 p.p.m. pentachlorobenzoic acid + 4000 p.p.m. maleic hydrazide (MH 3 wks. ahead def. + PCBA)	6.4	12.0	18.4	91	45

1951 and 1952 Experiments

Two greenhouse experiments were performed in 1951 and 1952 in which regrowth inhibtion by various growth regulators was studied. Two percent monosodium cyanamide (X-5) was used as the defoliant in the first experiment and in the second experiment 1 percent Endothal was used.

One hundred and twenty Stoneville 2B plants were grown in the greenhouse in the fall of 1951. The cultural conditions were the same as in the previous experiments. On December 15, when most of the bolls were mature, the plants were divided into 15 spray treatments of 8 plants each (Table 4). The inhibitors were applied 3 weeks before the defoliant in some treatments and with the defoliant on January 5, 1952 in other treatments (Table 4). The percentage defoliation was determined January 14 and all unabscised leaves were removed. The secondary growth produced was weighed January 26 and the cotton picked and ginned (Table 5). The seed were acid-delinted and 200 seed of each treatment were germinated in white silica sand. The percentage germination was recorded February 10 and the survival of healthy seedlings determined during the following week (Table 5). All seedlings received uniform amounts of Hoagland's nutrient solution as needed.

Table 6. Effects of various growth regulators upon defoliation, regrowth inhibition, seed cotton production, and seed germination when applied with uniform 1% Endothal, 1952

Treatment	Average % defoliation	Av. wt. regrowth, gms. per plant	Seed cotton, gms. per plant	% germination
1% Endothal control	57	24.4	35	90
1000 p.p.m. indoleacetic acid	57	22.5	46	73
1000 p.p.m. coumarin	75	7.7	41	90
1000 p.p.m. amino triazole	56	4.8	32	56
5000 p.p.m. amino triazole	76	3.0	35	71
1000 p.p.m. alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid	76	16.0	36	73
1000 p.p.m. alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid (ethyl ester)	60	22.3	41	68
1000 p.p.m. alpha-cyano-beta-(2,4-dichloropheny) acrylic acid (sodium salt)	80	13.7	36	77
1000 p.p.m. alphacyano-beta (2,4-dichloropheny) acrylic acid (triethanolamine salt)	90	21.0	36	64
1000 p.p.m. 2,4,5-trichloro-phenoxy propionic acid (amine salt)	3	none lethal	39	73
1000 p.p.m. dinitrophenol	58	22.3	37	90
1000 p.p.m. alpha-o-chloro-phenoxypropionic acid (amine salt)	7	5.0	41	85
1000 p.p.m. maleic hydrazide	51	15.5	34	81
1000 p.p.m. N-1-napthyl phthalmic acid	34	9.0	33	81

Table 7. Temple regrowth inhibitor field test, summer 1952[1]

Treatment	Average % defoliation	Relative amount of second growth (% controls)
Control (4 qts. Endothal per acre)	92	100
2500 p.p.m. coumarin	90	75
5000 p.p.m. coumarin	87	70
5000 p.p.m. amino triazole	90	50
5000 p.p.m. alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid	75	85
5000 p.p.m. alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid (ethyl ester)	80	100
5000 p.p.m. alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acil (sodium salt)	45	45
5000 p.p.m. maleic hydrazide	83	55
200 p.p.m. 2,4,5-trichlorophenoxypropionic acid	40	30
500 p.p.m. 2,4,5-trichlorophenoxypropionic acid	5	20
1000 p.p.m. 2,4,5-trichlorophenoxypropionic acid	5	10

[1]All materials applied with 4 quarts of Endothal per acre.

The second 1952 experiment, consisting of 112 plants (14 treatments), was much the same as the first except different inhibitors and concentrations were tested (Table 6). The treatments were applied June 3 and defoliation counts were made June 16 when all unabscised leaves were removed. The plants were continued in the greenhouse until June 24 when the weight of secondary growth was determined. The lint and seed were harvested, ginned, and germination and seedling survival counts were made (Table 6) as in the first 1952 experiment.

Some of the inhibitors showing promise in the greenhouse were tested in the summer of 1952 in the field at Temple and College Station. At the concentrations shown in Tables 7 and 8, the inhibitors were applied in Endothal at the rate of 4 quarts per acre. A hand sprayer was used. The plants in both tests were small and drouth-stressed, the Temple plants being more so than those at College Station.

Table 8. College Station regrowth inhibitor field test, summer 1952[1]

Treatment	Average % defoliation	Av. weight of regrowth, gms. per plant	Av. no. of axillary buds forced per plant	% of forced buds
Control (4 qts. Endothal per acre)	74.5	17.65	23	85
1% alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid	60.0	8.05	51	60
1% alpha-cyano-beta-(2,4-dichlorophenyl) acrylic acid (sodium salt)	87.0	7.00	20	40
0.25% coumarin	77.2	6.15	12	20
0.5% coumarin	92.9	10.90	12	24
0.75% coumarin	96.8	7.00	22	34
2% maleic hydrazide	77.0	4.95	12	24
1% amino triazole	76.0	3.63	2	4

[1]All materials applied with 4 quarts of Endothal per acre.

All treatments were applied to 100 feet of row and, in most cases where sufficient material was available, were replicated. The percentage of defoliation was determined 8 or 9 days after treatment and the amount of regrowth was assessed 2 weeks after defoliation was complete. The amount of regrowth at Temple was expressed as a percentage of the controls (which were rated at 100 percent). Axillary growth at College Station was determined in two ways: by determining the average weight of regrowth per plant in each treatment, and by counting the average number of forced buds per plant, which were expressed as a percentage of the average number of original leaves per plant per treatment.

RESULTS

1950 and 1951 Experiments

In the winter-spring series, the addition of sucrose to the Endothal and SAL sprays significantly increased the defoliation obtained (Table 1). The application of 4,800 p.p.m. of MH 1 week ahead of the defoliants also increased defoliation, as compared with the defoliants alone, but not to the extent of the sucrose-defoliant treatments. When MH was combined with the defoliants, a slightly lower percentage defoliation was obtained than with its pre-application. However, the differences are of doubtful significance. The same trends were apparent when sucrose was added to the defoliants and MH was applied 1 week prior to or with the defoliant-sugar applications.

MH reduced regrowth to 20 percent or less of that produced by the controls. In these experiments, MH was apparently equally effective in suppressing regrowth, whether applied 1 week before the defoliant or with it. However, the addition of sucrose in most cases increased the amount of axillary growth (Table 1). The effect of 4,800 p.p.m. of MH on suppressing regrowth is illustrated in Figure 1.

The effect of adding sucrose to SAL in the spring-summer experiments was not as pronounced as in the case of the winter-grown plants of 1950, although defoliation was increased slightly (Table 2). The stimulating effect of the sugar-defoliant treatment on defoliation was still apparent when it was combined with MH at 1,500 and 3,000 p.p.m., but not at the 4,500 p.p.m. level.

All levels of MH applied 2 weeks prior to the defoliant increased defoliation over SAL alone. When MH was applied

simultaneously with SAL, defoliation was reduced, as compared with pre-spraying with MH. This was particularly apparent at the 4,500 p.p.m. MH level where defoliation dropped below that of the treatment with 2 percent SAL alone (Table 2).

The weight of regrowth produced was stimulated by the 1,500 p.p.m. MH application, but was significantly reduced at the 3,000 and 4,500 p.p.m. levels. All three concentrations of MH inhibited regrowth when applied 2 weeks before the defoliant, but the combination of MH with sugar increased second growth in most cases (Table 2). The effects of SAL, sucrose and the 3 levels of MH on regrowth, when applied singly and in various combinations, are shown in Figure 2.

Analyses of the leaf-blades disclosed that SAL lowered the total carbohydrates 72 hours after application (Table 3) in accordance with a previous report (6). On the other hand, the three levels of MH, when sprayed separately, induced a progressive build-up of carbohydrates, particularly of the reserve fractions, over the same period of time. When MH was applied with SAL or with SAL + sucrose, total carbohydrates

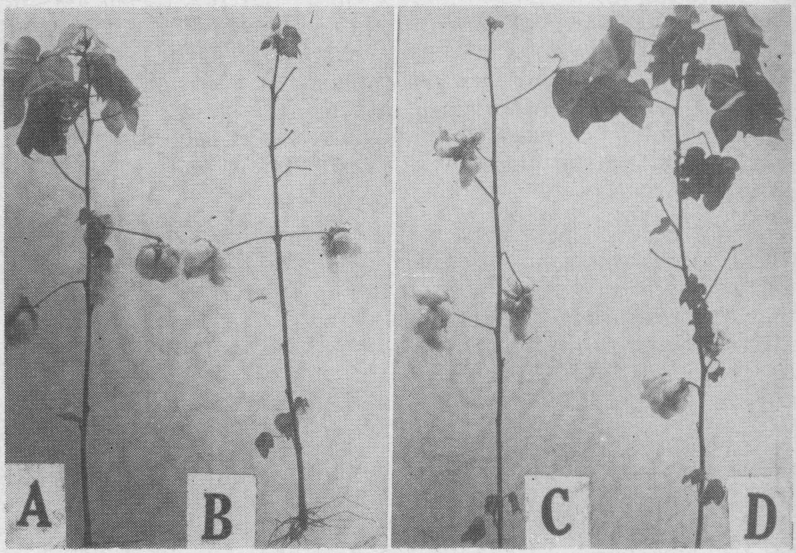

Figure 1. Effects of 4.48 percent maleic hydrazide on second growth production of plants in winter-spring 1950-51 experiments. A. Check plant defoliated with 2 percent Endothal. B. Plant defoliated with 2 percent Endothal + 0.48 percent MH. C. Plant defoliated with 2 percent Shed-A-Leaf + 0.48 percent MH. D. Check plant defoliated with 2 percent Shed-A-Leaf.

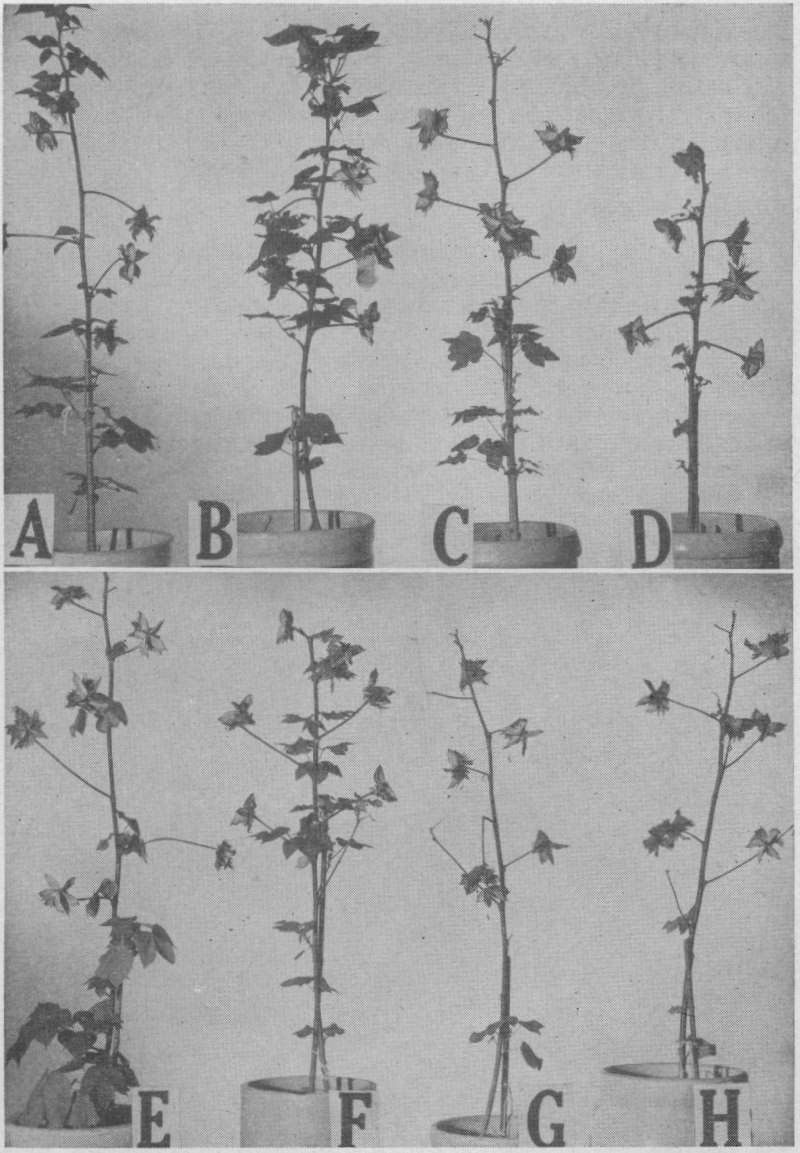

Figure 2. Representative plants of spring-summer 1951 experiments showing the effects of Shed-A-Leaf, sucrose and three levels of maleic hydrazide on regrowth when applied singly and in combination: A. control. B. 1,500 p.p.m. MH. C. 3,000 p.p.m. MH. D. 4,500 p.p.m. E. 2 percent Shed-A-Leaf F. 2.5 percent sucrose. G. 4,500 p.p.m. MH + 2 percent Shed-A-Leaf. H. 4,500 p.p.m. MH + 2 percent Shed-A-Leaf + 2.5 percent sucrose.

increased except in the 4,500 p.p.m. + SAL + sucrose treatment. With the exception of two treatments (3,000 p.p.m. MH before defoliant + sugar and 4,500 p.p.m. MH before defoliant), the most marked carbohydrate accumulation was obtained by spraying MH 2 weeks prior to the other treatments.

1952 Experiments

In the fall-winter experiment, the plants pre-sprayed with 4,000 p.p.m. MH (3 weeks before defoliant) showed more signs of advanced maturity (such as yellowed basal leaves and some abscissions, more open bolls) than the other treatments at the time of application of the defoliant on January 5. The 2,000 p.p.m. pre-application of the amine salt of alpha-ortho-chlorophenoxypropionic acid (alpha-O-CPA) was toxic and resulted in drying and death of the foliage. For that reason, the concentration of this compound was lowered to 500 p.p.m. in the later treatments (Table 4).

This experiment indicated the following (Tables 4, 5): MH was more effective in increasing defoliation than any of the other growth regulators tested. However, there was de-

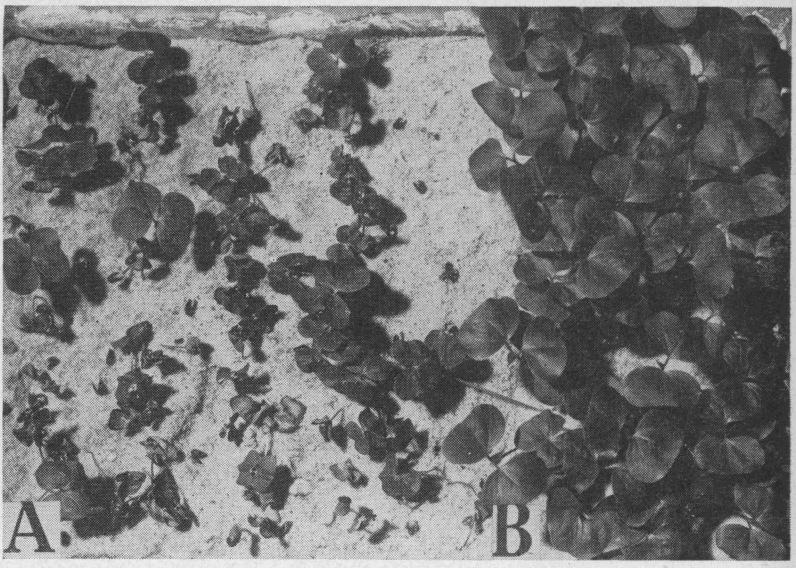

Figure 3. Effects of maleic hydrazide on seedling survival of germinated seed from plants treated with 4,000 p.p.m. maleic hydrazide 3 weeks prior to the defoliant, 1951-52 experiment. A. Seedlings from plants treated with MH. B. Seedlings from plants defoliated with 2 percent monosodium cynamid.

creased defoliation when the auxins were combined with MH. Among the auxin treatments there was essentially no difference in the amount of defoliation obtained. There was a significant difference in defoliation in all treatments in which growth regulators were applied 3 weeks before the defoliant, as compared with their application with the defoliant.

MH applied 3 weeks before the defoliant was not as effective in checking regrowth as it was when applied with the defoliant. In fact, the pre-application stimulated regrowth in all cases (Table 4). With the exception of pentachlorobenzoic acid (PCBA), the other synthetic auxins reduced regrowth when applied with the defoliant. There was essentially no difference among treatments in the regrowth produced when the growth regulators were applied 3 weeks before the defoliant, although they were less effective in reducing regrowth than when applied with the defoliant.

Seed germination tests showed that, except for the 2,000 p.p.m. pre-application of the amine salt of alpha-O-CPA, the other materials had little effect on seed viability. This material, however, as well as all early MH applications, substantially reduced seedling survival. Figure 3 shows the low rate of seedling survival of germinated seed from plants treated with 4,000 p.p.m. MH 3 weeks prior to the defoliant. With the exception of the 2,000 p.p.m. alpha-O-CPA treatment applied 3 weeks before the defoliant, there was no significant treatment effect on seed and fiber production. Decreased yield in the plants sprayed with alpha-O-CPA is attributed to its lethal action prior to maturity of the bolls. A closeup of the distorted new growth appearing in the PCBA sprayed plants is shown in Figure 4.

In the spring experiments, the CPA materials severely reduced defoliation (Table 6) and in most cases killed the leaves. The napthylphthalmic acid (NPA) treatment also resulted in considerable less defoliation than the Endothal control, whereas the other materials in some cases increased the percentage of defoliation.

The coumarin and amino triazole treatments had the least regrowth (Table 6). The acrylic acid formulations showed some promise as regrowth inhibitors and undoubtedly would have given greater suppression of regrowth if they had been tested at the higher concentration recommended by the manufacturer. The 1,000 p.p.m. concentration of the CPA and NPA materials was lethal, and the relatively low regrowth noted in these treatments was largely due to the death of the plants. Because of their detrimental effects upon defoliation,

Figure 4. Typical regrowth of plants in 1951-52 experiment. A. Normal regrowth from plant treated with 2 percent monosodium cynamid (check). B. Distorted regrowth in plant treated with 2 percent monosodium cynamid + 2,000 p.p.m. pentachlorobenzoic acid.

it appears that the use of these materials with true defoliants is undesirable. The effect of some of the more promising materials on regrowth is shown in Figure 5.

Production of seed cotton was not significantly affected by any of the treatments (Table 6). Even though the seed germination tests showed decreased percentage germination in some of the treatments, it is questionable whether this was due solely to the chemicals, as all seedlings were normal. The survival rate of the seedlings was essentially the same as the percentage germination.

The results of the inhibitor tests at Temple are given in Table 7. Treatments with 2,4,5-T caused the greatest reduction in regrowth and, as noted in the greenhouse experiments, severely reduced defoliation. As the concentration of this material was increased, drying and killing of the foliage and death of the plants became accelerated, but defoliation was reduced. In terms of both high defoliation and reduction of regrowth, amino triazole was most effective. Some difficulty

was encountered in keeping the 5,000 p.p.m. coumarin treatment in solution. As a result, much of it precipitated out in the sprayer and did not get on the foliage. A different solvent for coumarin was used in the College Station tests and reduced this loss.

Table 8 indicates that the weight of regrowth is not always an absolute index of the extent of second growth renewal. For example, in the alpha-cyano-beta (2,4-dichlorophenyl) acrylic acid treatment, the weight of the regrowth was less than half that of the controls, yet the percentage of forced axillary buds was relatively higher. This is due to a large number of small but lighter leaves being produced. Regrowth in the coumarin treatments was both terminal and lateral and the new leaves produced, although fewer, were relatively larger and heavier. The amino triazole treatment gave more desirable results. The regrowth was small, chlorotic, light in weight and was confined mostly to the basal stem.

Figure 5. Representative plants from 1952 greenhouse regrowth inhibition test. A. 1 percent Endothal control. B. 1,000 p.p.m. coumarin. C. 1,000 p.p.m. amino triazole. D. 1,000 p.p.m. alpha-cyano-beta + (2,4-Dichlorophonyl) acrylic acid.

As the concentration of coumarin was raised, the amount of defoliation was significantly increased. With the exception of the alpha-cyano-beta (2,4-dichlorophenyl) acrylic acid treatment, all materials resulted in a high or a higher percentage defoliation than the checks.

DISCUSSION

Although the data of this paper do not offer a direct solution to practical regrowth inhibition in cotton nor add greatly to the theoretical explanation of the process, they do bring out several important factors which should have ultimate bearing on both aspects of the problem, as well as the abscission process itself. The importance of leaf carbohydrates in abscission is demonstrated by a comparison of the difference in defoliation obtained in the winter and spring-grown plants in the 1951 experiments. Apparently carbohydrates were limiting in the winter-grown plants as supplementary sucrose greatly increased the percentage defoliation. On the other hand, in the spring-grown series, presumably higher in carbohydrates, added sucrose did not greatly increase defoliation. The role of sugar in axillary bud growth is also shown by the contrasting response to applied sucrose of the plants in the 1951 experiments. Previous work (6) has indicated that good defoliation is interrelated with hydrolysis, under the influence of the defoliant, and movement of carbohydrates and nitrogen out of the leaves into the stalk and possibly on into the root system. Analysis of the leaf blades of the spring-grown plants of the 1951 experiment confirmed that SAL applied by itself lowered the percentage carbohydrates by 5 percent within 72 hours after application. Undoubtedly the translocation of soluble nitrogen and carbohydrates from the leaves during the abscission process and their accumulation in the stalk and root system play an instrumental role in the differentiation and growth of the axillary buds.

In earlier work (7), it was suggested that abscission was basically controlled by the relative balance of auxin to ethylene in the plant. It was assumed that whenever the IAA content of an organ was high it inhibits the abcission process, and any factor or combination of factors that reduces IAA accelerates ethylene production, and leads ultimately to abscission of the organ. From the present work it can be noted that MH promoted abscission and forced axillary bud growth, particularly at the lower concentrations. Many workers have observed that certain levels of MH break apical dominance; whereas higher levels of MH are necessary to inhibit lateral bud growth to any extent. Leopold and Klein (10) performed

experiments showing clearly that MH acts as an auxin antagonist. They showed that inhibition of growth by high concentrations of auxin could be relieved by the addition of MH, whereas the effects of MH could be reversed by auxin. In the present work it was noted that coumarin signifcantly increased abscission in several of the experiments. This material is also known to be an auxin antagonist under certain conditions. In the 1951-52 experiments, the addition of synthetic auxins to the defoliant sprays generally retarded defoliation. Collectively, these observations confirm the supposed effect of auxin on the abscission process, and the necessity of lowering the auxin content to obtain good defoliation.

Forcing of regrowth and the detrimental effect on seedling vigor do not indicate any practical advantage of applying MH prior to the defoliant. Reduction in seed germination of cotton by early applications of MH have also been noted by Ergle and McIlrath (3). Observations that rather high concentrations of MH are required to reduce secondary growth in the field may prove its use uneconomical and impractical from the agricultural viewpoint. The use of synthetic auxins as inhibitors also does not appear to be promising, particularly in view of their effect upon abscisison. The fact that high application rates of IAA and other synthetic auxins did not effectively inhibit axillary bud development suggests that, in cotton, other factors may be more directly concerned in axillary bud suppression.

The results with coumarin, an unsaturated lactone, and other inhibiting materials, although far from conclusive, favor the hypothesis that an inhibitor is formed from or by auxin in the lateral buds. The possible use of coumarin, amino triazole and other materials for practical control of regrowth in the field, although encouraging, needs further investigation before recommendations can be made.

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