EVALUATION OF SEVERAL PLANT GROWTH REGULATORS IN SMALL GRAINS AND PEANUTS

By

CHU-HUANG WU

Bachelor of Science in Agriculture
National Taiwan University
Taipei, Taiwan
1970

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1973

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1976

EVALUATION OF SEVERAL PLANT GROWTH REGULATORS

IN SMALL GRAINS AND PEANUTS

Thesis Approved:

Paul W. Santelmann
Thesis Adviser

Eddie Basler

R W Payne

Lester W. Reed

Norman N Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

The author wishes to express his deepest appreciation to his major adviser, Dr. P. W. Santelmann, for his advice, consideration and valuable training during this study.

Sincere gratitude is extended to Dr. Eddie Basler, Dr. R. N. Payne and Dr. L. W. Reed for their guidance and counsel in this research.

Special appreciation is expressed to Stassen Soong and Dr. R. S. Matlock to provide the opportunity for the author to study in the U.S.

The author is indebted to the Department of Agronomy for providing the facilities and to many of his associates who had helped the author in many different ways.

The author is most grateful to his wife, Sue, for her patience and assistance. Special thanks are also extended to Diane Monn for typing the final copy of this manuscript.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
II.	LITERATURE REVIEW	4
	Small Grains	4
	Peanuts	12
III.	MATERIALS AND METHODS	15
	Growth Chamber Studies	15
	Small Grains	15
	Peanuts	17
	Field Studies	18
	Small Grains	18
	Peanuts	20
IV.	RESULTS AND DISCUSSION	22
	Small Grains	22
	Growth Chamber	22
	Field Studies	24
	Peanut	31
	Growth Chamber Study	31
	Field Studies	33
V.	SUMMARY AND CONCLUSIONS	38
LITERATURE CITED		41
APPENDIX		45

LIST OF TABLES

Table		Page
I.	Chemical Name of Plant Growth Regulators and Herbicides Used in the Study	3
II.	The Growth Stages of Small Grains at the Time of Treatments	19
III.	The Growth Stages of Peanut at the Time of Treatments	21
IV.	The Effect of CCC on Chlorophyll Content and Other Characteristics of Wheat in Growth Chamber	23
V.	The Effect of Some Plant Growth Regulators Applied at Early Tillering on Green Forage Weight of Small Grains	25
VI.	The Degree of Oat Lodging Affected by Plant Growth Regulators	26
VII.	Effect of Plant Growth Regulators on Grain Yields of Small Grains in 1974	27
VIII.	Effect of Plant Growth Regulators on the Grain Yield of Three Small Grains in 1975	28
IX.	Effect of SADH on Vegetative Growth of Peanut Grown in Two Soil Moisture Regimes	32
X.	Effect of SADH on Total Dry Weight and Root Weight of Peanut Grown in Two Soil Moisture Regimes	32
XI.	Effect of Plant Growth Regulators on Plant Height and Width of Spanish Peanuts	34
XII.	Effect of Plant Growth Regulators on Yield of Spanish Peanuts	35
XIII.	Effect of Fluoridamid and SADH on Yield of Two Peanut Cultivars in 1973	46

CHAPTER I

INTRODUCTION

With the steadily-increasing world population, worldwide food shortage is about to take place unless we have a breakthrough in boosting crop production or stop people breeding. It takes six to ten years to breed a 'miracle' or new improved variety of crops. Years of crossing, selection and testing is not only time and labor-consuming but costly in money. The alternative of the possible use of chemicals to help improve the yield or quality of present crop species sounds logical and promising. Therefore, plant growth regulators have raised much interest in the past five years and might be emerging as significant in the production increase of major food crops.

In causing yield or quality increases plant growth regulators also modify the plants morphologically, physiologically, and biochemically. For instance, they might change the morphology of crop plants so that more light interception and thus more photosynthesis could occur. Perhaps they might reduce unneeded or excessive vegetative growth and facilitate late applications of pesticides and also aid mechanical harvesting. They might also alleviate stress phenomena - causing drought survival, salinity tolerance, and response to both low and high temperatures. A plant growth regulator which could reduce or diminish the photorespiration of crops might provide a significant tool in food production of subhumid areas like Oklahoma.

CCC (Table I) is widely used in Europe for the treatment of cereal crops and SADH has received a federal label clearance on peanut, the performance of these two growth regulators and of several new materials is little known for Oklahoma. Experiments were conducted to evaluate the performance of several growth regulators and to study their possible uses in cereal and peanut crops.

The objectives of these studies were two fold: (1) to examine the effect of soil moisture on peanut response to SADH and the effect of CCC on chlorophyll content in the growth chamber and (2) to evaluate the morphological and yield responses of peanuts and small grains to several plant growth regulators in the field.

TABLE I

CHEMICAL NAME OF PLANT GROWTH REGULATORS AND HERBICIDES USED IN THE STUDY

Common or Code Name		Trade Name
Plant Growth Regulator		
Chlorflurenol	Methyl 2-chloro-9-hydroxy-fluorene-9-carboxylate	Maintain CF-125
Chlormequat (CCC)	2-chloroethyl-trimethyl-ammonium chloride	Cycocel
Daminozide (SADH)	Succinic acid, 2,2-dimethyl hydrazide	Kylar, Alar
Ethephon	2-chloroethylphosphonic acid	Ethrel
Fluoridamid (MBR 6033)	N-[3-[(1,1,1-trifluoromethyl-sulfonyl)amino]-4-methyl-phenyl]acetamide	Sustar
FMC-28979	2-chloro-3-(3-chloro-2-methylphenyl)propionitrile	-
MBR 12325	N-[2,4-dimethyl-5-[(trifluoro-methyl)sulfonyl]-amino]phenyl acetamide	-
TIBA	2,3,5-triiodobenzoic acid	Regim 8
Herbicide		
2,4-D	(2,4-dichlorophenoxy)acetic acid	-
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid	-
Butralin	4-(1,1-dimethylethyl)-N-(1-methylpropyl)-2,6-dinitrobenzenamine	Amex
Profluralin	N-(cyclopropylmethyl)-α,α,α-trifluoro-2,6-dinitro-N-propyl-p-totuidine	Tolban

CHAPTER II

LITERATURE REVIEW

Small Grains

Plant growth regulators were first identified in the early 1930's as significant in crop production. A milestone in the use of growth regulators was reached when Hamner and Tukey announced the herbicidal effects of 2,4-D and 2,4,5-T (Table I) (46). By mid-1950's the gibberellins and cytokinins in addition to the auxins were discovered. During the late 1940's and early 1960's growth retardants such as maleic hydrazide, chlormequat and SADH were introduced. Growth retardants have been used extensively for control of growth in flower and ornamental species (13). In agronomic crops Tolbert pioneered the work reporting the growth retarding properties of CCC in 1960 (42,43). He treated wheat seedlings in the greenhouse and reported that the most characteristic growth change of wheat was a reduction in plant height accompanied by an increase in stem diameter. The shorter and thicker stems resulted in wheat plants which grew very erect with less tendencies to lodging. The treated wheat was also darker green in color and showed earlier tillering. Lockart confirmed the ability of CCC to influence stem elongation while permitting essentially normal plant development (30,31). This property of dwarfing plants without deleterious effects had aroused interest in growth retardants from the standpoint of their possible use in field crops to reduce the incidence of lodging. Linser and Kuhn also reported that CCC-treated wheat was shorter, spring wheat more so than winter wheat. Barley was shorter when young, but later-treated plants became taller than untreated ones (29). Humphries *et al*. treated spring wheat with CCC and reported that the height of treated plants was only 60% of that of untreated plants. The percentage shortening was less as nitrogen increased. They suggested a nullifying effect of CCC in proportion to nitrogen fertilizer applied to soil. CCC also delayed ear emergence by up to 8 days. Leaf area index and net assimilation rate were decreased (24). Appley *et al*. observed the characteristic wheat response described by Tolbert. The length of the coleoptile, length to first leaf, total shoot length and dry weight of shoots were all reduced in their greenhouse studies (3). A shortening of stem length of about 29% in CCC-treated wheat and a better lodging resistance in CCC-treated spring wheat than winter wheat were reported by Martin (32). A reduction in plant height was also reported (28,19). A 19% leaf width increase of barley and no alternation of maturity by CCC treatment were reported (20).

CCC increased yield of wheat when the weather favored lodging; it could also increase the yield of wheat that would not lodge (3,24,25, 26,42). Tolbert mentioned the early tillering resulted in the appearance of bushier plants than the controls. The treated plants were also much more uniform in height than control plants and in time of heading of the grain. There were no increases in the number of leaves. He obtained some yield increase in the greenhouse. The increase was accounted for by a higher weight per kernel of grain, since the total number of kernels per head and the total number of heads of grain per plant did not vary (42). Humphries *et al*. found CCC increased grain yield by 5% by increasing the number of ears and number of grains per ear. However, plants treated with CCC had less dry matter than untreated plants at harvest (24). Humphries and Bond studied CCC in spring and winter wheat over four years. They concluded that using CCC gave a more than even chance of a profitable yield increase. CCC increased yield in two ways, either by increasing ears or grain per ear. In an unlodged crop CCC usually made the grain smaller, but by preventing lodging it can also increase size. In their studies lodging occurred in one year and CCC increased grain by as much as 30% (26). Appleby et al. reported test weights were slightly increased from CCC treatment. Yield increases were obtained in the three tall varieties while a reduction in yield was noted for semidwarf variety. The yield increase was due to the increase in stand, the increase in chlorophyll and total nitrogen per gram of fresh weight tissue from CCC-treated plants (3). Larter stated that CCC was effective in reducing plant height also tended to retard maturity. Grain yields, kernel weights, tiller number per plant, protein percentage from treated plants were not influenced by any treatments (28). Pacucci noted that CCC-treated wheat did not change in grain yield, straw yield or kernel characteristics (36). A significant increase in seed yield at high rate of CCC application and no significant increase in yield at low rate of CCC application were also reported (20). Wittwer predicted that CCC could lead to a major advance in wheat growing and influence the breeding program (45). The usefulness of CCC on wheat in western Europe is related to the high fertility level and the considerable rainfall during the ripening-harvesting period, along with the intensity of cultivation practices that produce tall leafy stalk and a tendency to lodge. It has been estimated that 20 to 25% of the wheat acreage in Germany and Austria is treated with CCC. The desirable effects on cereal crops are, however, not universal. Favorable results have not been obtained in Sweden, and it is not used in the U.S.A. or Canada, or in the East (46). Based on the use of CCC in different areas around the world, climatic factors such as temperature and moisture might have a drastic effect on the effectiveness of CCC. Farah evaluated the effect of soil moisture levels on the yield of CCC-treated spring wheat. Under CCC treatment the number of spikes, number of grains per spike, and the leaf area decreased as water stress increased. Although kernel weight of CCC-treated plants increased as water stress increased, the kernel weight of treated plants was less than that of the control. He suggested that the reduced yield of grain in the wet regime might be due to inter and intra-spike competition for available nutrients during and after heading, especially when CCC produces many spike-bearing tillers in a favorable moisture condition. In the medium water regime the effects of an increase in number of grains per ear was offset by a decrease in 1000-grain weight. In the dry regime a large increase in number of grains per ear was offset by the large decrease in 1000-grain weight plus a decrease in the ear number of about 10%. The reduction of 1000-grain weights, regardless of water regime, was about 17% (19). El Damaty et al. showed that CCC-treated wheat seedlings were more tolerant of high water stress than non-treated seedlings. However, CCC had no effects on the transpiration coefficient (17). Farah commented the reduced evapotranspiration and the evapotranspiration/grain yield ratio, particularly in the dry regimes, might indicate that in the arid regions

CCC might provide some of the conditions that tended to increase yields of wheat with limited quantities of water, whereas in regions where water for irrigation is not a limiting factor, CCC might produce some agronomic advantages; for example, many tillers, ears, and grains per ear besides reducing lodging by producing a short straw (19). Goodin et al. also said that CCC might offer advantages for increased grain production in arid regions (20). Adler et al. observed yield increase of 10 to 30% in CCC-treated winter wheat as a result of a more vigorous root system (1). Appleby et al. suspected that coleoptiles from treated seeds were stronger, enabling them to penetrate the soil more effectively than untreated ones, or that the retardation in emergence served as an escape mechanism to allow treated seedlings to avoid a period of severely cold weather (3).

Working on winter barley, Linser and Kuhn reported that barley was shorter when CCC was applied early, but later-treated plants became taller than untreated ones (29). CCC was ineffective on barley and was of little value for oats (45). Humphries found that some of the newer varieties were not shortened much by CCC (25). Larter treated two varieties of barley with one to three applications of CCC. He showed that the two varieties used exhibited a differential response. One of the concentrations used was not effective in reducing the height of mature plants. To the contrary, CCC appeared to have a slight stimulatory effect on growth when applied at particular stages of plant development (28). Humphries concluded in 1968 that the response of wheat plants to CCC might depend upon the species and variety (25). Climatic conditions also influenced the dwarfing response of barley to CCC. Moist conditions favoring a greater height reduction compared to untreated material grown under the same conditions. When environmental conditions already imposed a limitation on the growth of plants, the action of CCC in reducing height was minimized. Treatments that were effective in reducing mature height of barley also had a tendency to delay maturity. Differences in the time of maturity between treated and control plots tended to be greater under conditions of limited moisture than when moisture was adequate. There was a considerable resistance exhibited by barley to the action of CCC (28). Linser and Kuhn observed no CCC effect for barley (29). Bokhari and Youngner observed supernumerary spikes induced by CCC. It appeared to result from an interaction of cool temperatures and short days with CCC treatments. A greater grain yield on CCC-treated barley resulted directly from the greater number of tillers (6).

The mode of action of CCC has not been fully investigated. However, Birecka found that CCC did not change the amount of photosynthate moved from the leaves but increased the proportions of photosynthate in the ear, either because less photosynthate was used in stem growth or because the shorter stem stores less (4). Zeevart (48) found that CCC inhibited gibberellin synthesis. CCC and SADH inhibit the conversion of acetate to melvonic acid in gibberellin synthesis. Calder _et al_. (12) reported that SADH increased chlorophyll and starch-sugar content of clover. It increased the development of phloem fibers, the thickness of the palisade parenchyma, and the concentration of photosynthetic pigments. SADH also induced greater translocation of cellular contents (44). In general, SADH and CCC inhibit gibberellin synthesis and cell division and enlargement in the subapical meristem.

Ethylene inhibited the movement of both auxins in stem tissue and IAA in petiole tissue (33). Stanley et al. (39) summarized that ethylene caused the inhibition of lateral auxin transport. Alternation of microtubule structure and DNA synthesis and inhibition of cell division, cellular expansion and polar auxin transport.

Some information on oat response to growth regulators has been reported. CCC applied to oats reduced plant height (5,25,27,41) and lodging (27,41). Grain yield increase and nitrogen content of oat grain were increased by CCC (25,38). However, no oat yield or 1000-kernel weights increase was reported (41). Oplinger et al. reported that ethephon decreased oat yield when applied at rates above 1.12 kg/ha. Lodging and plant height were reduced; however, this was generally accompanied by yield reductions. Lodging of oats either remained unaffected or was increased by application of more than 0.56 kg/ha of ethephon at stem elongation. They also showed that reduced plant height and lodging resulted from treatments of SADH, Uni-C997, TIBA, and fluoridamid. The height reduction by these compounds was generally accompanied by grain yield reductions. Rates that were ineffective in reducing lodging had few beneficial effects on yield. They summarized their studies by saying that time and rate of application and oat cultivar were critical in influencing response of oats to several of the chemicals tested. Environmental factors, such as temperature, soil moisture, fertility and soil type may also influence particular responses. The use of these specific chemical plant growth regulators to consistently alter the agronomic or grain quality aspects of oats does not appear feasible (35).

Little work has been published on the effect of growth regulators on triticale. When no lodging occurred, CCC at 6.0 kg/ha increased triticale yields only on plots receiving no nitrogen. Protein contents and 1000 kernel weights of triticale were unchanged (41). An intense dark green coloration during the entire growing period was observed by Cole. The length of the first internode was significantly reduced by CCC. Triticale cultivars responded differently to growth regulators. However, the length of the first internode and the response to growth regulators would be useful in identifying cultivars of triticale (14).

Duke and Rutger (16) reported the effect of ethephon on winter wheat. The spring stages of application of ethephon reduced plant height and lodging, and increased the number of kernels per head. Yield, heads per plot and kernel weight were not affected by stage of treatment. They noted that if growth conditions were such that lodging was not expected to be a problem, there would be no advantage to using ethephon, inasmuch as it did not increase grain yield. Brown and Earley treated winter wheat with ethephon at late boot stage. They reduced plant height by approximately 25 cm without reducing yield. Their opinion was ethephon had little or no potential for use on spring oats because beneficial effects such as reduced height and lodging were accompanied by lower yields. The potential for use of ethephon on winter wheat could be affected by environmental and varietal differences (8). The use of ethephon as gametocide to sterilize the male flower of wheat was recently reported (18,37). The effect of ethephon on barley had been studied in Europe and the United States. Applied during the tillering stage, ethephon increased tiller numbers but resulted in no increase in yield. When it was applied at mid-boot stage yield was actually decreased (2). Ethephon had little or no potential for use on oats as reported by Brown and Earley (8).

Peanuts

The use of SADH has been remarkably successful on tree fruits and ornamentals. The use of SADH might increase yields and induce higher grades and drought resistance of peanuts (46). Halevy *et al*. found that SADH modified the position of the side branches of both erect and prostrate types of peanuts (23). SADH caused some growth reduction as main stem length of peanuts was reduced by 30 to 40% (9,10). The reduction was proportional to the amount of SADH applied and resulted from decreased internode length (9). Brown *et al*. reported that pod lengths were reduced by 4-10%. Peg length was 2.7 cm on SADH - treated plants compared to 3.4 cm for controls. Pod yields were increased in one out of three years. The increase in yield was similar for irrigated and non-irrigated peanut. Leaf area of leaflets was reduced by SADH applications. The authors concluded that although yields might be affected only slightly, if at all, beneficial effects of SADH application could occur from control of vegetative growth. Application of insecticides and fungicides with ground equipment without damage to plants were possible later in the season than usual when SADH was applied to control excessive growth. During wet growing seasons, decay of plant stems in dense stands of Spanish varieties might be avoided if plants were erect rather than lodged (9). Brittain found that SADH increased yields of runner type peanuts planted in eighteen inch rows (7). Brown and Ethredge applied SADH at 0.95 kg/ha 60 days after planting to several cultivars. They reported that pod yield of all cultivars were increased an average of 20% by SADH one out of three years. Yields of Spanish type cultivars were increased in 1971 but not in 1972, while yields of runner and Virginia cultivars were not affected. There was a trend for increases in the number of pods per plant in Spanish cultivars in all three years and in runner and Virginia types in one year. Weights per 100 pods was reduced in the Spanish cultivars in one year. They also pointed out that the lack of consistent effects of SADH on pod yields was not explainable. Variations in environment from one year to year may play a part in the erratic response (10). Daughtry et al. studied the effect of time of application of SADH. SADH tended to increase peg numbers of both cultivars beyond 90 days after planting regardless of when it was applied. Weight per pod at harvest was reduced by early SADH application (6 weeks after planting) on Spanish type cultivars. Late SADH application (8 to 12 weeks after planting) either had no effect or tended to increase weight per pod. Pod weight per plant and harvest yields were not significantly affected by time of SADH application. They also confirmed the erratic nature of yield response of SADH (15). Morris found little effect of SADH on yield or plant height. There was a decrease in pods per plant, percent sound, and mature seed and an increase in weight per seed on SADH-treated plants (34). Gorbet and Rhoads studied the response of two peanut cultivars to irrigation and SADH. SADH reduced vegetative growth and increased pod yield at low soil-water tension, but reduced the value per metric ton. SADH appeared to reduce the water required to maintain the desired soil water level in the irrigated plots (21). Wynne et al. investigated the different plant population by the use of different inter-and intra-row spacing and SADH. They concluded that a reduction in plant size either by breeding or by SADH, coupled with an increased plant population, would not lead to an increase in productivity. Although the plant size could be changed by SADH, present methods of intra- and inter-row spacings should not be changed (47).

The effect of TIBA or other growth regulators on peanut has not been evaluated. However, growth response of soybean to TIBA might be worth noting. Burton and Curley showed that TIBA produced smaller soybean leaves which were more vertically oriented, were deeper green and crinkled between the veins. The treated plants showed increased branching, shortened internodes and a conical canopy. The treated plants were shorter in height and produced 4% more pod per plant. Seed size was reduced by the TIBA treatment (11). Greer and Anderson (22) found that TIBA caused the soybean plant to change from vegetative to reproductive development more rapidly than normal. Seed yields were increased approximately 10%. Recently Tanner and Ahmed summarized the following to be typical TIBA responses: reduced height, reduced lodging, smaller leaflets, vertical orientation of leaflets, darker green color, puckered interveinal areas, and earlier maturity (40).

CHAPTER III

METHODS AND MATERIALS

Growth Chamber Studies

Small Grains

Wheat ('Triumph 64') grown in a growth chamber was used to study the effect of CCC on the chlorophyll content of the foliage. The growth chamber was programmed for 21 C at day and 10 C at night with 12 hours day length at 23.7 klux. Two wheat plants were grown in a standard 15.2 cm pot. The plants were placed outdoors for one month (January) in the winter to obtain good tillering. After bringing into the growth chamber, the plants were watered and fertilized adequately to supply sufficient moisture and nutrients for good growth. The plants were grown in the growth chamber for one month and then treated in a laboratory spray chamber. At the time of treatment the plants had 8 to 10 tillers and were about 20 to 25 cm in height. Three weeks after treatments the plant height was measured from the soil surface to the upmost point of natural stands. Both the fertile and infertile tillers were counted. The plants were then assayed for chlorophyll contents. Fifteen grams of fresh wheat leaf was ground for 5 minutes in a Waring blender in 150 ml of acetone to which about 1 gm of $CaCO_3$ had been added. The solution was filtered through 2 thickness of filter paper in a Buchner funnel. The blender was washed with additional acetone and filtered also. The filtrate was filtered once more and then placed in a separating funnel. Then 150 ml of diethyl ether and 150 ml of distilled water were added into the funnel. This mixture was allowed to stand for about 30 minutes and then the water-acetone (lower) layer was discarded. The ether layer containing chlorophyll A and B was then washed with 300 ml of water added dropwise to prevent emulsion. The water layer was then discarded and the ether layer was cooled in a 4.5 C cold room for one hour. The ether layer was also dried further by adding about 10 grams of anhydrous sodium sulphate. The sodium sulphate was then removed by filtering through filter paper in a Buchner funnel. The filtrate was cooled again in the cold room for one hour. The final extract was made up to 150 ml total volume and used as a stock solution for determining chlorophyll A and B. The extract was then diluted with diethyl ether so that the absorbance was in the correct range when reading was taken at 642 nm. The dilution was 0.2 ml of extract and 2.8 ml of ether in the sample cuvette and the blank was 3 ml of ether. The quantity of chlorophyll in the plant extract was then calculated by using Lambert-Beer law which was the fraction of the incident light absorbed by a solution at a given wavelength as related to the thickness of the absorbing layer and to the concentration of the absorbing species. With an absorbing layer of fixed thickness, the absorbency is directly proportional to the concentration of the absorbing solute. The concentration of chlorophyll A and B was calculated using the following two equations:

$$C_m = \frac{(A_n\lambda 1)(A_x\lambda 2) - (A_n\lambda 2)(A_x\lambda 1)}{(A_n\lambda 1)(A_m\lambda 2) - (A_n\lambda 2)(A_m\lambda 1)}$$

$$C_n = \frac{(A_m\lambda 1)(A_x\lambda 2) - (A_m\lambda 2)(A_x\lambda 1)}{(A_m\ 1)(A_n\ 2) - (A_m\ 2)(A_n\ 1)}$$

C_m = Concentration of chlorophyll B
C_n = Concentration of chlorophyll A
$A_n\lambda 1$ = Specific extinction of chlorophyll A at 642 nm
$A_x\lambda 2$ = Absorbency at 661 nm
$A_n\lambda 2$ = Specific extinction of chlorophyll A at 661 nm
$A_x\lambda 1$ = Absorbency at 642 nm
$A_m\lambda 2$ = Specific extinction of chlorophyll B at 661 nm
$A_m\lambda 1$ = Specific extinction of chlorophyll B at 642 nm

Peanuts

The plants were grown in a constant temperature of 21.1 C at 12 hours day length. The light intensity was 16.1 klux at the upper parts of the plants. There was one plant in a standard 30.5 cm pot. SADH was applied one month after planting to plants 25 to 30 cm tall at early blooming. Leaf area was measured 2 months after treatment with a portable area meter which utilized an electronic method of rectangular approximation with one square millimeter resolution. When the scanning head passed over a leaf, it scanned by means of a flying spot which appears on a row of narrow-band red light emitting diodes (LEDS). The scanning head base contains a lensphotodiode system which responds to the LED light. The measurements are not affected by leaf transmission properties. The plant sizes were measured 1 month and 2 months after treatments. The pots were divided into two water regimes--the wet and dry regimes. For the wet regimes the plants were watered approximately once a day to keep the soil moisture level at 12 to 15% by weight. The plants in the dry regimes were first watered to a field capacity. Whenever the soil moisture dropped to 3 to 5% by weight, the plants were re-watered to field capacity. The moisture level was detected by a soil moisture tester. The peanuts were harvested at the end of four months. The foliage to root ratio was calculated after the plants were dried in an oven for 24 hours.

Field Studies

Small Grains

Field experiments were conducted at Stillwater, Oklahoma to evaluate the performance of some plant growth regulators used in wheat, oat, barley and triticale. The soil type was Port silty clay loam with 1.8% of organic matter. The experimental site had a normal average annual rainfall of 81 cm over the growing season of small grains. The average rainfall can be broken down into 12.2 cm in the winter, 34.9 cm in the spring and 33.9 cm in the summer. No supplemental water was added. The average temperature in Stillwater was 16.1 C. The crops were planted in 25.4 cm rows in 1974 and 16.9 cm rows in 1975. The plot size was 15.2 x 33.5 m. An additional 56 kg/ha of nitrogen was applied in the spring of each year. The varieties used were 'Will' barley, 'T 131' triticale, 'Centurk' and 'Triumph 64' wheat, 'Checotah' and 'Chilloco' oat (in 1974 and 1975 respectively). The seeding rates were 78 kg/ha for wheat and triticale and 56 kg/ha for barley and oat. Growth regulator treatments were applied with an experimental plot tractor sprayer. The stages of crop growth at the time of the various treatments were shown in Table II. The experimental design was a split plot randomized complete block design. The four species of small grains were assigned to main plot and plant growth regulator treatments to subplots. The subplots had four replications. The plots were clipped with hand clippers and 2 rows by 33.5 m were harvested for both forage in the spring and grain in the summer. Visual observations were

TABLE II

THE GROWTH STAGES OF SMALL GRAINS AT THE TIME OF TREATMENTS

		I Early Tillering	II Early Jointing	III Booting
1974	Wheat	All 3-5 leaf 7.6-12.7cm tall	Wheat and triticale 28-30 cm tall	30 cm tall with 1 cm heads
	Triticale			18 cm tall with 0.5 cm heads
	Oat		Oat and barley 18 cm tall with a joint 0.3 cm above ground	28 cm tall with 1 cm head
	Barley			46 cm tall with 1 cm head
1975	Wheat	5-8 cm tall, 3 tillers	15-20 cm tall, 1 joint	60 cm tall, late boot
	Triticale	2.5 cm tall, 4-6 tillers	12.7-15 cm tall, 2 joints	70 cm tall, early boot
	Oat	5-8 cm tall, 4 tillers	7.6-10 cm tall, 1 joint	58 cm tall, early boot
	Barley	5 cm tall, 4 tillers	7.6-12.7 cm tall, 1 joint	51 cm tall, late boot

made carefully through the whole growing season for any abnormal symptom.

Peanuts

The plant growth regulators used in peanuts were evaluated at Perkins, Oklahoma. The soil type was Teller loam with 1.2 percent of organic matter. The average rainfall during the growing season in Perkins was 89 cm. An additional 10.2 cm of sprinkler irrigation was supplied in the early growing season each year. The average annual temperature was 16.1 C. However, the average summer temperature was 24 C. The entire plot area was treated with butralin or profluralin (Table I) preplant incorporated to control weeds. Hand-hoeings were conducted several times during the growing season of peanuts to keep the plots weed-free. 'Comet' peanuts were planted in a 101.6 cm row at 50.4 kg/ha. The plot size was 2 rows by 91.4 m. The chemical names of plant growth regulators and herbicides are listed in Table I. The growth stages at the time of treatments are shown in Table III. The treatments were applied with an experimental plot tractor sprayer in a randomized complete block design with four replications. Crop vigor and other symptoms were rated based on a 0 to 10 scale where 0 represents no reduction in crop vigor or no visible symptoms and a 3 would represent 30 percent reduction in crop stand or the symptoms described. The peanuts were harvested with a commercial digger and then dried in the field for about one week. The peanuts were threshed with a small commercial thresher and weighed after the soil was cleaned out.

TABLE III

THE GROWTH STAGES OF PEANUT AT THE TIME OF TREATMENTS

	I Early-Bloom	II Pegging	III Late-Bloom
1973	Early blooming 30 days after planting	-	Late blooming, early pegging, 50 days after planting
1974	15-20 cm tall 10 flowers/plant 32 days after planting	20-30 cm tall 5 pegs/stem small pods appeared	25-35 cm tall small pods developed 60 days after planting
1975	12-18 cm tall 7.6-10 cm wide 10 flowers/plant 41 days after planting	-	15-20 cm tall, 10-13 cm wide 3 pegs/stem 57 days after planting

CHAPTER IV

RESULTS AND DISCUSSION

Small Grains

Growth Chamber

CCC-treated wheat plants showed a greener and shorter leaf than untreated plants in the growth chamber. A reduction of plant growth was also noted in the growth chamber (Table IV) as the both rates of CCC significantly reduced the height of wheat. A 25 to 40% plant height reduction was obtained. The degree of height reduction was greater in the growth chamber than in the field. Generally our observations of CCC-induced morphological changes were in agreement with those reported by other authors (3,19,28,30,31,32,40,41,43). However, tiller number (both fertile and infertile) was not increased by CCC treatments in our study. Several authors indicated that the number of ears was increased and accounted for yield increase (24,26), but Larter reported that tiller numbers per plant was not affected by CCC (28). The darker green color of the wheat leaves is a result of increased chlorophyll content. The low rate of CCC (1.12 kg/ha) did not significantly increase the chlorophyll content of wheat leaves, but the high rate did. An increase of chlorophyll content by CCC was also reported by Appleby *et al*. (3).

TABLE IV

THE EFFECT OF CCC ON CHLOROPHYLL CONTENT AND OTHER CHARACTERISTICS OF WHEAT IN GROWTH CHAMBER

Chlormequat Rate (kg/ha)	Plant Height (cm)	Number of Tillers	Chlorophyll (mg/g of leaf)		
			a	b	Total
Check	41	140	0.101	0.21	0.122
1.12	30	136	0.103	0.42	0.145
2.24	22	153	0.163	0.32	0.195
$LSD_{0.05}$	3.4	22			0.032

Field Studies

Fluoridamid and MBR 12325 are closely related compounds (Table I). Both compounds applied at early stage (stage I, II of Table II) to small grains caused severe injury and stand losses of all species. Considerably less injury was observed when these compounds were applied after tillering stage. Barley and wheat were more tolerant than oat and triticale to these two compounds (Tables V, VI, VII). The injury caused by MBR 12325 was more severe than that of fluoridamid. Plants treated with MBR 12325 had greener leaves and shorter plant height. However, it also caused smaller seedheads and delayed maturity for about two weeks. The severe injury caused by the two compounds significantly decrease both the forage and grain yield of all species (Tables V, VII, VIII). Chlorflurenol, a morphactin, also caused severe chlorosis and stand reduction when used at the early growth stage. Bokhari and Youngner (6) reported that chlorflurenol caused curled spikes of barley and also supernumerary spikes. CCC did not induce supernumerary spikes in barley in our studies. Chlorflurenol was evaluated only in 1974 and was dropped in 1975 because of severe crop injury. The CCC-induced dark green color and wider leaf observed by other researchers and in our growth chamber were not noticeable in the field. Only MBR 12325 induced the darker and thicker leaves. However, height reduction caused by CCC, Uni-C-997, BASF 85559, and ethephon was observed in wheat, barley and oat, but not triticale. In 1975, ethephon and Uni-C-997 did not have any effect on plant height. However, the CCC and BASF 85559-treated wheat were 50 to 60 cm tall as compared to the untreated plants of 70 to 80 cm tall. A 30% plant height

TABLE V

THE EFFECT OF SOME PLANT GROWTH REGULATORS APPLIED AT EARLY TILLERING ON GREEN FORAGE WEIGHT OF SMALL GRAINS

Treatment	Rate (kg/ha)	Wheat 1974	Wheat 1975	Barley 1974	Oat 1974	Triticale 1974
Uni-C-997	2.24	3662*bcd**	772 abc	5555 b-e	3662 b	6104 bc
	4.48	4491 cd	649 abc	7403 e	3841 b	7683 c
CCC	1.12	4816 d	1232 c	5812 b-e	2665 b	7425 bc
	2.24	4289 bcd	1042 bc	6496 c-e	2990 b	8108 c
	4.48	-	1120 bc	-	-	-
BASF 8559	1.12	4244 bcd	1097 bc	5745 b-e	4390 b	7862 c
	2.24	3987 bcd	683 abc	7123 de	1612 ab	6686 bc
	4.48	-	1254 c	-	-	-
Fluoridamid	0.28	3136 bcd	-	4334 bc	2923 b	6932 bc
	0.56	3058 bc	-	5600 b-e	2486 b	6059 bc
	2.24	390 a	-	691 a	806 a	2699 a
MBR 12325	0.14	-	582 ab	-	-	-
	0.28	-	403 a	-	-	-
Chlorflure-nol	1.12	3203 bcd	-	5163 b-d	156 a	5252 b
	2.24	3392 bcd	-	5275 b-e	134 a	6339 bc
	3.36	2788 b	-	4244 b	179 a	6339 bc
Ethephon	0.28	-	605 ab	-	-	-
	0.56	-	828 abc	-	-	-
	1.12	-	1153 bc	-	-	-
Untreated Check		3483 bcd	840 abc	6798 d-e	4054 b	6339 bc

*Unit: kg/ha

**Values within columns followed by the same letter are not significantly different at 5% level of Duncan's multiple range test. A dash means "through".

TABLE VI

THE DEGREE OF OAT LODGING AFFECTED BY PLANT GROWTH REGULATORS

Treatment	Rate (kg/ha)	Treatment Stage	Percent Lodging
Uni-C-997	2.24	I*	50
	4.48		90
	2.24	III	30
	4.48		20
Chlormequat	1.12	I	40
	2.24		40
	1.12	II	30
	2.24		30
	1.12	III	30
	2.24		30
BASF 85559	1.12	I	30
	2.24		20
	1.12	II	50
	2.24		70
	1.12	III	50
	2.24		40
Ethephon	0.28	II	80
	0.56		30
	1.12		30
	0.28	III	40
	0.56		10
	1.12		20
Fluoridamid	0.28	I	30
	0.56		50
	2.24		-
	0.28	II	50
	0.5		70
	2.24		50
Untreated Check			50
$LSD_{0.05}$			30

*See Table II for the details of growth stage at time of treatment.

TABLE VII

EFFECT OF PLANT GROWTH REGULATORS ON GRAIN YIELDS OF SMALL GRAINS IN 1974

Treatment	Rate (kg/ha)	Treatment Stage	Grain Yield (kg/ha)		
			Wheat	Barley	Triticale
Uni-C-997	2.24	I*	1982 g-1**	1265 d-h	1926 e-g
	4.48		2060 i-1	1321 e-h	1915 e-g
	2.24	III	1881 f-1	1724 i	1870 d-g
	4.48		2161 j-1	1411 g-i	2016 fg
CCC	1.12	I	2284 1	1243 d-h	2195 g
	2.24		2172 j-1	1512 hi	1948 fg
	1.12	II	1982 g-1	1220 d-h	1825 c-g
	2.24		1993 g-1	1299 e-h	1937 fg
	1.12	III	2038 i-1	1355 e-i	1870 d-g
	2.24		2083 i-1	1299 e-h	2128 g
BASF 85559	1.12	I	1881 f-1	1366 f-i	1411 b-e
	2.24		1948 f-1	1349 e-i	2004 f-g
	1.12	II	2118 i-1	1052 c-g	1870 d-g
	2.24		2139 j-1	1512 h-i	2094 g
	1.12	III	2004 h-1	1232 d-h	1814 c-g
	2.24		2072 i-1	1142 c-h	1836 c-g
Ethephon	0.28	II	2251 k-1	1265 e-h	2060 g
	0.56		1747 f-i	1030 c-g	1769 c-g
	1.12		1993 h-1	1265 d-h	1769 c-g
	0.28	III	2161 j-1	1310 e-h	2105 g
	0.56		1859 f-h	1377 g-i	1836 c-g
	1.12		2049 i-1	649 b	1534 b-f
Fluoridamid	0.28	I	2004 h-1	1108 c-h	1892 e-g
	0.56		1646 e-h	1064 c-g	1792 c-g
	2.24		873 b	179 a	1523 b-f
	0.28	II	1971 g-1	952 b-e	1960 fg
	0.56		2228 j-1	1377 g-i	1892 e-g
	2.24		1601 d-f	952 b-e	1713 c-g
Chlorflurenol	1.12	I	1624 d-g	963 b-f	1377 b-d
	2.24		1310 c-e	862 b-d	1153 ab
	3.36		1299 cd	817 bc	1086 ab
	1.12	II	1108 bc	1232 d-h	1713 c-g
	2.24		515 a	996 b-g	851 a
	3.36		840 ab	1332 e-i	1355 bc
Untreated check			1859 f-k	1288 e-h	1892 e-g

*See Table II for the details of growth stages of crops.

**Values within the same column followed by the same letter are not significantly different at 5% level of Duncan's multiple range test. A dash means "through".

TABLE VIII

EFFECT OF PLANT GROWTH REGULATORS ON THE GRAIN YIELD OF THREE SMALL GRAINS IN 1975

Treatment	Rate (kg/ha)	Treatment Stage	Grain Yield (kg/ha) Wheat	Oat	Triticale
Uni-C-997	2.24	I*	2374 cd**	1512 a-d	985 b-e
	4.48		1814 b-d	1254 a-c	1086 b-e
	2.24	II	2105 b-d	1332 a-d	840 a-c
	4.48		2116 b-d	1489 a-d	1254 b-e
	2.24, 2.24	I,II	2072 b-d	1400 a-d	806 a-c
	4.48, 4.48		2296 b-d	963 a	1209 b-e
CCC	1.12	I	1881 b-d	1848 d	1120 b-e
	2.24		1691 b-d	1534 a-d	1120 b-e
	4.48		1960 b-d	1411 a-d	1030 b-e
	1.12	II	1937 b-d	1388 a-d	1209 b-e
	2.24		1859 b-d	1590 b-d	1052 b-e
	4.48		1736 b-d	1523 a-d	1075 b-e
	1.12	III	1960 b-d	1668 cd	1008 b-e
	2.24		1769 b-d	1232 a-d	1041 b-e
	1.12, 1.12	I,II	2430 cd	1411 a-d	963 b-e
	2.24, 2.24		2307 bd	1444 a-d	772 a-c
BASF 85559	1.12	I	2441 cd	1209 a-c	1243 b-e
	2.24		1568 bc	1523 a-d	1164 b-e
	4.48		1926 b-d	1254 a-c	1411 b-e
	1.12	II	2004 b-d	1512 a-d	1467 c-e
	2.24		2116 b-d	1377 a-d	1164 b-e
	4.48		2262 b-d	1299 a-d	896 a-d
	1.12, 1.12	I,II	2352 b-e	1142 a-c	996 b-e
	2.24, 2.24		2150 b-d	1433 a-c	1243 b-e
Ethephon	0.28	I	2072 b-d	1164 a-c	1041 b-e
	0.56		2430 cd	952 a	1243 b-e
	1.12		2206 b-d	1299 a-d	1254 b-e
	0.28	II	2029 b-e	1500 a-d	963 b-e
	0.56		2520 d	1747 b-d	1299 b
	1.12		2083 b-d	1624 b-d	1624 de
	0.56, 0.56	I,II	1904 b-d	1456 a-d	1657 e
MBR 12325	0.14	I	1433 b	1422 a-d	1052 b-e
	0.28		1523 bc	1041 ab	716 ab
	0.14	II	649 a	1489 a-d	425 a
	0.28		470 a	1120 ab	224 a
	0.14	III	2340 b-d	1288 a-d	1097 b-e
	0.28		2027 b-d	1153 a-c	918 b-e
Untreated Check			1612 b-d	1265 a-d	1064 b-e

*See Table II for details of growth stage at time of treatment.
**Values within the same column followed by the same letter are not significantly different at 5% level of Duncan's multiple range test.

reduction by CCC reported by other authors (19,24,28,32) was confirmed. MBR 12325 reduced the plant height to about 43 cm. Unfortunately, the height reduction was accompanied by stand reduction and yield decrease.

Green forage yields for 1974 are shown in Table V. Only wheat forage was harvested in 1975 and the results were similar to 1974. No significant forage yield increase was obtained from any plant growth regulator treatments. However, there was a trend for CCC and BASF 85559 to increase wheat and triticale forage production, and Uni-C-997 to increase wheat and barley forages in 1974. The trend for CCC to increase wheat forage was observed again in 1975. The following treatments significantly reduced the forage weights: fluoridamid at 2.24 kg/ha, chlorflurenol at 3.36 kg/ha and MBR 12325 at 0.28 kg/ha. The significant reduction of forage by the high rate of these compounds were primarily due to stand reduction and severe injury.

Lodging did not occur in wheat, barley or triticale during these experiments. Severe oat lodging occurred in 1974. As shown in Table VI Uni-C-997, CCC and ethephon had the potential to reduce oat lodging when applied after tillering (stage II or III). Oplinger et al. (41) obtained a reduction in lodging by Uni-C-997 and fluoridamid and others have with CCC (27,41).

Owing to the severe lodging oat yields were not taken in 1974. Barley was not harvested in 1975 due to an infestation of disease. Tables VII and VIII show the effect of plant growth regulators on grain yields. Although there was a trend that Uni-C-997, CCC, BASF 85559, and ethephon increased the yield of wheat and triticale, only 1.12 kg/ha CCC applied at the 3 to 5 leaf in wheat and 2.24 kg/ha Uni-C-997 at early boot resulted in a significant yield increase in 1974. It also appeared that there was no significant yield differences due to growth stage of application. It might be noteworthy, however, that the application at boot stage with ground equipment damaged crops by tractor trampling. Fluoridamid applied at 3 to 5 leaf stage at 2.24 kg/ha and chlorflurenol applied before booting significantly reduced grain yields of all species of small grains. Barley and triticale were less consistent in response to plant growth regulators. Barley was the least responsive species in 1974. Grain yield was not significantly increased over the untreated check by any chemicals on any application stage in 1975. The trend of yield increases by Uni-C-997, CCC, BASF 85559 and ethephon treatments were obtained in 1975 again. The increases ranged from 80 to 900 kg/ha. Oat and triticale showed lack of consistency in response to these plant growth regulators. MBR 12325 applied at early jointing stage significantly reduced the grain yield of wheat and triticale. When the compound was applied at boot stage it did not cause any yield reduction.

These two years of data indicated that the small grains did not consistently respond to plant growth regulators in proportion to their concentrations. The high rate of these compounds did not increase the responses obtained. The split or repeated application of a compound did not significantly enhance productivity, even though a higher yield was obtained from repeated application. It also appeared that late tillering stage might be the ideal growth stage for plant growth regulator application. At early tillering or late booting stage crop injury was liable to happen from chemicals toxicity or mechanical trampling respectively.

Peanut

Growth Chamber Study

The plant height, width, leaf area and internode length of peanuts grown in the wet regime was greater than for those grown in dry regime (Table IX). The SADH treatments significantly reduced the plant size (both height and width) in wet growing condition. The plant size was not significantly affected in dry regime. There was no difference in SADH effect on plant size between wet and dry condition. Even though a greener and thicker leaf was induced by SADH, the average leaf area was not affected by SADH. This founding is contradictory to others (9). We also found no difference in average internode length between SADH treated and untreated peanuts, even though the main stem length (plant height) was reduced by SADH application.

The total dry weight of peanuts was reduced under the dry regime. However, the influence of SADH on total dry weight was not consistent. The dry root weight was significantly increased by 2.24 kg/ha rate of SADH in either wet or dry condition. The more extensive root system might explain the observation of Gorbet and Rhoads (21). They stated that SADH appeared to reduce the water required to maintain the desired soil water level in the irrigated plots. However, the reduced plant size by SADH exposed the field to water evaporation. Under a drought condition, SADH-treated peanuts received more sun scorching. The rapid moisture loss from less ground cover may explain our yield reduction from SADH treatment in 1975's field study. The increase in root weight was overridden under drought conditions.

TABLE IX

EFFECT OF SADH ON VEGETATIVE GROWTH OF PEANUT GROWN IN TWO SOIL MOISTURE REGIMES

SADH Conc. (kg/ha)	Plant Height (cm)		Plant Width (cm)		Leaf Area (cm^2)		Internode Length(cm)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Check	27.7	20.3	30.7	21.3	10.47	8.37	1.60	1.49
1.12	21.0	18.3	25.3	22.6	9.78	8.84	1.80	1.54
2.24	20.3	17.3	25.3	19.0	10.07	8.20	1.53	1.59
$LSD_{0.05}$	5.6		3.9		2.34		0.80	

TABLE X

EFFECT OF SADH ON TOTAL DRY WEIGHT AND ROOT WEIGHT OF PEANUT GROWN IN TWO SOIL MOISTURE REGIMES

SADH Conc.(kg/ha)	Root Weight		Topgrowth Wt.		Total Dry Wt.	
	Wet	Dry	Wet	Dry	Wet	Dry
	(gm)					
Check	8.0	2.9	34.9	16.1	42.9	19.5
1.12	8.6	4.4	28.4	19.6	37.1	24.3
2.24	13.1	6.0	34.5	16.7	47.6	22.7
$LSD_{0.05}$	2.6		5.1		5.3	

Field Studies

Two locally adapted cultivars of Spanish peanuts ('Spanhoma' and 'Comet') were treated in 1973. There were no visible differences in the response of these two cultivars to plant growth regulators. The SADH, fluoridamid treatments did not alter any peanut yield significantly (Table XIII). Some leaf roll was observed in fluoridamid and MBR 12325 treated peanuts. However, MBR 12325 reduced the plant size only at the highest rate used--0.84 kg/ha (Table XI). The following symptoms characterized SADH-treated plants: (a) reduced vegetative growth, (b) shorter internodes, (c) more compact and robust plants, (d) increased thickness and greenness of leaf. PP 528 and TIBA also induced symptoms similar to SADH, however TIBA did not cause the dark green color of peanut leaves. Ethephon reduced the horizontal spread-out of peanut plants. The ethephon-treated plants also showed slight chlorosis. TD 6817 applied at early stages (within 60 days after planting) caused severe leaf necrosis. The discoloration was less severe when the compound was applied 60 days after planting. In either case the discoloration was outgrown within two weeks.

In 1973 plant heights of SADH treatments were reduced to 33 cm as compared to 43 cm of untreated plants. In 1974 the SADH treatment reduced the plant height from 37 cm to 30 cm--a reduction of 23%. The plant height reduction was even more significant in 1975. The SADH-treated plants had an average plant height of 31 cm compared to the control plants of 41 cm. Our 25% plant height reduction was comparable to a 30 to 40% reduction reported by other authors (9,10). The other plant growth regulators which significantly reduced the plant height were PP 528, ethephon and high rates of TIBA. PP 528 caused a 24%

TABLE XI

EFFECT OF PLANT GROWTH REGULATORS ON PLANT HEIGHT AND WIDTH OF SPANISH PEANUTS

Treatment	Rate (kg/ha)	Treatment Stage	Plant Height 1974	Plant Height 1975	Canopy Width 1974	Canopy Width 1975
			(cm)			
SADH	1.12, 0.56	I*,II	31	32	65	50
	2.24, 0.56	I,II	-	29	-	49
	0.34	I,II,III	30	-	67	-
	1.12	I	-	33	-	54
	2.24		-	31	-	48
	3.36		-	28	-	46
	1.12	II	-	33	-	57
	2.24		-	29	-	50
Uni-P-293	1.68	I	34	-	64	-
	3.36		35	-	73	-
	2.24	I	-	41	-	62
	4.48		-	40	-	60
	2.24, 2.24	I,II	-	40	-	58
TD 6817*	2.34 (l/ha)	I	37	-	74	-
	4.67		34	-	76	-
	9.35		37	40	65	63
	4.67	II	33	40	72	60
	9.35		39	38	63	58
PP 528**	1.12(kg/ha)	I	27	32	62	51
	2.24		29	30	63	49
	1.12	II	29	32	60	54
	2.24		26	26	62	47
	1.12, 0.56	I,II	-	28	-	51
	2.24, 0.56	I,II	-	26	-	42
FMC 28979	0.56	I	33	-	72	-
	0.84		33	-	73	-
	1.12		-	39	-	61
	0.56	II	33	-	75	-
	0.84		35	-	74	-
MBR 12325	0.28	I	-	42	-	62
	0.56		34	38	69	58
	0.84		31	37	69	58
	0.28	II	-	40	-	62
	0.56		35	37	71	57
	0.84		35	40	70	61
Ethephon	0.28	I	37	-	70	-
	0.56		33	-	76	-
	2.24		-	34	-	59
	4.48		-	34	-	57
	6.72		-	32	-	54
TIBA	0.28	I	29	-	60	-
	0.56		25	-	49	-
	2.92 (l/ha)		-	38	-	57
	5.84 (l/ha)		-	35	-	57
	0.28 (kg/ha)	II	32	-	62	-
	0.56		29	-	61	-
Untreated Check			37	41	76	65
$LSD_{0.05}$				4		7

*See Table III for details of growth stage.

TABLE XII

EFFECT OF PLANT GROWTH REGULATORS
ON YIELD OF SPANISH PEANUTS

Treatment	Rate (kg/ha)	Treatment Stage	Yield (kg/ha) 1974	Yield (kg/ha) 1975
SADH	1.12, 0.56	I*,III	2251 abc**	4883 a-g
	2.24,0.56	I,III	-	5264 a-h
	0.34	I,II,III	2654 abc	-
	1.12	I	-	5656 a-h
	2.24		-	4390 a-c
	3.36		-	4289 ab
	1.12	III	-	6003 e-h
	2.24		-	5902 d-h
Uni-P-293	1.68	I	2553 abc	-
	3.36		22/3 abc	-
	2.24	I	-	5756 c-h
	4.48		-	5560 a-h
	2.24,2.24	I,III	-	5712 b-h
TD 6817	2.34 (1/ha)	I	2150 abc	-
	4.67		2352 abc	-
	9.35		2105 ab	6294 gh
	4.67	III	2475 abc	5910 d-h
	9.35		2128 abc	5902 d-h
PP 528	1.12 (kg/ha)	I	2296 abc	5415 a-h
	2.24		2038 a	5465 a-h
	1.12	III	2587 abc	6395 h
	2.24		2083 a	4782 a-f
	1.12, 0.56	I,III	-	5264 a-h
	2.24, 0.56	I,III	-	4732 a-1
FMC 28979	0.56	I	2956 c	-
	0.84		2553 abc	-
	1.12		-	6048 e-h
	0.56	II	2564 abc	-
	0.84		2352 abc	-
MBR 12325	0.28	I	-	5364 a-h
	0.56		2284 abc	5415 a-h
	0.84	I	1904 a	5465 a-h
	0.28	III	-	7560 h
	0.56		2173 abc	5712 b-h
	0.84		2464 abc	6294 gh
Ethephon	0.28	I	2497 abc	-
	0.56		2934 bc	-
	2.24		-	5118 a-h
	4.48		-	4491 a-d
	6.72		-	4244 a
TIBA	0.28	I	2240 abc	-
	0.56		1960 a	-
	2.92 (1/ha)		-	6244 f-h
	5.84 (1/ha)		-	5801 c-h
	0.28 (kg/ha)	II	1960 a	-
	0.56		2016 a	-
Untreated Check			2576 abc	5712 b-h

*See Table III for details of growth stage at time of treatment.
**Values within the same column followed by the same letter are not significantly different at the 5% level of Duncan's multiple range test.

plant height reduction, while ethephon only reduced the plant height by 15%. The 0.28 and 0.56 kg/ha rates of TIBA reduced plant size so much that it might not be desirable.

The following compounds significantly reduced the plant width: SADH, PP 528, TIBA and ethephon. In general, PP 528 was as effective as SADH in reducing plant size and causing a compact plant. There was no significant difference in plant responses when the plant growth regulators were applied at either a pre-bloom or post-bloom stage.

The sequential application of SADH at 15-day intervals was more effective in reducing the plant size than the single treatment at 30 days after planting in 1974 (Table XII). Daughtry _et al_. obtained a higher yield with the 8-week SADH application than with the 6-week application (15). However, the post-bloom or 8 weeks after planting treatment of SADH had a higher yield than the early bloom or sequential treatments. No general trend can be considered for the difference between stage of treatment for all the plant growth regulators. If a surfactant was tank-mixed with the plant growth regulators their effectiveness was enhanced. Table XII shows that no significant yield increase was obtained in 1974 and 1975. However, slight yield increase by FMC 28979 and ethephon was noted. In 1975, the 1.12 kg/ha of PP 528 applied at 8 weeks after planting gave a yield increase of 680 kg/ha. It seemed that FMC 28979 and TD 6817 were very promising in increasing pod yield of peanuts. In 1975 the ethephon at 6.72 kg/ha significantly reduced the peanut yield. A large number of ethephon-treated plants remained green at the time of digging. The green peanuts were difficult to thresh and a lower grade of peanuts occurred. There was a drought spell in the late growing season of 1975 and SADH-treated peanuts showed more severe drying and wilting than other peanuts. The peanuts treated with 3.36 kg/ha of SADH yielded 1420 kg/ha less than untreated peanuts. This decrease was thought to be caused by the smaller plant size and more sun exposure induced by SADH treatment. Thus, the possibility of using SADH to induce drought resistance is doubtful. This might imply that the yield increase by SADH probably required ideal growing conditions. The environmental variations produced the erratic responses of peanuts to plant growth regulators (10,15). Yield increases by plant growth regulators was then confounded with environmental factors. Several authors (10,15,34,47) have shown the lack of yield increase from growth regulator use.

CHAPTER V

SUMMARY AND CONCLUSIONS

The influence of plant growth regulators on wheat, barley, oat, triticale and peanut was examined in the growth chamber and field. The effects on plant height, tiller number, chlorophyll content and yield were measured and analyzed for small grains. Plant size, length of internode, leaf area, root to foliage ratio and yield were evaluated for peanuts.

CCC-treated wheat plants showed a greener and broader leaf than untreated plants in the growth chamber. The chlorophyll content per unit gram of leaf tissue was significantly increased by the high rate of CCC (2.24 kg/ha). The darker green color of the wheat leaves was a result of increased chlorophyll content. The number of tiller was not increased by CCC treatment. The plant height reduction of wheat by CCC was observed both in the growth chamber and field. Uni-C-997, BASF 85559, and ethephon also reduced plant height in wheat, barley, and oat.

No plant growth regulators used in this study significantly increased grain yield consistently over two years. However, the reduction in plant height by plant growth regulators might be beneficial. The dwarfed stems might help in reduction of lodging. Actually the degree of lodging in oats was reduced by CCC, Uni-C-997, BASF 85559 and ethephon. Although the effect of plant growth regulators on straw strength was not measured, the dwarfed plants might have more resistance to rain, hail, and windstorm damage after head emergence. In case of high rainfall with high nitrogen fertilizer rates, the reduction of plant height and lodging by plant growth regulators sounds promising. In the other case plant growth regulators might increase drought resistance in small grains. Drought resistance induced by plant growth regulators would be especially beneficial in Oklahoma.

SADH reduced plant height and plant width when peanuts were grown in wet regimes. There was no plant size reduction by SADH when peanuts were grown in dry regimes. The leaf area and internode length were not affected by SADH. However, SADH increased the root to foliage ratio of fully-grown peanuts. The yield was not increased by any plant growth regulators at any rate at any growth stage. The 6.72 kg/ha rate of ethephon reduced the grade and yield of peanuts. Plant maturity was delayed by this high rate of ethephon. The possible increase in drought resistance by SADH proposed by other workers (21,46) is proven to be misleading. SADH did increase the root system of peanuts. However, the reduction of plant size by the compound exposed more soil to evaporation. The benefit of more roots on drought resistance can be overwhelmed by more water loss in drought resulted from less ground cover by SADH reduction of plant size. The control of vegetative growth of peanuts can be achieved by the application of SADH, PP 528 and TIBA. The reduction of excessive growth can be beneficial; application of insecticides and fungicides with ground equipment without damage to plants were possible later in the season than usual. In Oklahoma leaf spot disease requires application of fungicide in the late growing season. The potential of plant size reduction by plant growth regulators makes the late application of fungicide with ground equipment possible.

The plant growth regulators tested in this study did not increase the yield of small grains and peanuts. However, the morphological and physiological changes induced by plant growth regulators might have some merits to be incorporated into the modern agricultural practices. More research should be conducted on the effect of plant growth regulators in reducing lodging of small grains growing under high moisture and fertility levels. In peanuts beneficial aspects from reduced plant size by plant growth regulators should be evaluated in runner type peanut as well as Spanish peanuts.

LITERATURE CITED

1. Adler, T., V. Caraus, G. Cloanda, V. Velciov, and V. Petea. 1968. Results obtained by applying the CCC to winter wheat. Probl. Agr. 20(1):26-35.

2. Amchem Products, Inc. 1969. H-96-Ethrel Tech. Ser. Data Sheet. Ambler, Pennsylvania.

3. Appleby, A.P., W.E. Kronstad, and C.R. Rohde. 1966. Influence of 2-chloroethyl trimethylammonium chloride (CCC) on wheat when applied as a seed treatment. Agron. J. 58:435-437.

4. Birecka, H. 1966. Effect of (2-chloroethyl) trimethylammonium chloride (CCC) on photosynthesis and photosynthate distribution in oats and wheat after heading. Bull. Acad. Pol. Sci. Cl. 14:261-267.

5. Blackett, G.A., and G.I.M. Martin. 1970. The effect of chlormequat on grain yield and straw length of spring barley and spring oats. Field Crop Abstr. 24:4635.

6. Bokhari, U.G., and V.B. Youngner. 1971. Effects of CCC on the growth of wheat plants and their untreated progeny. Agron. J. 63:809-811.

7. Brittain, J.A. 1968. Response of *Arachis hypogaea* to succinic acid-1,1-dimethylhydrazide. Diss. Abstr. Sec. B28.

8. Brown, C.M., and E.B. Earley. 1973. Response of one winter wheat and two spring oat varieties to foliar application of 2-chloroethyl phosphonic acid. Agron. J. 65:829-832.

9. Brown, R.H., W.J. Ethredge, and J.W. King. 1973. Influence of succinic acid 2,2-dimethylhydrazide on yield and morphological characteristics of Starr peanuts (*Arachis hypogaea* L.). Crop Sci. 13:507-510.

10. Brown, R.H., and W.J. Ethredge. 1974. Effects of succinic acid 2,2-dimethylhydrazide on yield and other characteristics of peanut cultivars. Peanut Sci. 1:20-23.

11. Burton, J.C., and R.L. Curley. 1966. Influence of triiodobenzoic acid on growth, nodulation, and yield of inoculated soybeans. Agron. J. 58:406-408.

12. Calder, F.W., W.D. Canham, and D.S. Fensom. 1973. Some effects of Alar-85 on the physiology of alfalfa and ladino clover. Can. J. of Plant Sci. 53:269-278.

13. Cathy, H.M. 1964. Physiology of growth retarding chemicals. Ann. Rev. Plant. Physiol. 15:271-302.

14. Cole, D.F. 1973. Cultivar differences among triticale seedlings treated with various growth regulators. Agron. J. 65:902-903.

15. Daughtry, C.S., R.H. Brown and W.J. Ethredge. 1975. Effects of time of application of succinic acid 2,2-dimethylhydrazide on yields and associated characteristics of peanuts. Peanut Sci. 2:83-86.

16. Duke, W.B., and J.N. Rutger. 1972. Effects of Ethrel on the growth of winter wheat. NEWSS Proc. 26:237-240.

17. El Damaty, A.H., H. Huhn, and H. Linser. 1965. Water relations of wheat plants under the influence of (2-chloroethyl) trimethylammonium chloride (CCC). Physiologia Pl. 18:650-657.

18. Fairey, D.T., and N.C. Stoskopf. 1975. Effects of granular ethephon on male sterility in wheat. Crop Sci. 15:29-31.

19. Farah, S.M. 1969. Effects of chlorocholine chloride and water regime on growth, yield, and water use of spring wheat. J. of Exp. Botany 20:658,663.

20. Goodin, J.R., C.M. McKell and F.L. Webb. 1966. Influence of (CCC) on water use and growth characteristics of barley. Agron. J. 58:453-454.

21. Gorbet, D.W. and F.M. Rhoads. 1975. Response of two peanut cultivars to irrigation and Kylar. Agron. J. 67:373-376.

22. Greer, H.A.L. and I.E. Anderson. 1965. Response of soybeans to triiodobenzoic acid under field conditions. Crop Sci. 5: 229-232.

23. Halevy, A.H., A. Ashri, and Y. Ben-Tal. 1969. Peanuts: Gibberellin antagonists and genetically controlled differences in growth habit. Science 164:1397-1398.

24. Humphries, E.C., P.J. Welbamk and K.J. Witts. 1965. Effect of CCC (chlorocholine chloride) on growth and yield of spring wheat in the field. Ann. Appl. Biol. 56:351-361.

25. ______________. 1968. CCC and cereals. Field Crop Abstr. 21:92-99.

26. Humphries, E.C., and W. Bond. 1969. Experiments with CCC on wheat: effects of spacing, nitrogen and irrigation. Ann. Appl. Biol. 64:375-384.

27. Koch, K. and H. Linser. 1969. The causes of increased standing ability of cereals after treatment with chlorcholine chloride (CCC). Field Crop Abstr. 22:1938.

28. Larter, E.N. 1967. The effect of (2-chloroethyl) trimethylammonium chloride (CCC) on certain agronomic traits of barley. Can. J. Plant Sci. 47:413-421.

29. Linser, H. and H. Kuhn. 1962. Prevention of lodging by using gibberellin antagonists such as CCC. Z PA-Ernahr Dung Bodenk 96:231.

30. Lockhart, J.A. 1961. Physiological mechanism of action of stem growth inhibitors. Plant Physiol. (suppl.) 36:38.

31. ______________. 1962. Kinetic studies of certain antigibberellins. Plant Physiol. 37:759-764.

32. Martin, K.H. 1968. The influence of 2-chloroethyltrimethylammonium chloride on the yield, yield structure, and the morphological and qualitative characteristics of cereals, in conjunction with varying application of nitrogen. I. Wheat. Z. Acker. Pflanz 128(3):177-196.

33. Morgan, P.W. and H.W. Gausman. 1966. Effects of ethylene on auxin transport. Plant Physiol. 41:45-52.

34. Morris, W.G. 1970. Effects of three growth regulating chemicals and three row spacings of Spanish peanuts. M.S. Thesis. Oklahoma State Univ., Stillwater, OK.

35. Oplinger, E.S., W.A. Vieth, and V.L. Youngs. 1975. Oat agronomic and grain quality responses to growth regulators. Agron. J. 67:443-445.

36. Pacucci, G. 1967. Research on the influence of CCC applied to dry grains: First experimental results. Agrochemiica 12(1): 5-27.

37. Rowell, P.L., and D.G. Miller. 1974. Effect of 2-chloroethylphosphonic acid (ethephon) on female fertility of two wheat varieties. Crop Sci. 14:31-33.

38. Schnee, M. 1966. Effect of chlorcholinechloride (CCC) on growth and yield of oats. Field Crop Abstr. 19:796.

39. Stanley, P.B., A. Apelbaum, W. Eisinger, and B.G. Kang. 1971. Physiology and mode of action of ethylene. Hort. Sci. 6:359-363.

40. Tanner, J.W. and S. Ahmed. 1974. Growth analysis of soybeans treated with TIBA. Crop Sci. 371-376.

41. Tennenhouse, A.N., and L.J. Lacroix. 1972. Effects of (2-chloroethyl) trimethylammonium chloride (CCC) on certain agronomic traits of oats and triticale. Can. J. Plant Sci. 52:559-567.

42. Tolbert, N.E. 1960. (2-chloroethyl) trimethylammonium chloride and related compounds as plant growth substances. II. Effect on growth of wheat. Plant Physiol. 35:380-385.

43. ____________. 1960. (2-chloroethyl) trimethylammonium chloride and related compounds as plant growth substances. I. Chemical structure and bioassay. J. Biol. Chem. 235:475-479.

44. Undurraga, M.J. and K. Ryngo. 1970. The effect of Alar on permeability, a possible explanation for its mode of translocation. J. of Am. Soc. of Horticultural Sci. 95:348-354.

45. Wittwer, S.H. 1968. Chemical regulators in horticulture. Hort. Sci. 3:163-167.

46. Wittwer, S.H. 1971. Outlook on agriculture. 6:205-217.

47. Wynne, J.C., W.R. Baker, Jr., and P.W. Rice. 1974. Effects of spacing and a growth regulator, Kylar, on size and yield of fruit of Virginia-type peanut cultivars. Agron. J. 66:192-194.

48. ZeeVaart, J.A.D. 1964. Effects of the growth retardant CCC on floral initiation and growth in Pharbitis nil. Plant Physiol. 39:402-408.

APPENDIXES

TABLE XIII

EFFECT OF FLUORIDAMID AND SADH ON YIELD OF TWO PEANUT CULTIVARS IN 1973

Treatment	Rate (kg/ha)	Treatment Stage	Peanut Yield	
			Spanhoma	Comet
Fluoridamid	2.34 (1/ha)	Pre-bloom	3304 a-f	3460 b-g
	4.67 (1/ha)		2710 ab	3012 a-e
SADH	0.95		2844 a-d	2464 ab
	1.68		2564 a	2732 a-c
Fluoridamid	2.34 (1/ha)	Post-bloom	4009 c-g	4278 f-i
	4.67 (1/ha)		3875 b-g	4032 e-i
	0.95		4032 c-g	3763 c-i
	1.68		3281 a-f	4334 f-i
Untreated check			3897 b-g	4278 f-i

VITA

Chu-huang Wu

Candidate for the Degree of

Doctor of Philosophy

Thesis: EVALUATION OF SEVERAL PLANT GROWTH REGULATORS IN SMALL GRAINS AND PEANUTS

Major Field: Crop Science

Biographical:

Personal Data: Born in Tainan, Taiwan, December 18, 1947, the son of Mr. and Mrs. Hai-yung Wu.

Education: Graduated from the First Tainan High School, Tainan, Taiwan, in May, 1966; received the Bachelor of Science in Agriculture degree from National Taiwan University with a major in Agronomy in May, 1970; received the Master of Science degree from Oklahoma State University with a major in Agronomy in July, 1973; completed the requirements for the Doctor of Philosophy degree in July, 1976, with a major in crop science.

Experience: Graduate Research Assistant, Oklahoma State University, August, 1971, to July, 1976.

Member of: Sigma Xi and Weed Science Society of America.