8209182

Thasanasongchan, Akwut

THE INFLUENCE OF ACETATES ON GROWTH AND YIELD OF CORN (ZEA MAYS L.) AND SOYBEAN (GLYCINE MAX (L.) MERR.)

Iowa State University PH.D. 1981

University
Microfilms
International 300 N. Zeeb Road, Ann Arbor, MI 48106

The influence of acetates on growth and yield of corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.]

by

Akwut Thasanasongchan

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements of the Degree of

DOCTOR OF PHILOSOPHY

Department: Agronomy
Major: Crop Production and Physiology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1981

TABLE OF CONTENTS

INTRODUCTION

High yielding crop varieties require maximum inputs such as fertilizer, management and pest controls in order to get maximum yield. Sometimes farmers do not get the expected return from maximum inputs due to environmental factors which adversely affect the crops. From an economic point of view, maximum input is not practical in view of the agronomic returns. For the past decade, agronomists as well as crop physiologists have searched for the best crops and best management system in order to get maximum returns from high yielding varieties of crops. The difficulty in obtaining high productivity stimulated the use of chemical growth regulators in the field of agriculture. Manipulation of crop production with chemicals has been considered to be very effective.

The use of chemicals to promote, depress or alter plant growth is not new. As far back as 1932, scientists were using ethylene and acetylene to promote flowering in pineapple. Probably the first commercial plant growth regulator was naphthaleneacetic acid which is still used to control preharvest drop of apples. In the 1950s, it was discovered that a preharvest foliar application of malic hydrazide would inhibit onions from sprouting while in storage. Then came the gibberellins. First discovered in Japan, the gibberellins had been known for years as an effective means of regulating growth. The most successful application was introduced in 1958 when it was found that application of gibberellic acid on Thompson seedless grapes would produce giant fruits and clusters that were loose and would not rot easily on the vine. Today, virtually 100% of the Thompson seedless grapes grown in the U.S. are treated with "gib".

Over the last ten years, there has been a rapid increase in the use of chemical growth regulators. These have proven profitable for farmers and manufacturers as well as consumers (Mitlehner, 1977).

However, in the study of the relationship between chemical growth regulators and plant response, there are some limitations involved. The stages of plant development, the environmental factors, time of application, responses that should be recorded, genetic variability of the plant etc., all make the study of plant growth regulators complex.

This study was undertaken to investigate the influences of acetates on the development and grain yield of corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.).

In 1979, the objectives of this study were to determine the effect of methyl acetate (MEAC), ethyl acetate (ETAC), butyl acetate (BUAC) and sodium acetate (NAAC) on vegetative growth (plant height, leaf length) and dry weight of corn measured 2 weeks after the chemicals had been sprayed at the 5th leaf stage. The experiment was done under growth-chamber conditions.

In 1980, the objectives of field studies were to determine:

1. The effects of MEAC, ETAC, BUAC, and NAAC on vegetative growth (plant height and leaf width), and on components of yield when the chemicals were applied at different rates and stages of corn growth (4th, 8th and 12th leaf stages).
2. The effects of MEAC, ETAC, and BUAC on yield of soybean.
3. The effects of zinc acetate (ACA) and ammonium acetate (ACE) on components of yield of corn when planted early or late with two methods of soil application (under the row and between the row).
4. The effects of ACA and ACE on components of yield of corn when the chemicals were injected into the soil as a sidedress treatment with anhydrous ammonia at different stages of corn growth (4th, 8th and 12th leaf stages).

LITERATURE REVIEW

Plant growth regulators usually are defined as organic compounds, other than nutrients, that, in small concentrations, affect the physiological processes of plants. For practical purposes, plant growth regulators can be defined as either natural or synthetic compounds that are applied directly to the plant to alter its life processes or structure in some beneficial way so as to enhance the yield, improve quality, or facilitate harvesting. Growth regulants have been most successfully used in production and processing of ornamental, vegetable, and fruit crops (Wittwer, 1971). Their successful use to increase yields of field crops has been more difficult to achieve. Climate during the growing season is a primary factor contributing to variability of plant response to growth regulators. Wittwer and Murneck (1946) indicated that temperature and moisture during flowering and pod formation influenced the effectiveness of regulants applied to bean plants. They also reported that the response of a plant or a plant part to a plant growth regulator may vary with the age of the plant, its physiological stage of development, and its state of nutrition.

Substances that have been applied to field crops with the objective of increasing yields include: para-chlorophenoxyacetic acid (CLPA); 2,3,5-triiodobenzoic acid (TIBA); succinic acid 2,2-dimethylhydrazide (SADH); and derivatives of 9-hydroxyfluorene-(9)-carboxylic acid (morphactins).

Sprays or dust of CLPA applied to varieties of green bush snap beans (Phaseolus vulgaris L.) resulted in an increase in yields and this was due to an increase in pod size (Wittwer and Murneck, 1946).

Sprays of TIBA decreased leaf and seed size, reduced plant height, shortened new petioles, and increased both above-ground dry weight and total seed yield of intermediate 'Hawkeye' soybeans [Glycine max (L.) Merr.] (Daughtry et al., 1975). A determinate variety of soybean, 'Bragg', also showed reduced height and increased yield after TIBA application (Clapp, 1973). The increase in yield was due to increased pod set (Anderson et al., 1965). Application of TIBA to peanut (Arachis hypogea L.) plants caused changes in vegetative growth and induced yield responses similar to those of soybeans (Bauman and Norden, 1971; Hallock and Alexander, 1970; Hartzook and Goldin, 1970).

Sprays of SADH shorten main stems, lateral branches, and internode lengths of soybean (Bauman and Norden, 1971; Brown and Ethredge, 1974; Brown et al., 1973).

Morphactins reduced soybean plant height and yield (Clapp, 1973). They altered apical dominance, promoted lateral branching and decreased peanut yields (Krishnamoorthy and Khun, 1972).

Miller and Ashby (1978) investigated the effect of a foliar application of 10^{-3} M phenylmercuric acetate on factors influencing the water balance of leaves of field corn. Leaves sprayed with phenylmercuric acetate had 3% of their stomates open, and the water potentials of the treated leaves exceeded those of control plants by 4 bars. The transpiration was reduced by 54%.

Rychter et al. (1979) examined the effects of ethanol, acetaldehyde, and acetic acid on potato (Solanum tuberosum) tubers when applied in a volatile state in air. They found that the application of these volatile materials led to a climacteric-like upsurge in respiration. The respiratory upsurge was markedly enhanced when the volatiles were applied in 100% O_2. Acetaldehyde appeared to be the most effective in inducing the stimulation in respiration compared with other volatiles. Ethanol induced a decline in the level of 2-phosphoglyceric acid and phosphoenolpyruvate (PEP) while leading to the accumulation of tricarboxylic acid cycle intermediates including isocitrate and α-ketoglutarate. They suggested that ethanol, acetaldehyde, or acetic acid can lead to the development of the cyanide-insensitive respiration.

It has been discovered (Ott, 1974, 1975, 1976) that a liquid solution consisting essentially of an ionic solution of zinc alkanoate in substantially anhydrous liquid ammonia can be used as a liquid fertilizer to provide nutrient amounts of nitrogen and zinc for the growing plants.

The zinc carboxylates suitable for use are the zinc salts of unsubstituted alkanoic acids having the formula RCOOH wherein R is hydrogen or alkyl, preferably C_1-C_5 alkyl and most preferably C_1 alkyl. The zinc salts of formic, acetic, propionic, butanoic, and pentanoic acids that are capable of reacting with ammonia and being soluble in aqua ammonia are suitable for forming the compositions.

Zinc acetate (ACA) had been especially preferred as a liquid fertilizer by Ott (1975) because of its ready availability or ease of formation from zinc oxide and acetic acid. The liquid zinc-nitrogen solutions may contain from about 0.01 to about 20%, preferably 0.025 to 10%, (by weight) of zinc. They contain at least about 4, preferably 6 or more, moles of ammonia per mole of zinc and at least about 10% water. Solutions containing from about 10% to about 20% zinc have a low vapor pressure and can be handled at ambient temperatures without the necessity of using pressurized equipment.

Ott (1975) compared three zinc carriers, zinc acetate, zinc sulfate, and a ligninsulfonate. Zinc was applied in the fluid fertilizer materials to the potted soil at rates of 0.0, 0.312, 1.25, 5.0, and 20.0 lb/acre equivalent. Single-cross corn hybrids Wf9xHy and N5xN15 were planted in the pots, grown in greenhouses for 8 weeks, and watered daily. Plant samples, taken at the end of 8 weeks, were cut off just above the ground level, dried, weighed, and ground for analysis by X-ray spectrograph for total zinc uptake. The data showed that zinc acetate (ACA) was more effective than zinc sulfate and only slightly less effective than the ligninsulfonate carrier as measured by the total zinc uptake by the plants.

Results of Ott's (1975) field tests using zinc-containing solutions and zinc-free liquid ammonia as fertilizer by corn by preplanting applications in soils classified as zinc-sufficient, and by sidedressing applications in zinc-deficient soils showed that zinc, when applied as a solution in liquid ammonia, is readily assimilated by the plants and provides an improvement in utilization of the plant nutrients applied to the soil. A yield advantage of about 8 bushels per acre of No. 2 corn has been obtained at 8 test plots out of 10 in favor of the ammonia-zinc combination versus ammonia only. At the other 2 plots, no significant change in yield was noted.

Developing soybean cotyledons have been shown to be able to incorporate acetate into fatty acids and water soluble constituents (Rinne and Canvin, 1971). The first fatty acid to be detected was oleic acid, ascertained by use of ^{14}C. The ^{14}C distribution pattern with time was consistent with it being a precursor of linoleic and linolenic acids. Rinne and

Canvin (1971) also showed that cotyledons fixed $^{14}CO_2$ by either dark or light fixation reactions, but little ^{14}C was incorporated into lipids.

Stearn and Morton (1975) incubated suspension cultures of finely divided soybean cells established from callus with sodium [1-^{14}C] acetate for periods up to 86 hours. Incorporation of acetate into cell lipid was directly proportional to the logarithm of time up to 32 hours, after an initial lag of 4-6 hours. Most of the lipid radioactivity was found in the phospholipid fraction.

Negishi (1976) showed that both cotyledon and axis of soybean seedlings incorporated [1-^{14}C] acetate into phospholipids, mainly phosphotidylethanolamine, in the cotyledon and phosphotidyl choline in the axis.

The initial incorporation of ^{14}C-acetate into total fatty acids in roots of frost-hardy and less hardy alfalfa (Medicago sativa) cultivars under hardening conditions was studied by Griener et al. (1975). They showed that the incorporation of ^{14}C-acetate into fatty acids of alfalfa roots at 22^{o}C was approximately twice that at 1^{o}C. At 22^{o}C, the percentage of labeling in individual fatty acids remained relatively constant throughout the incorporation, whereas at 1^{o}C, the percentages of oleic acid decreased and that of linoleic acid increased markedly with time. The absorption of ^{14}C-acetate increased approximately 20% in both alfalfa cultivars during the first day of hardening and remained constant thereafter. Incorporation of ^{14}C-acetate into lipids increased strongly during hardening in the hardy cultivar 'Rambler' at both temperatures of incorporation.

Wilson and Kates (1978) showed that suspension cultures of soybean cells incorporated [1-^{14}C] acetate very rapidly into fatty acid moieties of phospholipids and glycolipids when incubated at 26^{o}C for up to 22 hours. The most rapidly labeled lipid was 3-SN-phosphatidyl choline, which contained 58% of the total fatty acid radioactivity after 16 minutes; more than 75% of this label was found to be in the oleic acid of the phosphatidyl choline.

MATERIALS AND METHODS

1979 Growth-chamber Experiments

Experiment 1

On April 10, 1979, 200 small, white plastic pots (10 x 15 cm) were each filled with 1 kg of soil. The soil was a 1:1 mixture of soil (Nicollet clay loam) and washed sand. Seeds of A619xA632 single-cross hybrid corn cultivar were planted on the same day and the pots were placed in a growth chamber. The lighting in the growth chamber was adjusted to 16 hours per day at approximately 140 μEinsteins $m^{-2}sec^{-1}$ and 8 hours of dark. The daily temperature was 25-26^{o}C and the night temperature was 22-23^{o}C. The highest humidity during the experiment was close to 95% and the lowest was 60%. On April 17, 5 days after the seedlings emerged, and every fourth day thereafter, 30 ml of nutrient solution was applied to each pot as described by Rhue and Grogan (1977): 0.1 mM KH_2PO_4, 0.5 mM KNO_3, 2.0 mM $Ca(NO_3)_2$, 0.5 mM $MgSO_4$, 0.05 mM $(NH_4)_2SO_4$, 10.0 μM H_3BO_3, 2.0 μM $MgSO_4$, 0.8 μM $ZnSO_4$, 0.3 μM $CuSO_4$, 0.3 μM Na_2MoO_4, 20.0 μM NaCl, and 10.0 μM Fe (chelated form). In the remaining 33 days of the experiment, each pot received approximately 92 kg N/ha, 4.5 kg P_2O_5/ha, and 33.5 kg K_2O/ha, assuming that a hectare contains 2,250,000 kg of soil.

On May 5, when the 5th leaf was fully developed (counting from the bottom to top), the pots were taken from the growth chamber. The 170 pots with the most uniform seedlings were selected from the 200 pots and divided into 17 sets (treatments) of 10 pots per set (replications). Each set was sprayed with an acetate treatment using a small hand sprayer. The treatments were as follows:

Treatments 1-4: 10, 5, 2.5 and 1.25×10^{-3} M methyl acetate (MEAC), respectively,

Treatments 5-8: 10, 5, 2.5 and 1.25×10^{-3} M ethyl acetate (ETAC), respectively,

Treatments 9-12: 10,5, 2.5 and 1.25×10^{-3} M butyl acetate (BUAC), respectively,

Treatments 13-16: 10, 5, 2.5 and 1.25×10^{-3} M sodium acetate (NAAC), respectively.

Treatment 17: control (water).

These 170 pots, after being treated, were returned to a growth chamber using a complete randomized design with 17 treatments and 10 replications.

The highest concentration (10×10^{-3} M) of each acetate was freshly prepared one hour before spraying on the corn foliage. For the second and the lower rates, the solutions were prepared by diluting the highest rate of each acetate solution to the required concentrations. Each set of the seedlings was sprayed with the appropriate solution to the point of near runoff.

During the experiment, the following variables were measured:

1. Height of each plant before treatment
2. Height of each plant 7 days after treatment
3. Height of each plant 14 days after treatment
4. Length of the 5th leaf before treatment
5. Length of the 6th leaf 7 days after treatment
6. Length of the 7th leaf 14 days after treatment
7. The dry weight of the aerial part of each plant 14 days after treatment.

The height of the plant was measured from the soil level to the top of the longest leaf. Length of the 5th, 6th, and 7th leaves were measured from the collar to the tip of each leaf. At harvest (May 20, 1979), the aerial part of each plant was cut and dried in a forced air drier at 50^{o}C for 3 days before the dry weight was measured.

Statistical analysis of the data was by Fisher's F-test with mean separation by Duncan's multiple range test (Steel and Torrie, 1960).

Experiment 2

The only difference between Experiment 2 and Experiment 1 was that, instead of placing the pots in the growth chamber from the beginning of the experiment, on May 20, 1979, the pots of Experiment 2 were placed in a greenhouse. After the seedlings were grown in the greenhouse for 3 weeks, the pots were then transferred into the growth chamber. The reasons for the change were to reduce plant elongation due to relatively low light levels in the growth chamber and to confirm the results of the first experiment.

On June 15, 1979, two days sooner than in the first experiment, the 5th leaf was fully developed and treatments were applied. The treatments, variables measured, and statistical analysis were the same as in Experiment 1.

1980 Field Experiments

Experiment 3

The corn cultivar Pioneer 3780 was planted in Field A (located at the Agronomy and Agricultural Engineering Research Center) on May 2, 1980, at a population rate of 55,000 plants/ha, and a row spacing of 1.01 m. Emergence was on May 12, 1980. Anhydrous ammonia at the rate of 170 kg/ha was applied prior to planting. Four acetates (MEAC, ETAC, BUAC, and NAAC) at different rates (0, 0.2, 0.4, and 0.8 kg/ha of acetate ion equivalent) were sprayed on the corn foliage at the 4th, 8th, and 12th leaf stages of development. The chemicals were applied in 250 liters of water/ha. The water contained 0.25% Tween 20 as a surfactant.

The experiment was a split plot with the three stages of foliar spray as the main plot. For mechanical reasons, during spraying the main plot treatments were not completely randomized. The four chemicals and the four rates were completely randomized within the main plot. Each treatment was applied to 4 rows 9 m long. Data were collected from the center two rows.

Plant height, leaf width, ear per plant, average ear grain weight, and grain yield/ha were the responses measured in this experiment.

Plant height was measured two weeks before harvesting. Twenty plants for each treatment were randomly selected and measured. The height was obtained from ground level to the lowest branch of the tassel. At the same time, leaf width of the ear node leaf at the widest point was measured. Harvesting was done on October 4, 1980, using a two-row combine after plot length had been reduced to 6.6 m. Ears per plant was determined by dividing the number of ears by the number of plants. After determination of the total fresh weight of the grain harvested from each treatment, a sample of the grain was put in a paper bag and dried in a drier at 50°C for 5 days. Grain yield was reported at 15.5% moisture. Average ear grain weight adjusted to 15.5% moisture was calculated by dividing the grain weight by the number of ears. Statistical analyses were as in Experiment 1.

Experiment 4

On May 23, 1980, soybean cultivar Corsoy was planted in Field B located at the Bruner Farm near the Agronomy and Agricultural Engineering Research Center to study the influence of acetates on yield. Emergence was on May 30, 1980.

A plot consisted of 5 rows with a 35-cm row spacing and a length of 10 m. There was a 75-cm spacing between plots. Three acetates (MEAC, ETAC, and BUAC) at different rates (0, 0.2, 0.4, and 0.8 kg/ha of acetate ion equivalent) were sprayed on soybean foliage at the stages V_3, R_1, and $R_{2.5}$. The spray volume was 250 liters/ha with the water containing 0.25% Tween 20 as a surfactant.

The experimental design was a split plot with the three stages of foliar spray as the main plot. For mechanical reasons, during spraying the main plot treatments were not completely randomized. The three chemicals and the four rates were completely randomized within each stage. Harvesting was done on September 10, 1980, using a small commercial soybean combine after the plot length had reduced to 8.5 m. All five rows were harvested and for calculating yield the plot area was considered to be 2.5 m x 8.5 m. Moisture content was 14.5%. Statistical analyses were as in Experiment 1.

Experiment 5

During the growing season of 1980, liquid growth chemicals zinc acetate (ACA) and ammonium acetate (ACE) were used in Field C located at the Agronomy and Agricultural Engineering Research Center.

A week before the first planting date, different amounts of ACA, a solution containing 33% zinc acetate in 5 N NH_4OH, and ACE, a solution containing 16% acetic acid (the same amount of acetate as in ACA) in 5 N NH_4OH, were premixed with anhydrous ammonia (NH_3) and injected into the soil at a depth of 20 cm. Pioneer 3780 corn cultivar was planted May 2, 1980 (the early planting date) and June 2, 1980 (late planting date), using two methods:

1. The planting was over the premixed liquid growth chemicals and anhydrous ammonia (over the row)
2. The planting was one-half the distance between the premixed liquid growth chemicals and anhydrous ammonia (between the rows).

In this experiment, anhydrous ammonia was applied at a rate of 170 kg/ha. The corn was planted at a population rate of 55,000 plants/ha. Emergence was on May 12, 1980 for the early planting date and June 10, 1980 for the late planting date.

The experiment was a split-split plot with the two dates of planting as the main plot, the two methods of planting as the first split and the last split was a completely randomized block containing the two chemicals (ACA and ACE) each at four rates of chemical (0, 0.3, 0.6, and 1.2 kg/ha of product. The quantities of acetate ion used were 0, 0.048, 0.096, and 0.192 kg/ha. For mechanical reasons, the date of planting and method of planting treatments were not completely randomized. There were four replications. Each plot consisted of 4 rows 9 m long with a row spacing of 1.01 m. Data were collected from the center two rows.

Ears per plant (E/P), average ear grain weight (W/E), and grain yield (Y)/ha were the responses measured in this experiment. Procedures were the same as in Experiment 3.

Experiment 6

In this experiment, the two liquid growth chemicals, ACA and ACE, at different rates were premixed with anhydrous ammonia and injected into the soil in Field D (located adjacent to Field C) as a sidedressing application at three different stages of corn development (4th, 8th, and 12th leaf stages). The anhydrous ammonia was applied at a rate of 170 kg/ha. Pioneer 3780 corn cultivar was planted on May 2, 1980 at a population of 55,000 plants/ha. Emergence date was May 12, 1980. Within each stage of application there were six treatments (0.3, 0.6, and 1.2 kg/ha of ACA, 0.3 and 0.6 kg/ha of ACE, and the control with only anhydrous ammonia). In order to measure the effects of the six treatments most accurately, they were completely randomized in a subplot with the main plot consisting of the three stages of application.

Four replicates of 6-row plots of 9 m length with a row spacing of 1.01 m were used. Data were collected from the center two rows. Ears per plant (E/P), average ear grain weight (W/E), and grain yield (Y)/ha were the responses measured in this experiment. Procedures were the same as in Experiment 3 except Duncan's multiple range test was not used.

RESULTS

1979 Growth-chamber Experiments

Experiment 1

In this experiment, plants were grown inside the growth chamber from the time of seeding. Chemicals (MEAC, ETAC, BUAC, and NAAC) were sprayed on the foliage of corn seedlings at the 5th leaf stage at four rates (1.25×10^{-3} M, 2.5×10^{-3} M, 5×10^{-3} M, and 10×10^{-3} M). The attributes measured were height one week after spraying (HT_1), height two weeks after spraying (HT_2), leaf length of the 6th leaf one week after spraying (LL_6), leaf length of the 7th leaf two weeks after spraying (LL_7), and dry weight (DW) two weeks after spraying.

Main effects of chemicals and rates on HT_1, HT_2, LL_6, LL_7, and DW are shown in Tables 1 and 2. For each of the attributes there were significant differences due to chemicals and rates of application. As shown in Table 1, the chemicals MEAC and BUAC had a similar influence on HT_1 and were significantly different from both ETAC and NAAC in increasing HT_1. NAAC was the second most effective chemical in increasing HT_1 and was significantly different from ETAC which was the least effective among the four chemicals in influencing HT_1. For HT_2, the most effective chemical was MEAC followed by NAAC, ETAC, and BUAC as second, third, and fourth,

Table 1. The main effects of chemical (MEAC, ETAC, BUAC, and NAAC) on HT_1, HT_2, LL_6, LL_7, and DW of corn when sprayed at the 5th leaf stage (Experiment 1)[a]

Chemical	HT_1 (cm)	HT_2 (cm)	LL_6 (cm)	LL_7 (cm)	DW (g)
MEAC	126.80 a	150.78 a	86.00 ab	95.93 b	8.85 bc
ETAC	121.60 c	141.70 d	85.10 b	96.13 b	8.53 c
BUAC	125.30 a	145.89 c	87.08 a	97.53 b	8.92 b
NAAC	122.80 b	148.80 b	87.63 a	100.10 a	9.81 a

[a]Means in each column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test. The same statistical procedure is used in all following tables.

Table 2. The main effects of rate of chemical on HT_1, HT_2, LL_6, LL_7, and DW of corn when sprayed at the 5th leaf stage (Experiment 1)

Rate ($Mx10^{-3}$)	HT_1 (cm)	HT_2 (cm)	LL_6 (cm)	LL_7 (cm)	DW (g)
0	116.20 c	141.00 c	76.60 d	89.00 e	8.28 c
1.25	122.23 b	144.55 b	84.90 c	94.58 c	8.38 c
2.5	127.10 a	150.87 a	88.63 b	98.30 b	9.17 b
5	128.53 a	151.65 a	90.53 a	102.98 a	10.05 a
10	118.22 b	140.26 c	80.72 d	92.86 d	8.45 c

respectively. There were no significant differences among chemicals MEAC, ETAC, BUAC, and NAAC in increasing LL_6. The least effective chemical in increasing LL_6 was ETAC, but the increase was not significantly different from that produced by MEAC, which was among the most effective chemicals in increasing LL_6. For LL_7, the most effective chemical was NAAC. It was significantly different from other chemicals in increasing LL_7. The most effective chemical for increasing DW was NAAC. It was significantly different from the other chemicals in increasing DW. MEAC and BUAC were similar in their effect in increasing DW. ETAC showed an effect similar to that of MEAC but was significantly different from BUAC in increasing DW. The changes in HT_1 and HT_2, LL_6 and LL_7, and DW due to the main effect of chemicals are shown in Figures 1, 2, and 3.

As shown in Table 2, the application rates of the chemicals at $5x10^{-3}$ M and $2.5x10^{-3}$ M were the most effective in influencing HT_1 and HT_2. These two rates were significantly different from the other rates in increasing both HT_1 and HT_2. The highest rate ($10x10^{-3}$ M) and low rate ($1.25x10^{-3}$ M) had similar effects on HT_1 and were greater than the control (0 rate). However, the highest rate ($10x10^{-3}$ M) appeared to be inhibitory on HT_2 and resulted in a height similar to the control. For LL_6, LL_7, and DW, rate $5x10^{-3}$ M was the most effective. It was significantly different from the other rates in increasing LL_6, LL_7, and DW. The second most

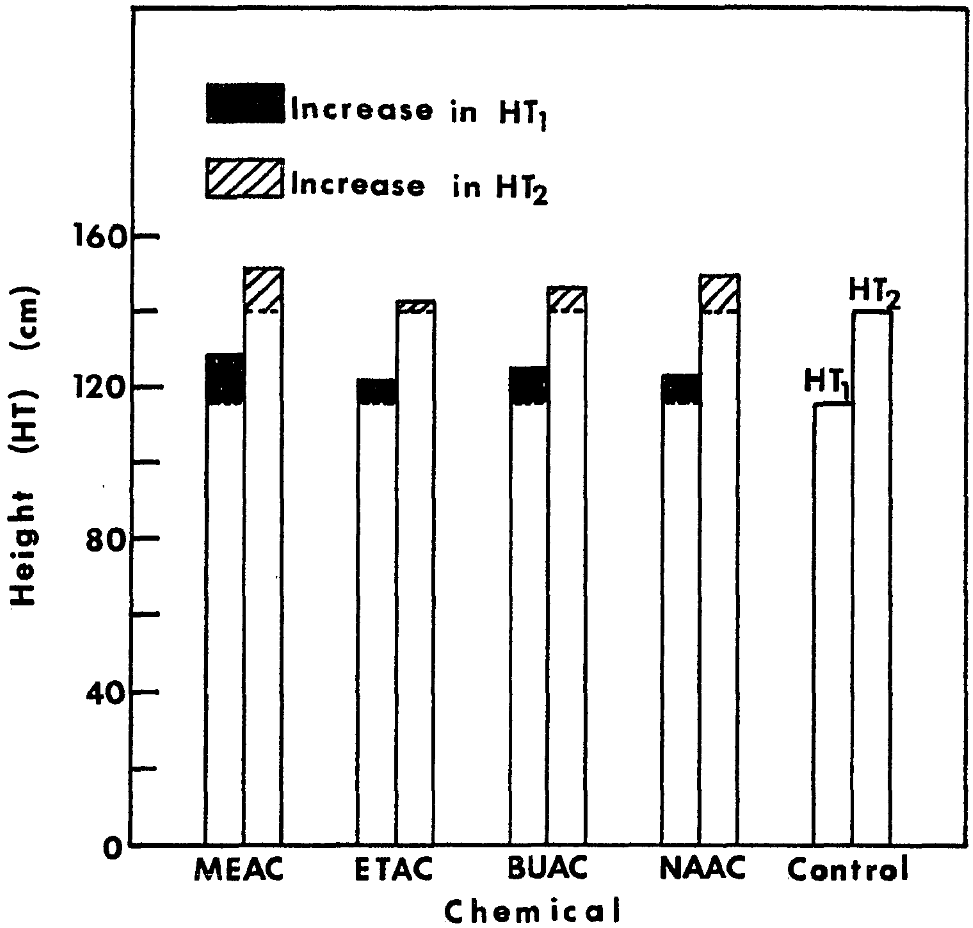

Figure 1. Effect of MEAC, ETAC, BUAC, and NAAC on HT_1 (one week after sprayed) and HT_2 (two weeks after sprayed) when averaged across the rates of chemical (Experiment 1)

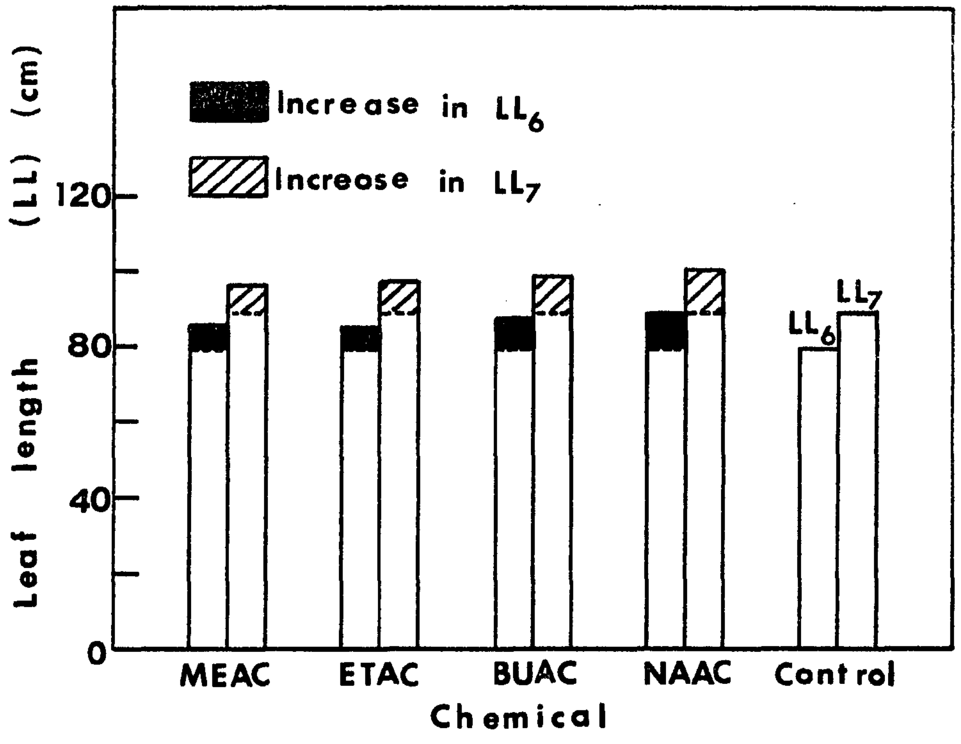

Figure 2. Effect of MEAC, ETAC, BUAC, and NAAC on LL_6 (leaf length of the 6th leaf measured one week after sprayed) and LL_7 (leaf length of the 7th leaf measured two weeks after sprayed) when averaged across the rates of chemical (Experiment 1)

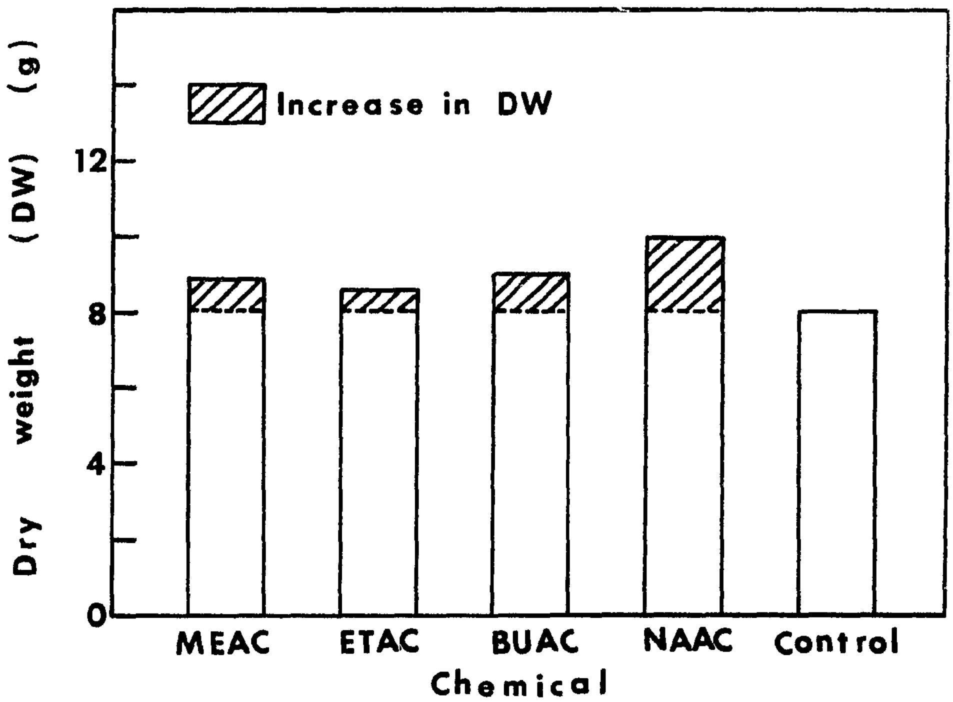

Figure 3. Effect of MEAC, ETAC, BUAC, and NAAC on DW two weeks after spraying the chemicals, and when averaged across the rates of chemical (Experiment 1)

effective rate of application in increasing LL_6, LL_7, and DW was 2.5×10^{-3} M. The highest rate (10×10^{-3} M) and the low rate (1.25×10^{-3} M) were similar to the control for LL_6, LL_7, and DW.

The interaction between chemicals and application rates of chemical was significant for all the attributes (Table 3). Most of the interaction was due to differences in the optimum rate for the four chemicals. In general, the optimum rate for BUAC was 1.25×10^{-3} M, for ETAC the optimum rate was 2.5×10^{-3} M, and for MEAC and NAAC the optimum rate was 5×10^{-3} M. The highest rate (10×10^{-3} M) suppressed growth to a value near that of the control. The effects of the different rates of MEAC, ETAC, BUAC, and NAAC on HT_1, HT_2, LL_6, LL_7, and DW are shown in Figures 4, 5, and 6.

Experiment 2

In this experiment, all treatments were the same as in Experiment 1 except that the plants were grown in a greenhouse for 3 weeks before being transferred into the growth chamber. The attributes measured were also the same as in Experiment 1. This experiment was done in order to reduce plant elongation caused by relatively low light levels in the growth chamber, and to confirm the results of the first experiment.

The results of main effects of chemicals and rates of chemical on HT_1, HT_2, LL_6, LL_7, and DW are shown in Tables 4 and 5. the effects of chemicals and application rates of

Table 3. The effects of chemical (MEAC, ETAC, BUAC, and NAAC) and rate of chemical on HT_1, HT_2, LL_6, LL_7, and DW of corn when sprayed at 5th leaf stage (Experiment 1)

Chemical	Rate ($Mx10^{-3}$)	HT_1	HT_2	LL_6	LL_7	DW
		(cm)				(g)
MEAC	1.25	122.0 de	140.7 def	82.3 cdef	89.9 fg	7.49 f
	2.5	135.6 a	160.2 a	94.1 ab	104.1 bc	10.66 a
	5	130.0 b	156.9 ab	92.3 b	101.7 c	9.70 b
	10	120.6 def	145.3 c	75.3 g	88.0 g	7.54 f
ETAC	1.25	118.9 efg	137.7 ef	81.7 cdef	91.1 efg	8.03 def
	2.5	117.3 fg	138.3 ef	81.3 ef	89.7 fg	7.40 f
	5	130.3 b	154.2 b	92.8 ab	107.5 ab	10.66 a
	10	120.0 efg	140.8 def	84.6 cde	96.2 d	8.01 def
BUAC	1.25	129.0 b	155.1 b	94.7 ab	108.2 a	9.71 b
	2.5	129.3 b	146.9 c	83.3 cdef	93.3 de	8.91 c
	5	124.6 cd	140.7 def	84.9 cd	94.4 de	8.54 cd
	10	118.4 efg	136.6 f	85.4 c	94.2 de	8.51 cd
NAAC	1.25	119.0 efg	144.7 cd	80.9 f	89.1 g	8.30 cde
	2.5	127.2 bc	158.1 ab	95.8 a	106.1 ab	9.73 b
	5	129.2 b	154.8 b	92.1 b	108.3 a	11.30 a
	10	115.9 g	137.6 ef	81.7 cdef	96.9 d	9.91 b
Control	0	116.2 fg	141.0 de	76.6 g	89.0 g	8.28 cde

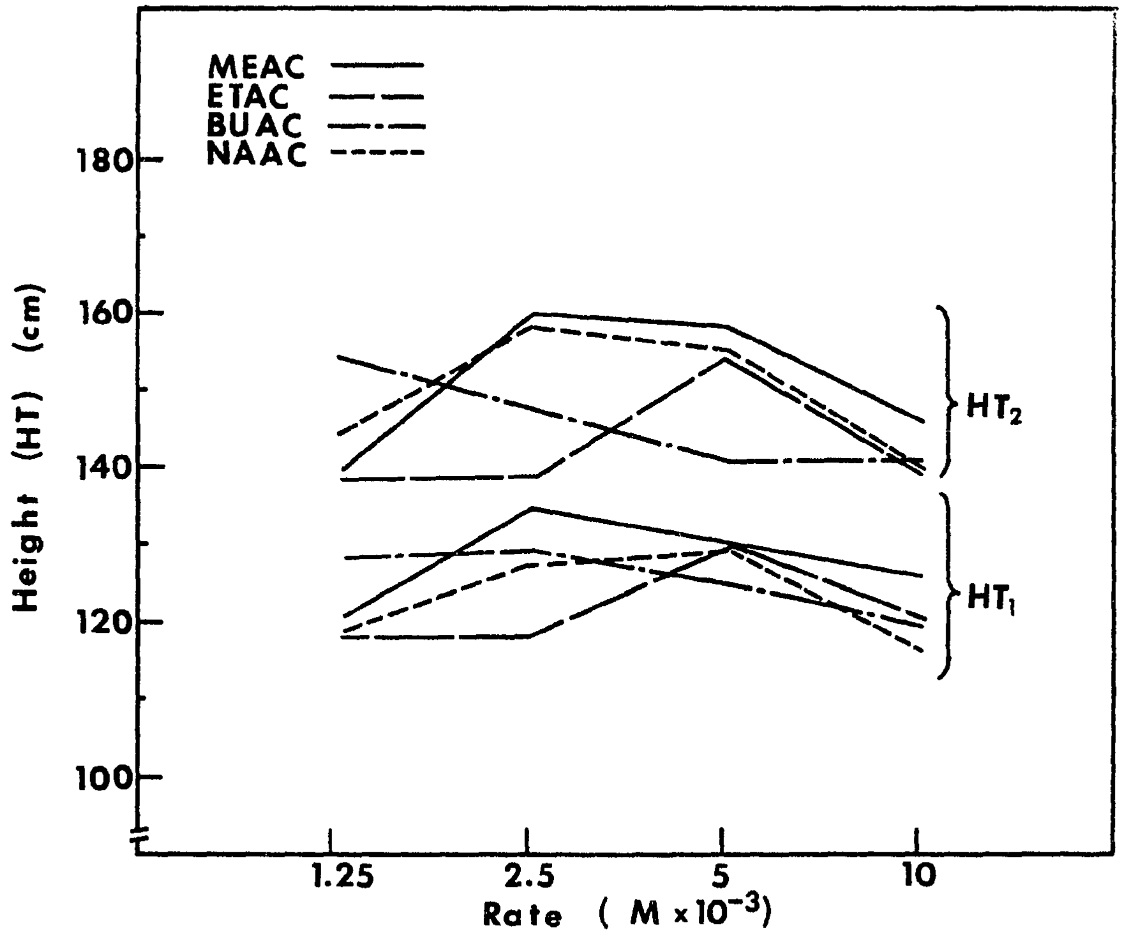

Figure 4. Effect of different rates of MEAC, ETAC, BUAC, and NAAC on HT_1 (measured one week after sprayed) and HT_2 (measured two weeks after sprayed) for Experiment 1 (see Table 3 for the control values)

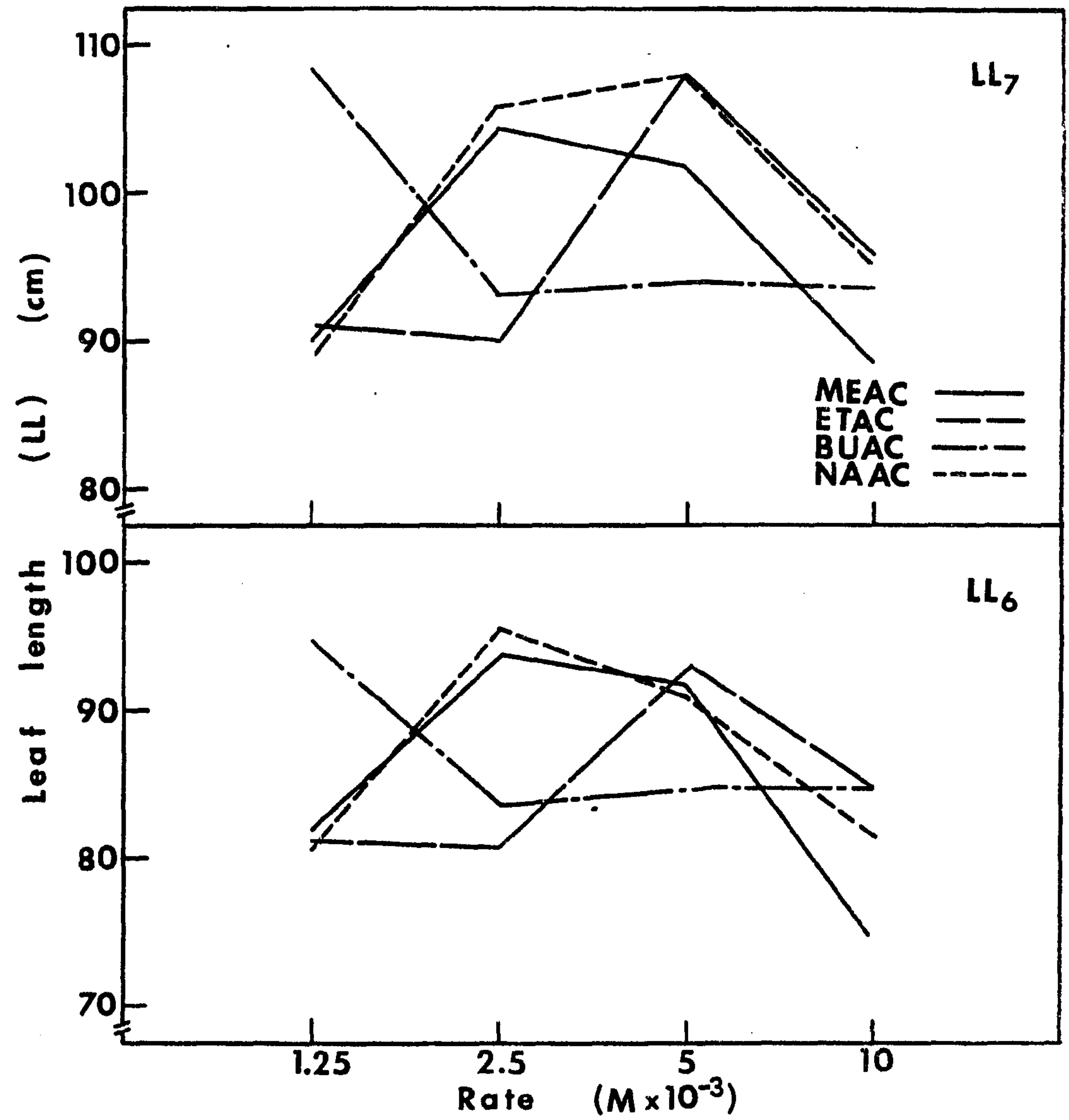

Figure 5. Effect of different rates of MEAC, ETAC, BUAC, and NAAC on LL_6 (leaf length of the 6th leaf measured one week after sprayed) and LL_7 (leaf length of the 7th leaf measured two weeks after sprayed) for Experiment 1 (see Table 3 for the control values)

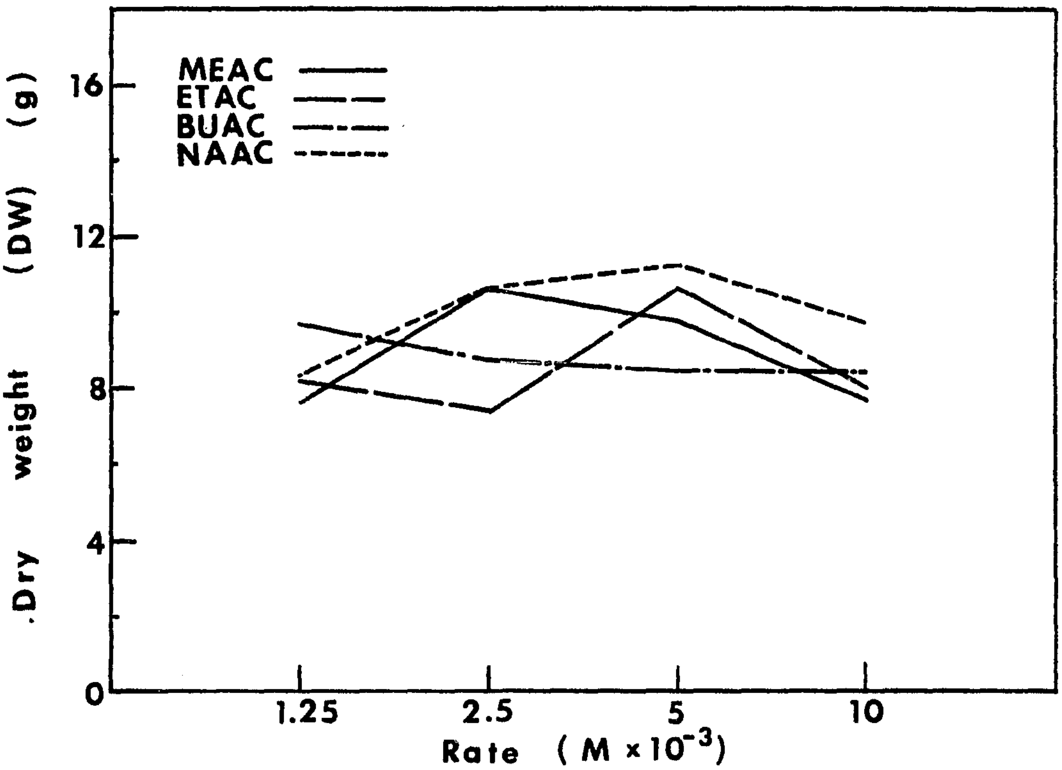

Figure 6. Effect of different rates of MEAC, ETAC, BUAC, and NAAC on DW (Experiment 1) (see Table 3 for the control values)

chemical were significant for each of the attributes. As shown in Table 4, for HT_1, BUAC was the most effective and was significantly different from the other three chemicals. For HT_2, MEAC and NAAC had a similar effect and were the most effective. BUAC was not significantly different from NAAC in contributing to HT_2. For LL_6, both BUAC and NAAC were the most effective and were significantly different from the other two chemicals. For LL_7, MEAC was the most effective and was significantly different from the other chemicals. BUAC and NAAC had a similar effect but were greater than ETAC. The most effective chemical in contributing to the DW was NAAC which was significantly different from the other three chemicals and there were no differences between those three chemicals. As shown in Table 5, the $5x10^{-3}$ M rate was the most effective in increasing HT_2, LL_6, and LL_7. It was significantly different from the other rates in increasing HT_2, LL_6, and LL_7. For HT_1, there was no difference between rate $2.5x10^{-3}$ M and $5x10^{-3}$ M, but both rates were significantly different from the other rates. For DW, the most effective rate was $2.5x10^{-3}$ M. It was significantly different from the other rates. The range of the most effective rates in contributing to HT_1, HT_2, LL_6, LL_7, and DW in this experiment was $2.5x10^{-3}$ M and $5x10^{-3}$ M. The changes in HT_1, HT_2, LL_6, LL_7, and DW due to main effects of chemicals are shown in Figures 7, 8, and 9.

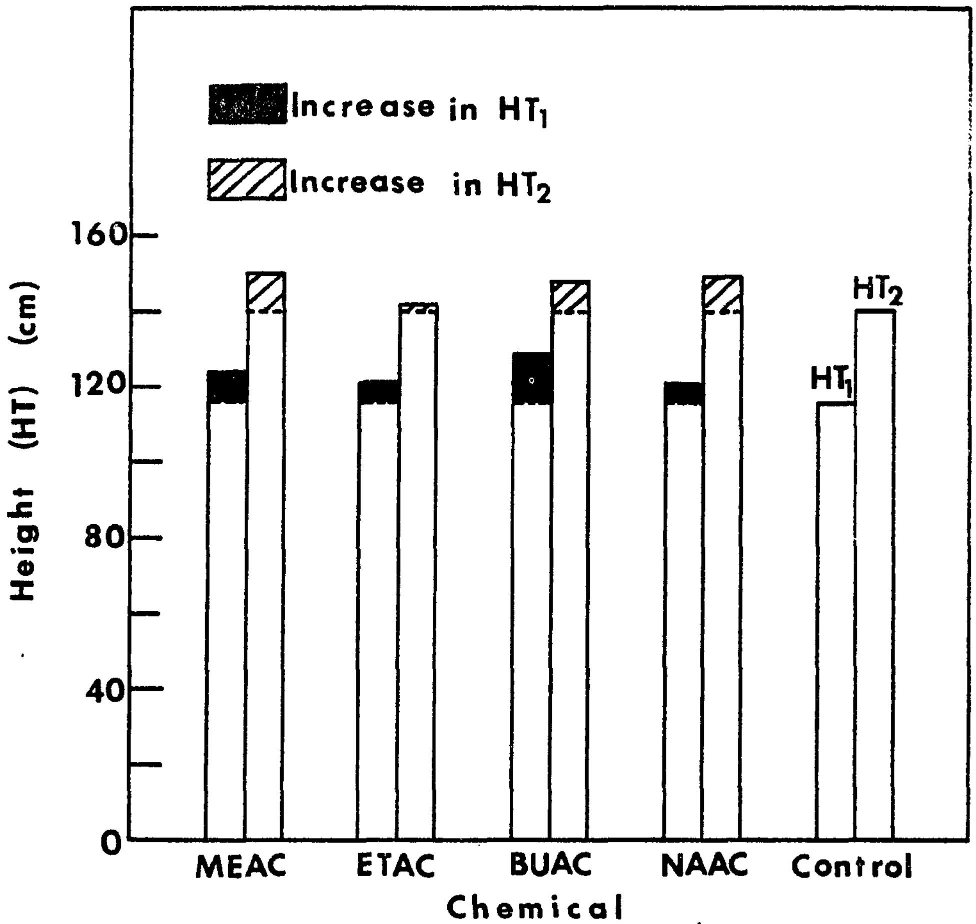

Figure 7. Effect of MEAC, ETAC, BUAC, and NAAC on HT_1 and HT_2 when averaged across the rates of chemical (Experiment 2)

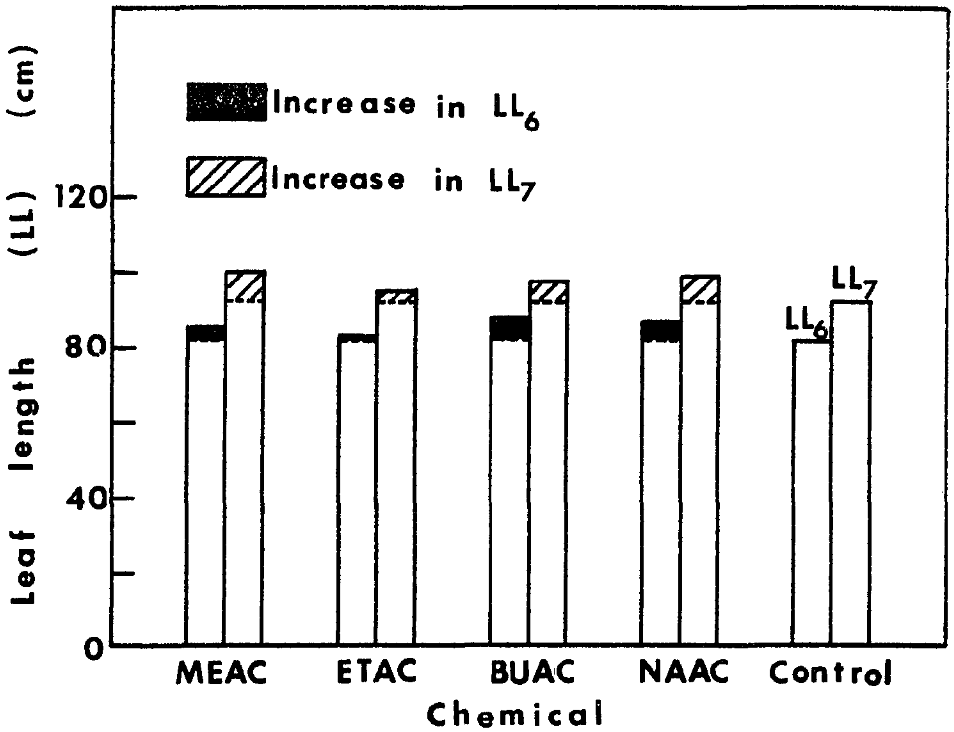

Figure 8. Effect of MEAC, ETAC, BUAC, and NAAC on LL_6 and LL_7 when averaged across the rates of chemical (Experiment 2)

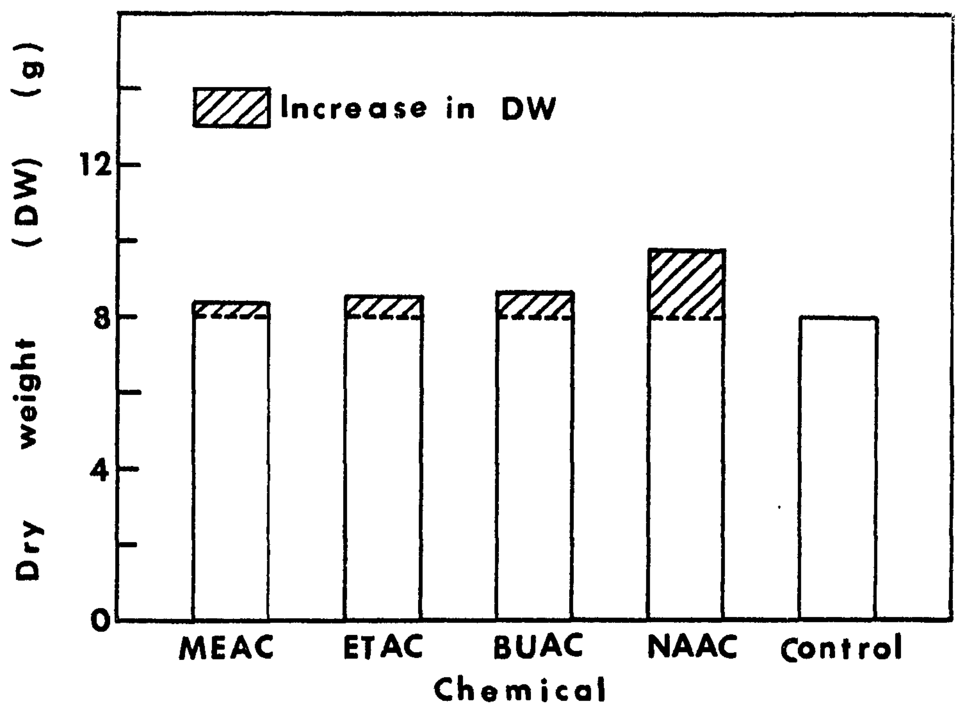

Figure 9. Effect of MEAC, ETAC, BUAC, and NAAC on DW when averaged across the rates of chemical (Experiment 2)

Table 4. The main effects of chemical (MEAC, ETAC, BUAC, and NAAC) on HT_1, HT_2, LL_6, LL_7, and DW of corn when sprayed at the 5th leaf stage (Experiment 2)

Chemical	HT_1	HT_2 (cm)	LL_6	LL_7	DW (g)
MEAC	123.10 b	149.65 a	85.08 b	100.15 a	8.35 b
ETAC	120.93 b	142.38 c	82.25 e	94.13 c	8.49 b
BUAC	128.65 a	146.90 b	87.73 a	97.13 b	8.60 b
NAAC	121.42 b	148.25 ab	86.45 a	97.80 b	9.85 a

Table 5. The main effects of rate of chemical on HT_1, HT_2, LL_6, LL_7, and DW of corn when sprayed at the 5th leaf stage (Experiment 2)

Rate ($Mx10^{-3}$)	HT_1	HT_2 (cm)	LL_6	LL_7	DW (g)
0	113.20 c	139.30 d	77.90 e	90.30 e	7.89 c
1.25	121.90 b	143.58 c	84.42 c	95.23 c	8.41 c
2.5	128.03 a	150.63 b	86.25 b	100.33 b	9.28 a
5	128.73 a	153.58 a	89.03 a	102.28 a	9.57 b
10	115.00 c	139.38 d	80.98 d	91.16 d	7.99 d

The interaction between chemicals and rates was significant for all attributes measured (Table 6). As in Experiment 1, the most common optimum rate for BUAC was 1.25×10^{-3} M, for MEAC it was 2.5×10^{-3} M, for ETAC it was 5.0×10^{-3} M, and NAAC tended to act more like MEAC than like ETAC as it did in Experiment 1. The contribution of each chemical at different rates on HT_1, HT_2, LL_6, LL_7, and DW are shown in Figures 10, 11, and 12.

1980 Field Experiments

Experiment 3

The results from the 1979 growth chamber experiments of the effects of MEAC, ETAC, BUAC, and NAAC on vegetative growth of corn led to field investigations. In 1980, field experiments were carried out in order to determine the effects of MEAC, ETAC, BUAC, and NAAC when sprayed at different rates at the 4th, 8th, and 12th leaf stages of corn development.

There were no significant differences on leaf width (LW), ears per plant (E/P), and weight per ear (W/E) attributable to time of application of the chemicals (Table 7). There were significant differences in plant height (HT) and grain yield (Y). When the chemicals were sprayed at the 4th leaf stage, they resulted in greater yield than when sprayed at the 8th and 12th leaf stages. Similar results were obtained for HT (Table 7).

Table 6. The effects of chemical (MEAC, ETAC, BUAC, and NAAC) and rate of chemical on HT_1, HT_2, LL_6, LL_7, and DW of corn when sprayed at the 5th leaf stage (Experiment 2)

Chemical	Rate ($Mx10^{-3}$)	HT_1 (cm)	HT_2 (cm)	LL_6 (cm)	LL_7 (cm)	DW (g)
MEAC	1.25	121.5 c	139.0 de	81.7 fghi	90.8 d	7.46 f
	2.5	130.1 b	158.6 a	84.6 def	105.6 b	9.86 b
	5	128.2 b	157.5 a	91.2 bc	108.2 a	9.21 c
	10	112.6 ef	143.5 bc	82.8 efg	93.0 d	6.86 g
ETAC	1.25	117.4 cde	137.2 e	80.6 ghij	90.6 de	7.59 f
	2.5	117.5 cde	138.6 de	79.8 hij	92.4 d	8.03 ef
	5	130.3 ab	156.3 a	89.0 c	104.6 b	10.42 a
	10	118.5 cd	137.4 e	78.8 ij	88.9 e	7.91 f
BUAC	1.25	134.7 a	158.1 a	95.6 a	105.4 b	9.84 b
	2.5	133.4 a	147.0 b	86.9 d	97.3 c	8.56 de
	5	128.1 b	142.7 cd	85.0 de	93.6 d	8.03 ef
	10	118.4 cd	139.8 cde	83.4 efg	92.2 de	7.95 f
NAAC	1.25	114.0 def	140.0 cde	79.8 hij	91.1 de	8.79 d
	2.5	131.1 ab	158.3 a	93.7 ab	106.0 ab	10.67 a
	5	128.3 b	157.8 a	90.1 c	102.7 b	10.60 a
	10	112.3 f	136.9 e	82.0 efgh	91.4 de	9.93 bc
Control	0	113.2 f	139.3 de	77.9 j	90.3 de	7.89 f

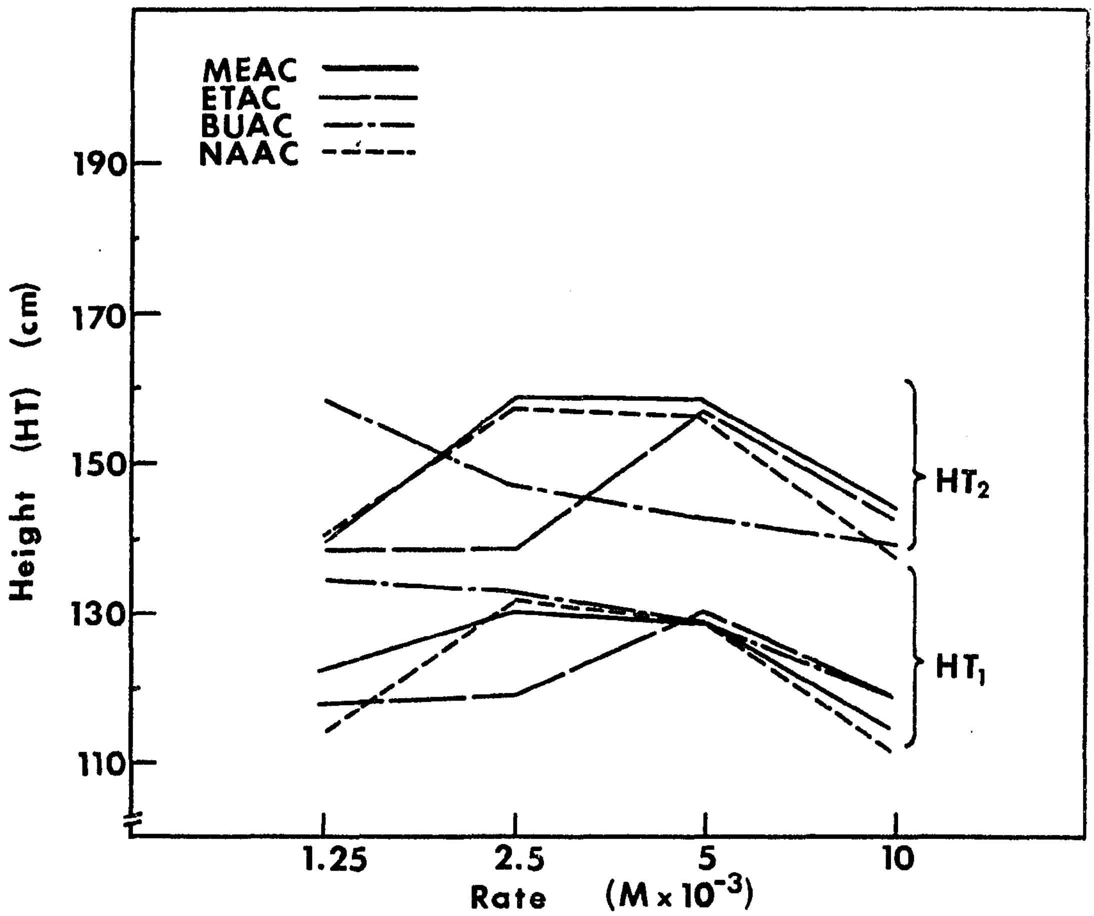

Figure 10. Effects of rate of chemical (MEAC, ETAC, BUAC, and NAAC) on HT_1 and HT_2 (Experiment 2) (see Table 6 for the control values)

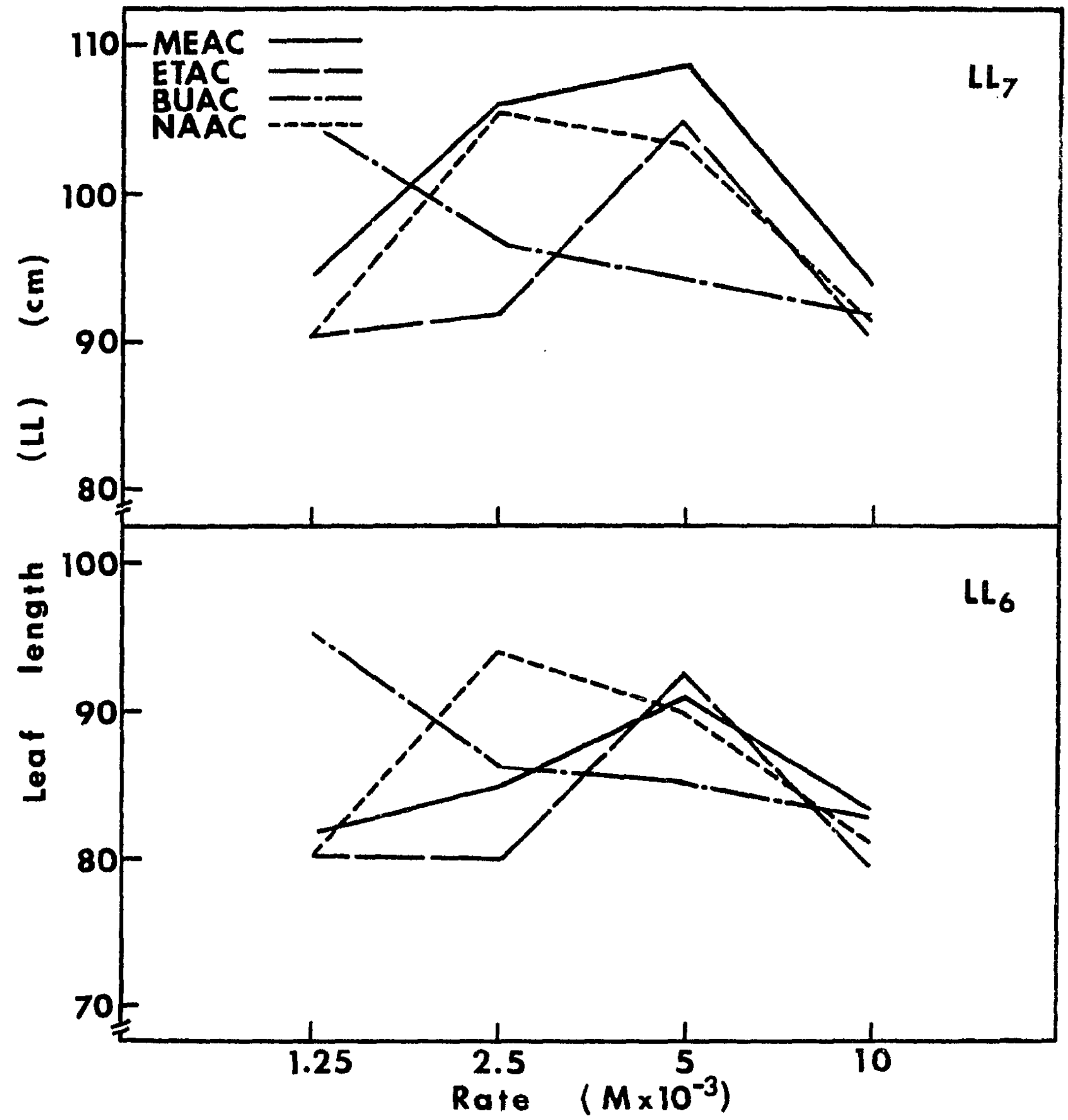

Figure 11. Effects of rate of chemical (MEAC, ETAC, BUAC, and NAAC) on LL_6 and LL_7 (Experiment 2) (see Table 6 for the control values)

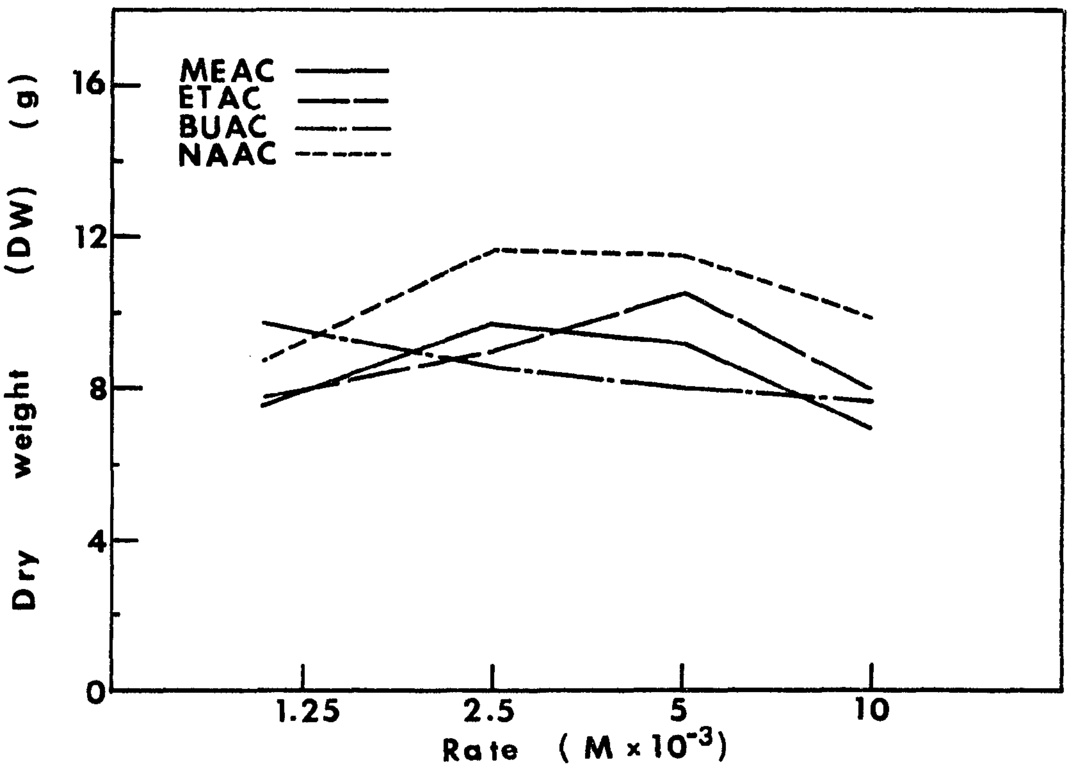

Figure 12. Effects of rate of chemical (MEAC, ETAC, BUAC, and NAAC) on DW (Experiment 2) (see Table 6 for the control values)

Table 7. The main effects of time of application of chemical on HT, LW, E/P, W/E, and Y of corn in Field A

Time (stage)	HT	LW	E/P	W/E (g)	Y (kg/ha)
	------(cm)-------				
4th leaf	175.57 a	10.38 a	0.999 a	174.52 a	9534 a
8th leaf	174.96 ab	10.33 a	0.995 a	173.31 a	9423 b
12th leaf	174.55 b	10.33 a	0.990 a	172.92 a	9415 b

Table 8. The main effects of chemical (MEAC, ETAC, BUAC, and NAAC) on HT, LW, E/P, W/E, and Y of corn in Field A

Chemical	HT	LW	E/P	W/E (g)	Y (kg/ha)
	------(cm)-------				
MEAC	175.08 a	10.30 a	0.998 a	172.24 a	9410 a
ETAC	175.50 a	10.35 a	0.997 a	174.30 a	9497 a
BUAC	175.21 a	10.41 a	0.995 a	173.93 a	9475 a
NAAC	174.31 b	10.33 a	0.989 b	173.87 a	9447 a

The main effect of type of chemical was not significant for LW, W/E and Y. For HT and E/P, NAAC was significantly less than the other chemicals (Table 8).

The results obtained for the main effect of rates of chemical on HT, LW, E/P, W/E, and Y were significantly different (Table 9). Spraying chemicals at the rate of 0.4 kg/ha was the most effective rate for increasing HT, LW, E/P, W/E, and Y.

Since time of application was not completely randomized, separate analysis within each time was conducted. The main effect of chemical on HT, LW, E/P, W/E, and Y at the 4th, 8th, and 12th leaf stages are shown in Tables 10, 11, and 12, respectively. There were no significant differences between chemicals on LW, E/P, W/E, and Y at any of the three times of application (Tables 10, 11, and 12). MEAC and ETAC increased HT more than BUAC and NAAC at the 4th leaf stage (Table 10). However, when the chemicals were sprayed at the 8th leaf stage, BUAC was the most effective in increasing HT (Table 11), and at the 12th leaf stage, the chemicals were not different (Table 12).

There were significant differences due to rate of chemical on most of the attributes measured at the 4th, 8th, and 12th leaf stages except for E/P at the 12th leaf stage as shown in Tables 13, 14, and 15, respectively. At the 4th leaf stage, the 0.2, 0.4, and 0.8 kg/ha rates showed

Table 9. The main effects of rate of chemical on HT, LW, E/P, W/E, and Y of corn in Field A

Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
0	173.75 c	10.07 b	0.985 b	168.45 c	9122 c
0.2	175.74 b	10.42 a	0.997 a	173.94 b	9499 b
0.4	176.51 a	10.48 a	0.998 a	177.04 a	9656 a
0.8	174.10 c	10.42 a	0.999 a	174.91 b	9554 ab

Table 10. The main effects of chemical (MEAC, ETAC, BUAC, and NAAC) on HT, LW, E/P, W/E, and Y of corn when sprayed at the 4th leaf stage in Field A

Chemical	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
MEAC	176.13 a	10.34 a	0.997 a	171.92 a	9386 a
ETAC	176.60 a	10.40 a	1.000 a	175.63 a	9602 a
BUAC	176.12 b	10.44 a	1.004 a	175.48 a	9597 a
NAAC	174.36 c	10.37 a	0.996 a	175.07 a	9552 a

Table 11. The main effects of chemical (MEAC, ETAC, BUAC, and NAAC) on HT, LW, E/P, W/E, and Y of corn when sprayed at the 8th leaf stage in Field A

Chemical	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
MEAC	174.56 bc	10.27 a	0.998 a	172.81 a	9401 a
ETAC	175.24 ab	10.33 a	0.999 a	173.68 a	9470 a
BUAC	175.76 a	10.38 a	0.994 a	172.73 a	9423 a
NAAC	174.28 c	10.35 a	0.988 a	172.44 a	9400 a

Table 12. The main effects of chemical (MEAC, ETAC, BUAC, and NAAC) on HT, LW, E/P, W/E, and Y of corn when sprayed at the 12th leaf stage in Field a

Chemical	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
MEAC	174.56 a	10.30 a	0.999 a	171.98 a	9444 a
ETAC	174.65 a	10.33 a	0.991 a	173.59 a	9421 a
BUAC	174.69 a	10.40 a	0.987 a	173.58 a	9406 a
NAAC	173.30 a	10.29 a	0.982 a	174.10 a	9390 a

Table 13. The main effects of rate of chemical on HT, LW, E/P, W/E, and Y of corn when sprayed at the 4th leaf stage in Field A

Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
0	174.03 c	10.09 c	0.982 b	167.07 b	9013 b
0.2	176.89 b	10.51 ab	1.006 a	175.79 a	9633 a
0.4	177.68 a	10.58 a	1.006 a	178.94 a	9821 a
0.8	173.68 c	10.40 b	1.003 a	176.29 a	9669 a

Table 14. The main effects of rate of chemical on HT, LW, E/P, W/E, and Y of corn when sprayed at the 8th leaf stage in Field A

Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
0	173.99 c	9.98 b	0.986 a	168.62 b	9151 c
0.2	175.26 b	10.37 a	0.991 a	173.08 a	9431 b
0.4	176.36 a	10.51 a	1.006 a	176.51 a	9692 a
0.8	174.23 c	10.48 a	0.995 a	173.46 a	9419 b

Table 15. The main effects of rate of chemical on HT, LW, E/P, W/E, and Y of corn when sprayed at the 12th leaf stage in Field A

Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
0	173.24 b	10.14 a	0.988 a	169.65 b	9201 b
0.2	175.08 a	10.39 a	0.994 a	172.96 a	9433 a
0.4	175.48 a	10.41 a	0.981 a	175.66 a	9451 a
0.8	174.40 a	10.39 a	0.998 a	174.98 a	9574 a

similar effects on E/P, W/E, and Y and were significantly different from the control (Table 13). When the chemicals were sprayed at the 8th leaf stage, the 0.4 kg/ha rate was shown to be the most effective in increasing HT, LW, W/E, and Y (Table 14). At the 12th leaf stage, the 0.2, 0.4, and 0.8 kg/ha rates increased HT, W/E, and Y but were not different among themselves (Table 15).

The interaction between chemicals and rates was significant for HT, LW, W/E, and Y but not for E/P when the chemicals were sprayed at the 4th leaf stage (Table 16). The medium rate (0.4 kg/ha) of all the chemicals contributed significantly to the effect of these chemicals on HT, LW, W/E, and Y (Table 16). MEAC and ETAC at the rates of 0.2 and 0.4 kg/ha were the most effective in increasing HT

Table 16. The effects of chemical and rate of chemical on HT, LW, E/P, W/E, and Y of corn when sprayed at the 4th leaf stage in Field A

Chemical	Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
MEAC	0	175.48 cd	10.18 def	0.985 a	164.58 e	8904 d
	0.2	178.25 b	10.43 abcd	1.003 a	172.68 abcde	9489 abc
	0.4	178.95 ab	10.40 abcd	1.003 a	179.10 ab	9770 a
	0.8	171.85 f	10.35 bcd	0.998 a	171.33 bcde	9383 abcd
ETAC	0	173.55 e	10.25 cde	0.975 a	169.68 cde	9084 bcd
	0.2	179.55 ab	10.33 cd	1.008 a	176.90 acd	9737 a
	0.4	179.80 a	10.65 a	1.013 a	177.60 abc	9791 a
	0.8	173.50 e	10.38 abcd	1.005 a	178.35 abc	9793 a
BUAC	0	173.55 e	9.95 f	0.980 a	167.23 de	9013 cd
	0.2	175.85 cd	10.65 a	1.015 a	175.50 abcd	9560 ab
	0.4	176.53 c	10.65 a	1.015 a	177.95 abc	9910 a
	0.8	174.80 de	10.53 abc	1.005 a	181.23 a	9904 a
NAAC	0	173.55 e	10.00 ef	0.988 a	166.80 de	9054 cd
	0.2	173.90 e	10.63 ab	0.998 a	178.38 abc	9747 a
	0.4	175.45 cd	10.45 abcd	0.995 a	181.13 a	9813 a
	0.8	174.55 de	10.35 bcd	1.005 a	174.28 abcd	9596 a

compared to BUAC and NAAC. For LW, W/E, and Y, the interactions were due to differences in response of the chemicals to various rates of chemical (Table 16).

When the chemicals were sprayed at the 8th leaf stage, the interaction between chemicals and rates was significant for all attributes measured (Table 17). The optimum rate frequently was different for the various chemicals and the highest rate was more inhibitory with some of the chemicals than with others. For Y, the 0.4 kg/ha rate was the best for MEAC, ETAC, and NAAC, and with BUAC the 0.2 kg/ha rate was greatest but not significantly greater than the 0.4 and 0.8 kg/ha rates.

There were no significant interactions for LW, E/P, and Y at the 12th leaf stage (Table 18). Significant interactions for HT and W/E were obtained (Table 18). The changes in HT, W/E, and Y at the 4th, 8th, and 12th leaf stages are shown in Figures 13, 14, 15, 16, 17, 18, and 19.

In the combined analysis of variance with time (T), chemical (C), and rate of chemical (R), there was a significant T x C interaction for HT, a significant interaction for T x R for HT, LW, and Y, a significant interaction for C x R for HT, and a significant interaction for T x C x R for HT.

Table 17. The effects of chemical and rate of chemical on HT, LW, E/P, W/E, and Y of corn when sprayed at the 8th leaf stage in Field A

Chemical	Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
MEAC	0	173.38 d	9.95 c	1.013 ab	169.23 bc	9100 d
	0.2	174.28 cd	10.40 ab	0.968 b	175.08 abc	9250 bcd
	0.4	175.98 bc	10.38 ab	1.018 a	177.05 ab	9818 a
	0.8	174.63 cd	10.35 ab	0.995 ab	169.90 bc	9132 cd
ETAC	0	175.10 bcd	9.98 c	0.988 ab	168.00 c	9109 d
	0.2	176.73 b	10.35 ab	0.988 ab	172.85 abc	9373 abcd
	0.4	175.25 bcd	10.55 a	1.003 ab	178.15 a	9732 ab
	0.8	173.88 d	10.43 ab	1.018 a	175.75 abc	9665 abc
BUAC	0	173.58 d	10.10 bc	0.968 b	168.35 c	8991 d
	0.2	175.13 bcd	10.33 ab	1.015 ab	173.63 abc	9680 abc
	0.4	180.08 a	10.63 a	1.003 ab	173.93 abc	9511 abcd
	0.8	174.28 cd	10.48 a	0.990 ab	175.00 abc	9511 abcd
NAAC	0	173.90 d	9.88 c	0.978 ab	168.90 bc	9099 d
	0.2	174.90 bcd	10.40 ab	0.995 ab	170.78 abc	9423 abcd
	0.4	174.15 cd	10.48 a	1.000 ab	176.90 ab	9708 ab
	0.8	174.15 cd	10.64 a	0.978 ab	173.20 abc	9730 abcd

Table 18. The effects of chemical and rate of chemical on HT, LW, E/P, W/E, and Y of corn when sprayed at the 12th leaf stage in Field A

Chemical	Rate (kg/ha)	HT (cm)	LW (cm)	E/P	W/E (g)	Y (kg/ha)
MEAC	0	173.08 b	10.08 a	1.000 a	167.58 d	9170 a
	0.2	174.93 ab	10.38 a	1.005 a	170.48 bcd	9398 a
	0.4	175.48 ab	10.35 a	0.990 a	176.78 ab	9612 a
	0.8	174.75 ab	10.40 a	1.003 a	173.08 abcd	9599 a
ETAC	0	173.10 b	10.10 a	0.998 a	170.45 bcd	9315 a
	0.2	174.95 ab	10.35 a	0.993 a	175.18 abc	9534 a
	0.4	175.80 a	10.38 a	0.973 a	173.10 abcd	9231 a
	0.8	174.75 ab	10.48 a	1.003 a	175.65 abc	9605 a
BUAC	0	173.60 ab	10.33 a	0.978 a	171.50 bcd	9198 a
	0.2	175.78 a	10.48 a	0.983 a	173.33 abcd	9352 a
	0.4	175.68 ab	10.45 a	0.993 a	174.10 abcd	9496 a
	0.8	173.70 ab	10.35 a	0.995 a	175.38 abc	9578 a
NAAC	0	173.20 ab	10.08 a	0.975 a	169.08 cd	9123 a
	0.2	174.65 ab	10.35 a	0.995 a	172.89 abcd	9449 a
	0.4	174.95 ab	10.45 a	0.968 a	178.65 a	9473 a
	0.8	174.40 ab	10.30 a	0.990 a	175.83 abc	9515 a

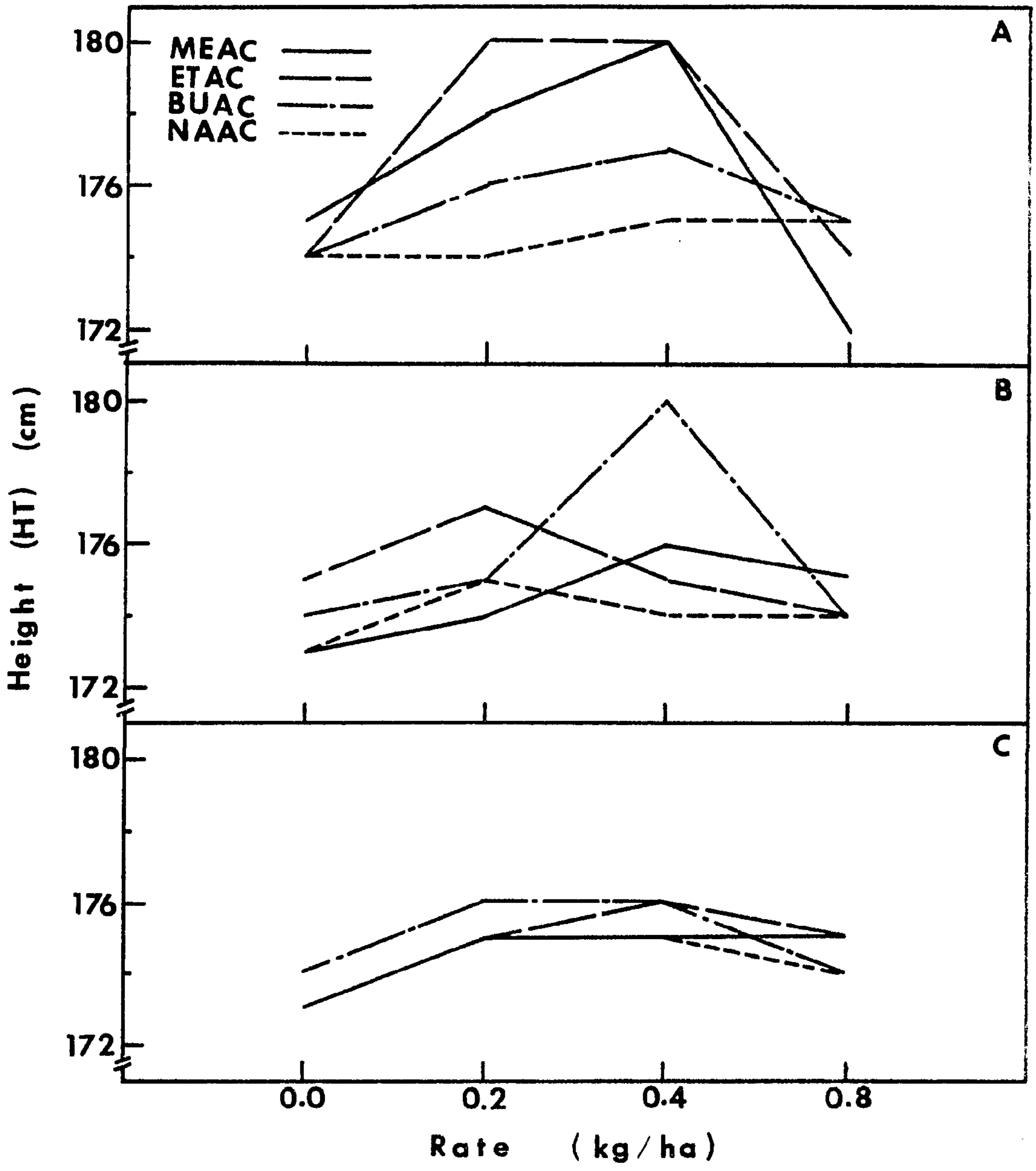

Figure 13. Effects of rate and chemical on HT when sprayed at the 4th leaf stage (A), the 8th leaf stage (B), and the 12th leaf stage (C) in Field A

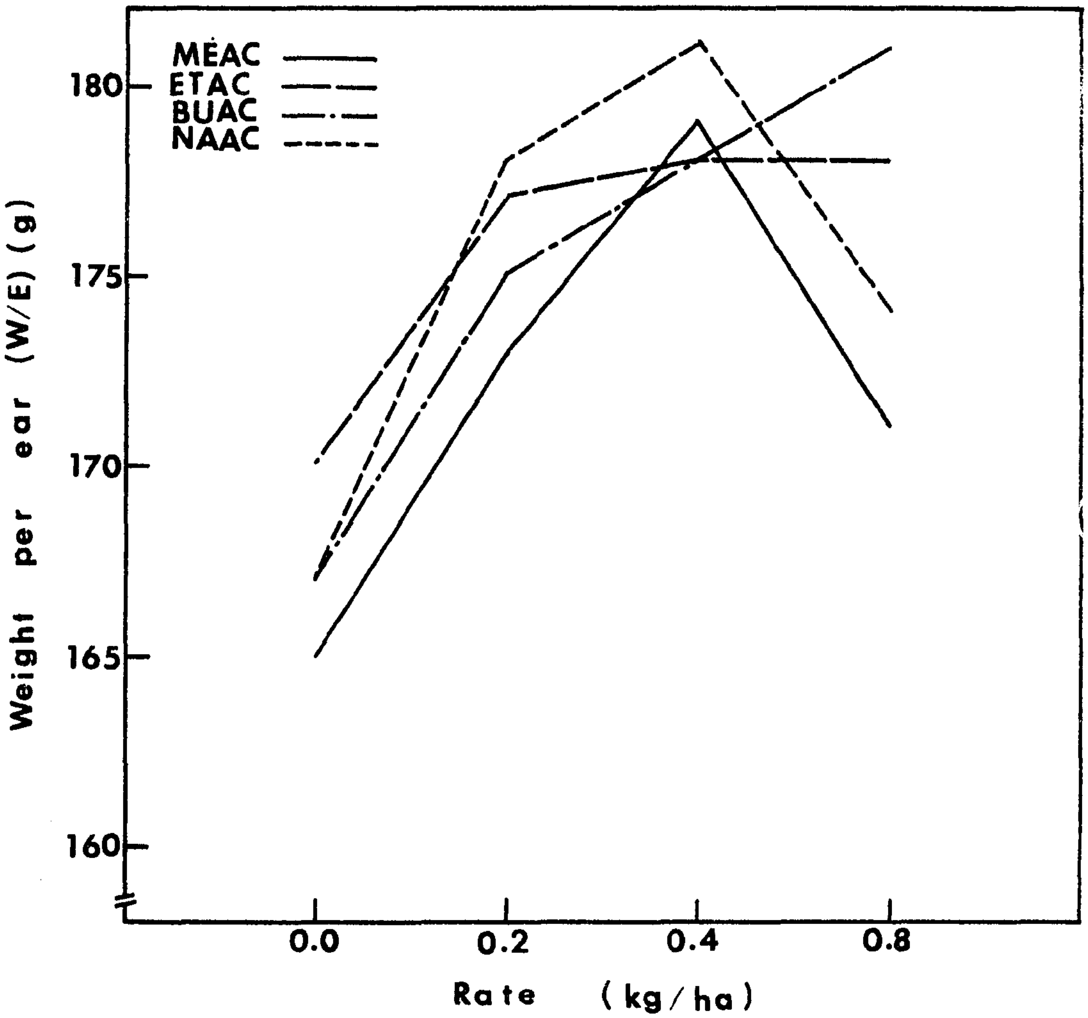

Figure 14. Effects of rate and chemical on W/E when sprayed at the 4th leaf stage in Field A

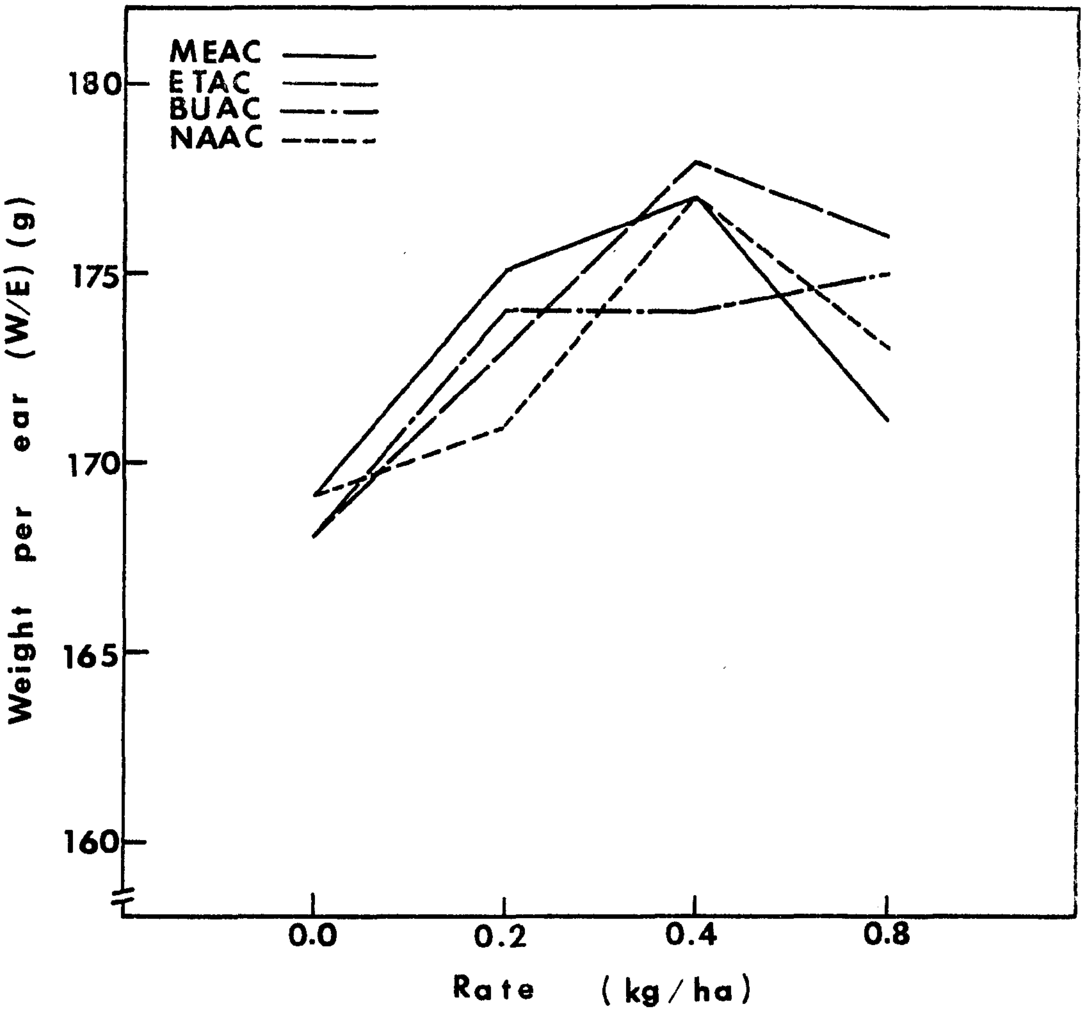

Figure 15. Effects of rate and chemical on W/E when sprayed at the 8th leaf stage in Field A

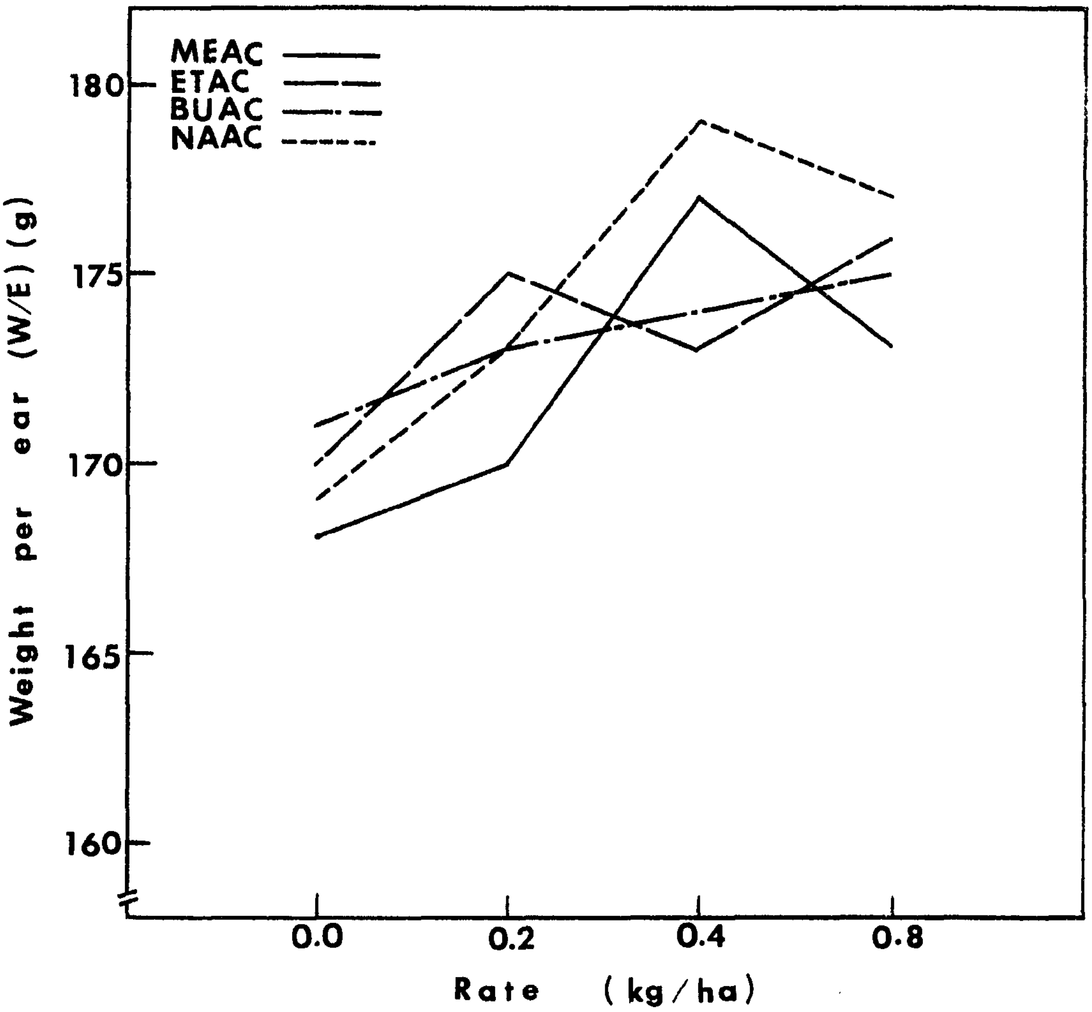

Figure 16. Effects of rate and chemical on W/E when sprayed at the 12th leaf stage in Field A

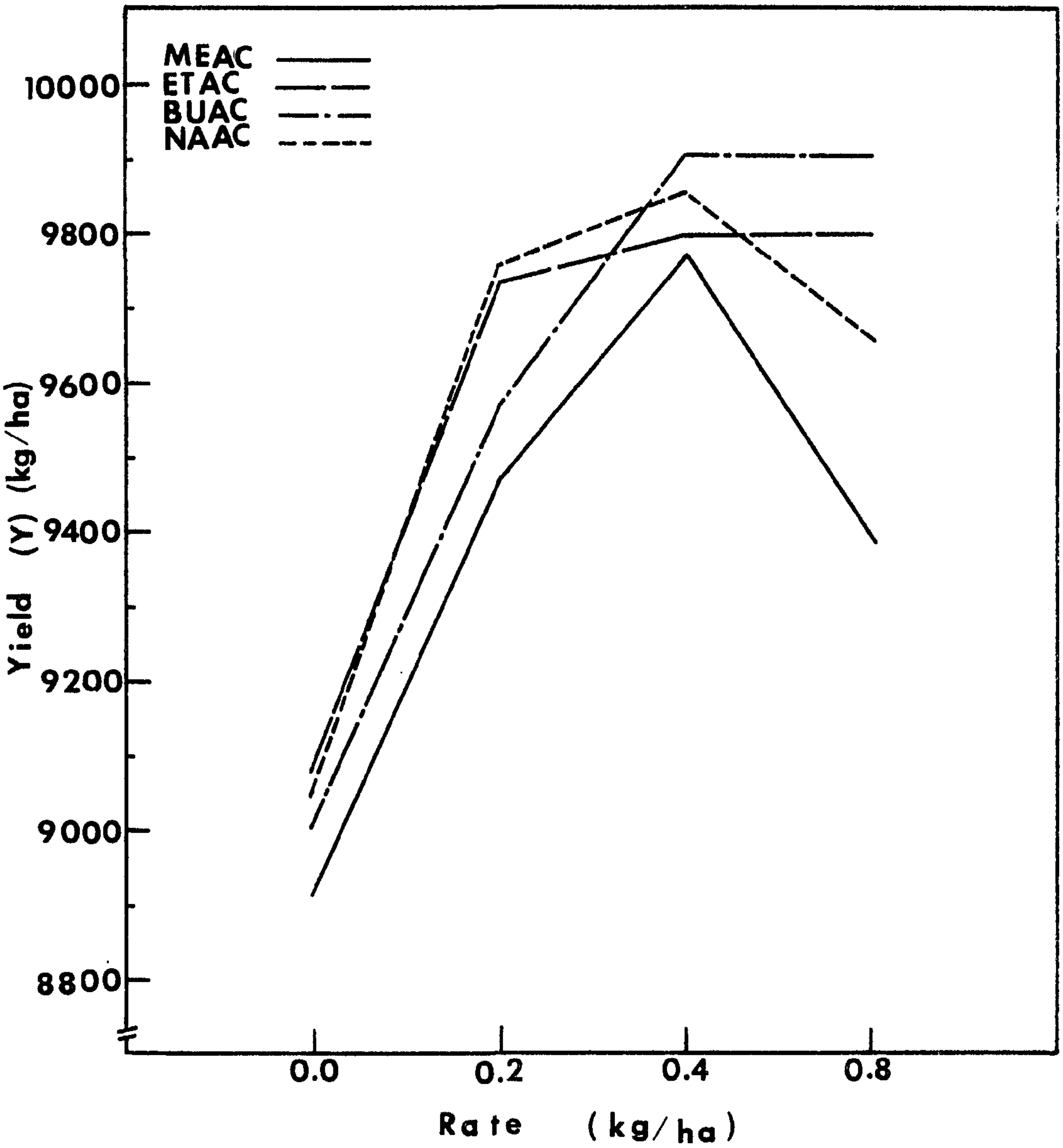

Figure 17. Effects of rate and chemical on Y when sprayed at the 4th leaf stage in Field A

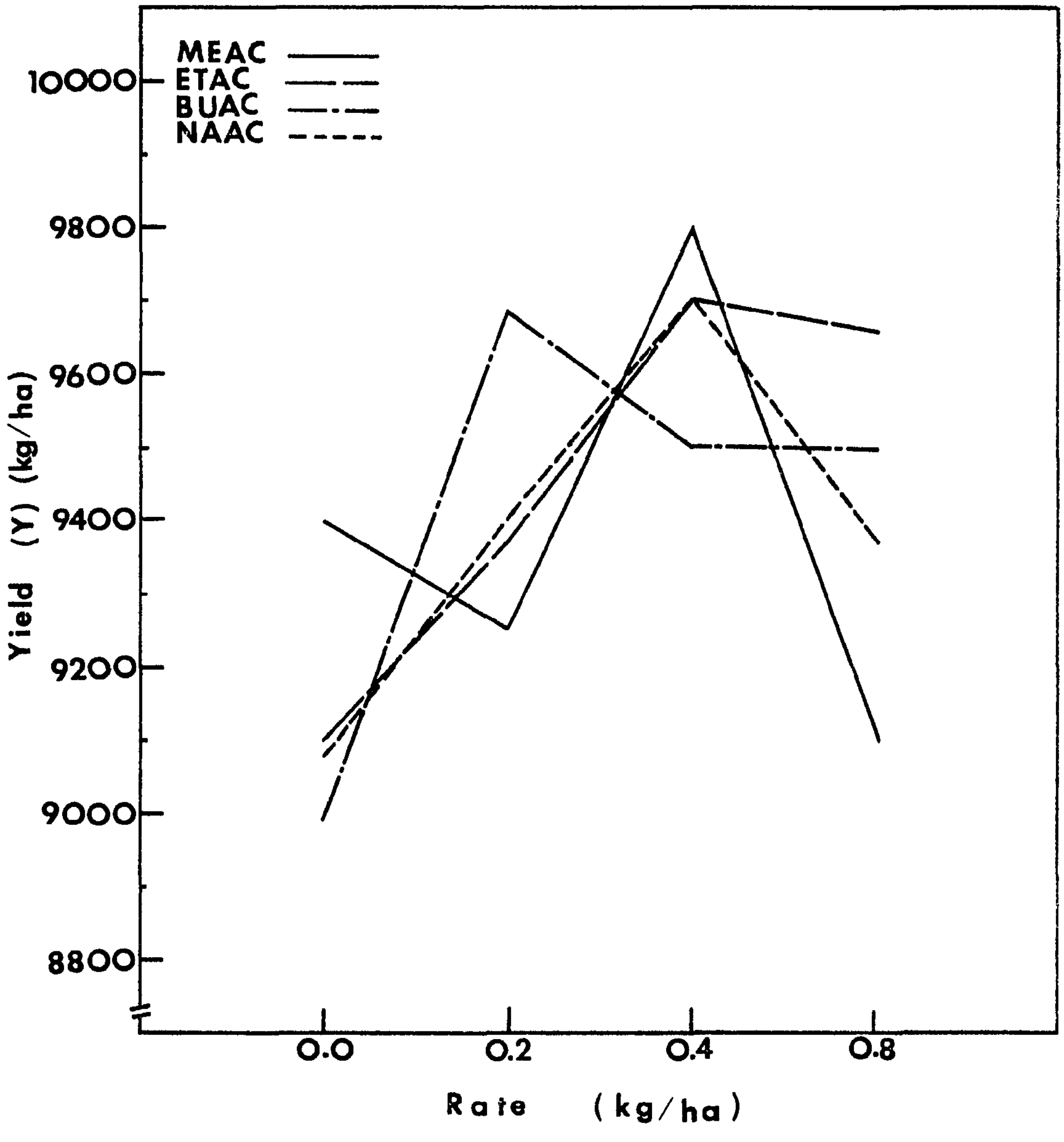

Figure 18. Effects of rate and chemical on Y when sprayed at the 8th leaf stage in Field A

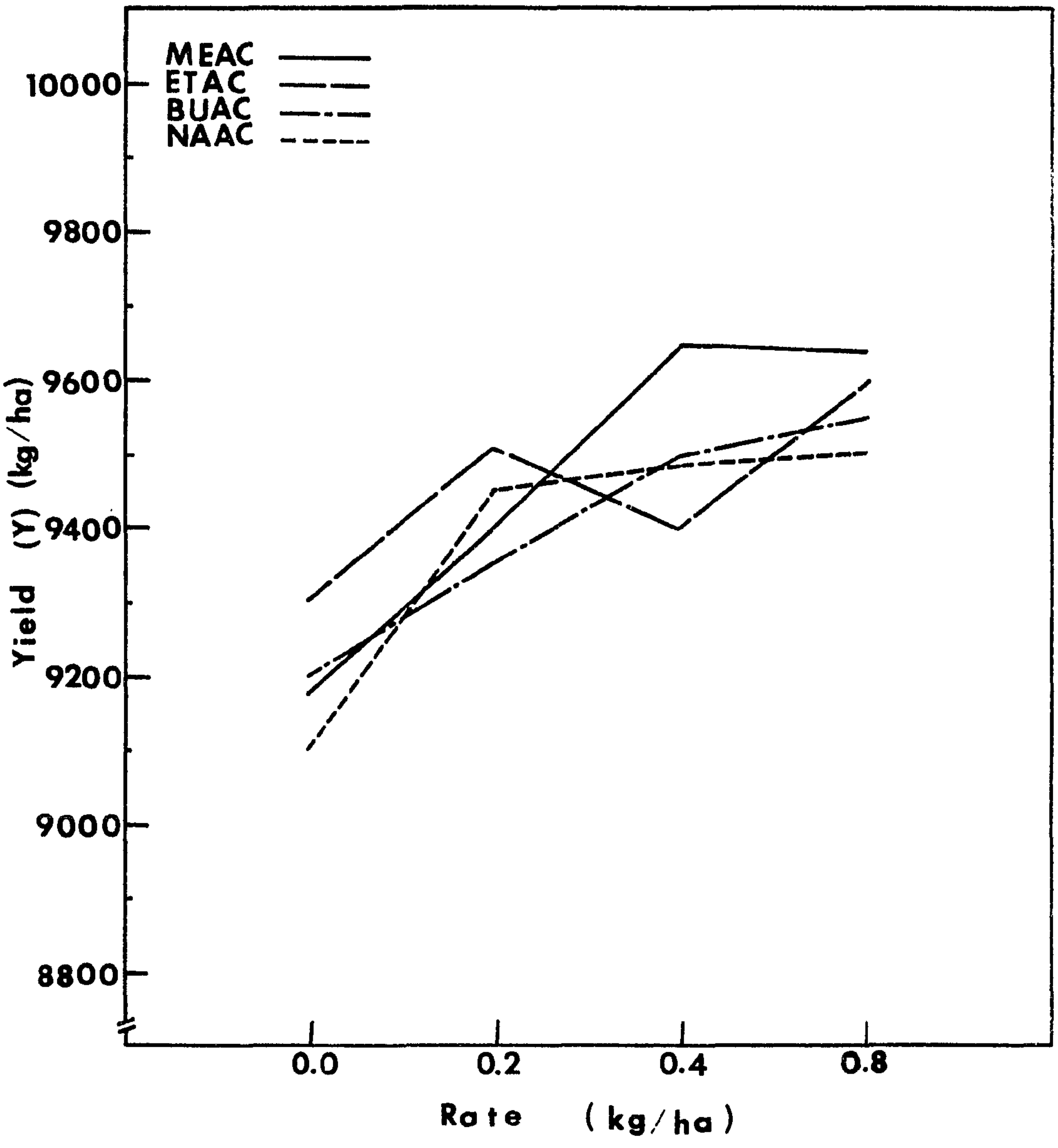

Figure 19. Effects of rate and chemical on Y when sprayed at the 12th leaf stage in Field A

Experiment 4

This experiment was conducted to study the effects of MEAC, ETAC, and BUAC on grain yield of soybean when these chemicals were applied at different rates (0, 0.2, 0.4, and 0.8 kg/ha) and stages of soybean development (V_3, R_1, and $R_{2.5}$).

The main effects of time of spraying on Y are shown in Table 19. There was a significant difference on Y due to the different time of spraying. Spraying the chemicals at stage $R_{2.5}$ appeared to be the least effective in increasing Y.

The main effect of type of chemical was not significant for Y. All the chemicals appeared to give a similar Y (Table 20).

There was a significant effect of rate. The 0.2, 0.4, and 0.8 kg/ha rates were greater than the control but not different among themselves (Table 21).

Since time of application was not completely randomized, a separate statistical analysis was made within each time (Table 22). There were no significant differences between chemicals on Y at any of the three stages of application. However, it appeared that application of the chemicals at the latest stage ($R_{2.5}$) resulted in the lowest Y. The 0.2, 0.4, and 0.8 kg/ha rates increased Y at V_3 and R_1 but not at $R_{2.5}$ (Table 23). The interaction between chemical and rate of chemical was not significant at any of the growth stages.

Table 19. The main effects of time of application on Y of soybeans

Time	Y (kg/ha)
V_3	3429 a
R_1	3426 a
$R_{2.5}$	3293 b

Table 20. The main effects of chemical (MEAC, ETAC, and BUAC) on Y of soybeans

Chemical	Y (kg/ha)
MEAC	3413 a
ETAC	3390 a
BUAC	3346 a

Table 21. The main effects of rate of application on Y of soybeans

Rate (kg/ha)	Y (kg/ha)
0	3275 b
0.2	3447 a
0.4	3441 a
0.8	3374 a

Table 22. The main effects of chemical (MEAC, ETAC, and BUAC) on Y of soybeans when stages V_3, R_1, and $R_{2.5}$ were analyzed separately

Chemical	Y (kg/ha)		
	V_3	R_1	$R_{2.5}$
MEAC	3470 a	3477 a	3340 a
ETAC	3429 a	3405 a	3337 a
BUAC	3439 a	3399 a	3199 a

Table 23. The main effects of rate of application on Y of soybeans when stages V_3, R_1, and $R_{2.5}$ were analyzed separately

Rate (kg/ha)	Y (kg/ha)		
	V_3	R_1	$R_{2.5}$
0.0	3280 b	3281 b	3265 a
0.2	3517 a	3464 a	3363 a
0.4	3506 a	3510 a	3308 a
0.8	3418 a	3451 a	3252 a

In the combined analysis of variance with time (T), chemical (C), and rate of chemical (R), there were significant T x C interactions for Y, but no significant interactions for T x R, T x C x R, or C x R.

Experiment 5

In this experiment, liquid chemicals ACA and ACE were premixed with liquid anhydrous ammonia. This mixture was injected into the soil in Field C one week prior to early planting of the corn and one month prior to the late planting of the corn. At time of planting, one of the treatments (Over) consisted of planting the seed over the injected row of ACA and ACE and the other treatment (Between) consisted of planting the seed in-between the injected rows of ACA and ACE.

The main effects of chemical, planting time, method of planting, and rate of chemical were studied on the components that contributed to the final yield (E/P, W/E, and weight per 100 kernels--KW/100).

The main effects of ACA and ACE on E/P, W/E, KW/100, and Y are shown in Table 24. ACA increased W/E and Y significantly compared to ACE. The greater W/E with ACA was the main yield component contributing to the increase in Y. The effect on E/P and KW/100 was similar for the two chemicals. The changes in W/E and Y are shown in Figure 20.

The main effects of early and late planting on E/P, W/E, KW/100, and Y are shown in Table 26. Early planting resulted in slightly higher KW/100 and Y than did late planting (Table 25). The greater KW/100 of early planting was the main contributor to the significant difference in Y. There

Table 24. The main effects of chemical (ACA and ACE) on E/P, W/E, KW/100, and Y of corn in Field C

Chemical	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0.986 a	161.72 a	32.70 a	7686 a
ACE	0.989 a	158.67 b	32.73 a	7438 b

Table 25. The main effects of planting time on E/P, W/E, KW/100, and Y of corn in Field C

Planting time	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
Early	0.988 a	160.65 a	32.93 a	7681 a
Late	0.991 a	159.75 a	32.50 b	7444 b

Table 26. The main effects of rate of chemical on E/P, W/E, KW/100, and Y of corn in Field C

Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
0	0.991 a	153.04 c	30.39 b	7062 c
0.30	0.984 a	160.71 b	33.57 a	7564 b
0.60	0.986 a	163.71 a	33.51 a	7861 a
1.20	0.989 a	163.32 a	33.39 a	7762 a

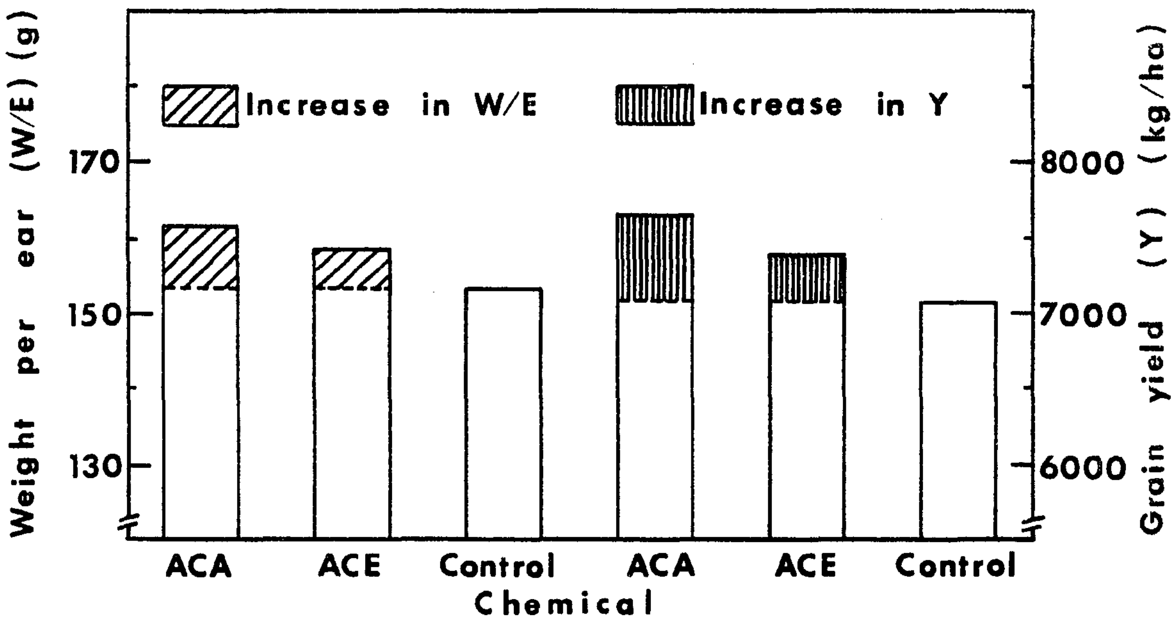

Figure 20. Effects of chemical on W/E and Y of corn when averaged across planting time, method and rate of application in Field C

were no significant differences in E/P and W/E at the two planting dates.

The main effects of rates of ACA and ACE on E/P, W/E, KW/100, and Y are shown in Table 26. There was no significant different effect on E/P as the result of rate of chemical. For W/E, KW/100, and Y, the two high rates generally were significantly greater than the low rate and the control.

There were no significant differences on E/P, KW/100, and Y as the result of different planting method (Table 27). However, planting the seed over the injected row of chemical caused a greater W/E than planting the seed between the rows. The trends in Y and KW/100 agree with the effect of method of planting on W/E but were not significant.

Since method of planting (over or between) and date of planting (early or late) were not completely randomized, the effects of chemical and rate of chemical were analyzed within each main plot (over-early, over-late, between-early, and between-late). The main effects of chemicals ACA and ACE on E/P, W/E, KW/100, and Y when the seed was planted early and over the chemicals are shown in Table 28. ACA contributed to greater increase in W/E and Y than did ACE, but there were no significant differences in effect between ACA and ACE on E/P and KW/100. The changes in W/E and Y are shown in Figure 21.

Table 29 shows the main effects of rate of the chemicals on E/P, W/E, KW/100, and Y when the seed was planted early

Table 27. The main effects of method of planting on E/P, W/E, KW/100, and Y of corn in Field C

Planting method	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
Over	0.988 a	161.66 a	32.80 a	7693 a
Between	0.987 a	158.73 b	32.63 a	7431 a

Table 28. The main effects of chemical (ACA and ACE) on E/P, W/E, KW/100, and Y of corn when planted early and over the chemical in Field C

Chemical	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0.988 a	165.34 a	32.98 a	7999 a
ACE	0.982 a	160.27 b	33.02 a	7608 b

Table 29. The main effect of rate of chemical on E/P, W/E, KW/100, and Y of corn when planted early and over the chemical in Field C

Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
0	0.993 a	153.35 b	31.04 b	7102 c
0.30	0.985 a	163.70 a	34.10 a	7883 b
0.60	0.983 a	168.06 a	33.40 a	8403 a
1.20	0.979 a	166.11 a	33.46 a	7827 b

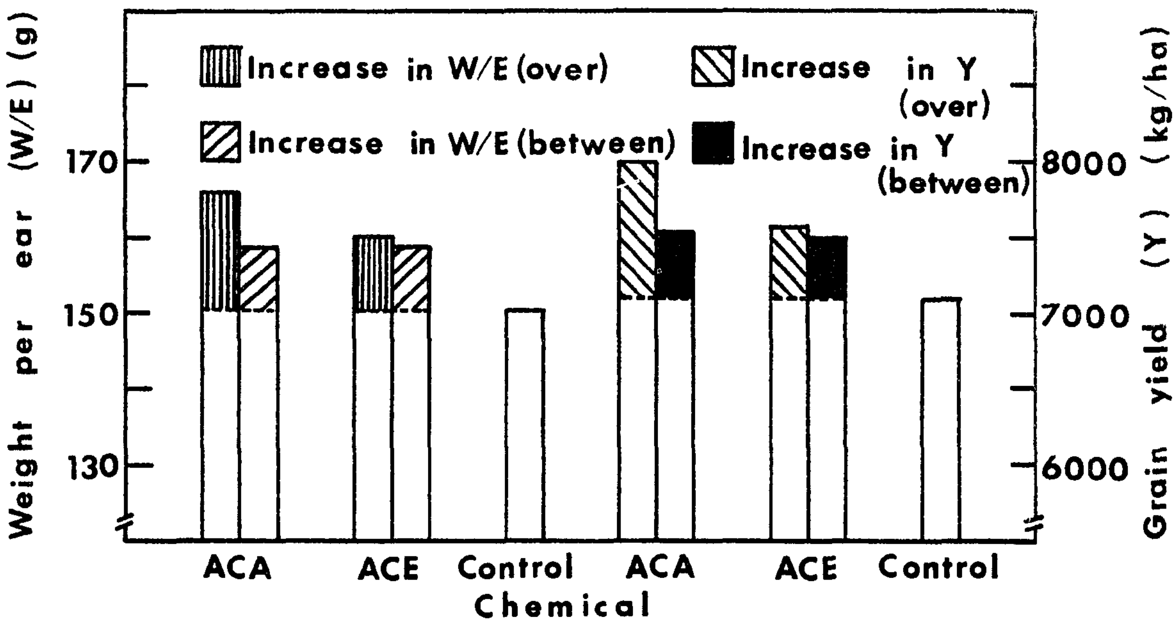

Figure 21. Effects of chemical on W/E and Y of corn when planted early and either over or between the chemical in Field C (averaged across rate of application)

and over the chemicals. There was no significant effect of rate on E/P. For W/E and KW/100, the control was smaller but there were no differences among three rates of the chemical. For Y, the 0.6 kg/ha rate was greater than 0.3 and 1.2 kg/ha rates and the latter rates were greater than the control.

The interaction between chemical and rate was significant for W/E and Y when planted early and over the chemicals (Table 30). ACA at the rate of 0.6 kg/ha was the most effective in increasing Y when compared with the other chemicals and rates.

The results of main effects of chemicals, rates, and the interaction between chemical and rates when the seed was planted early and between the injected rows of chemical are shown in Tables 31, 32, and 33. There were no significant differences between ACA and ACE on E/P, W/E, KW/100, and Y (Table 31). The main effects of rates did not affect E/P (Table 32). However, the 0.3, 0.6, and 1.2 kg/ha rates significantly increased W/E, KW/100, and Y compared with the control. The interaction between chemicals and rates was significant for W/E and Y and is shown in Table 33. Most of the interaction appeared to be due to the more desirable response for the 1.2 kg/ha rate with ACA than with ACE. The changes in Y due to early planting over and between the chemicals are shown in Figure 22.

The main effects of chemical, rate, and the interaction

Table 30. The interaction between chemicals and rates for E/P, W/E, KW/100, and Y of corn when planted early and over the chemical in Field C

Chemical	Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0	0.988 a	152.23 e	31.33 b	6867 e
	0.30	0.995 a	167.75 ab	33.75 a	8297 b
	0.60	0.965 a	173.18 a	33.40 a	8786 a
	1.20	0.980 a	168.23 ab	33.45 a	8049 bc
ACE	0	0.998 a	154.48 de	30.75 b	7336 de
	0.30	0.975 a	159.65 cd	34.45 a	7470 d
	0.60	1.000 a	162.95 bc	33.40 a	8020 bc
	1.20	0.978 a	164.00 bc	33.48 a	7606 cd

Table 31. The main effects of chemical (ACA and ACE) on E/P, W/E, KW/100, and Y of corn when planted early and between the chemical in Field C

Chemical	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0.981 a	158.36 a	32.76 a	7595 a
ACE	0.984 a	158.61 a	32.96 a	7519 a

Table 32. The main effects of rate of chemical on E/P, W/E, KW/100, and Y of corn when planted early and between the chemical in Field C

Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
0	0.995 a	152.98 b	30.61 b	7112 c
0.30	0.964 a	158.69 a	33.70 a	7464 b
0.60	0.980 a	161.21 a	33.71 a	7862 a
1.20	0.993 a	161.06 a	33.41 a	7792 a

Table 33. The interaction between chemicals and rates for E/P, W/E, KW/100, and Y of corn when planted early and between the chemical in Field C

Chemical	Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0	0.995 a	150.80 c	30.80 b	7155 de
	0.30	0.960 a	158.13 ab	33.45 a	7422 cde
	0.60	0.980 a	161.53 a	33.45 a	7876 ab
	1.20	0.990 a	163.00 a	33.33 a	7928 a
ACE	0	0.995 a	155.15 bc	30.43 b	7069 e
	0.30	0.967 a	159.25 ab	33.95 a	7506 bcd
	0.60	0.980 a	160.90 a	33.98 a	7848 ab
	1.20	0.995 a	159.13 ab	33.50 a	7656 abc

Table 34. The main effects of chemical (ACA and ACE) on E/P, W/E, KW/100, and Y of corn when planted late and over the chemical in Field C

Chemical	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0.991 a	162.98 a	32.59 a	7826 a
ACE	0.993 a	158.06 b	32.59 a	7339 b

Table 35. The main effects of rate of chemical on E/P, W/E, KW/100, and Y of corn when planted late and over the chemical in Field C

Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
0	0.990 a	152.41 c	30.14 b	7002 c
0.3	0.993 a	160.68 b	33.31 a	7593 b
0.6	0.989 a	165.46 a	33.63 a	7801 ab
1.2	0.995 a	163.53 ab	33.29 a	7935 a

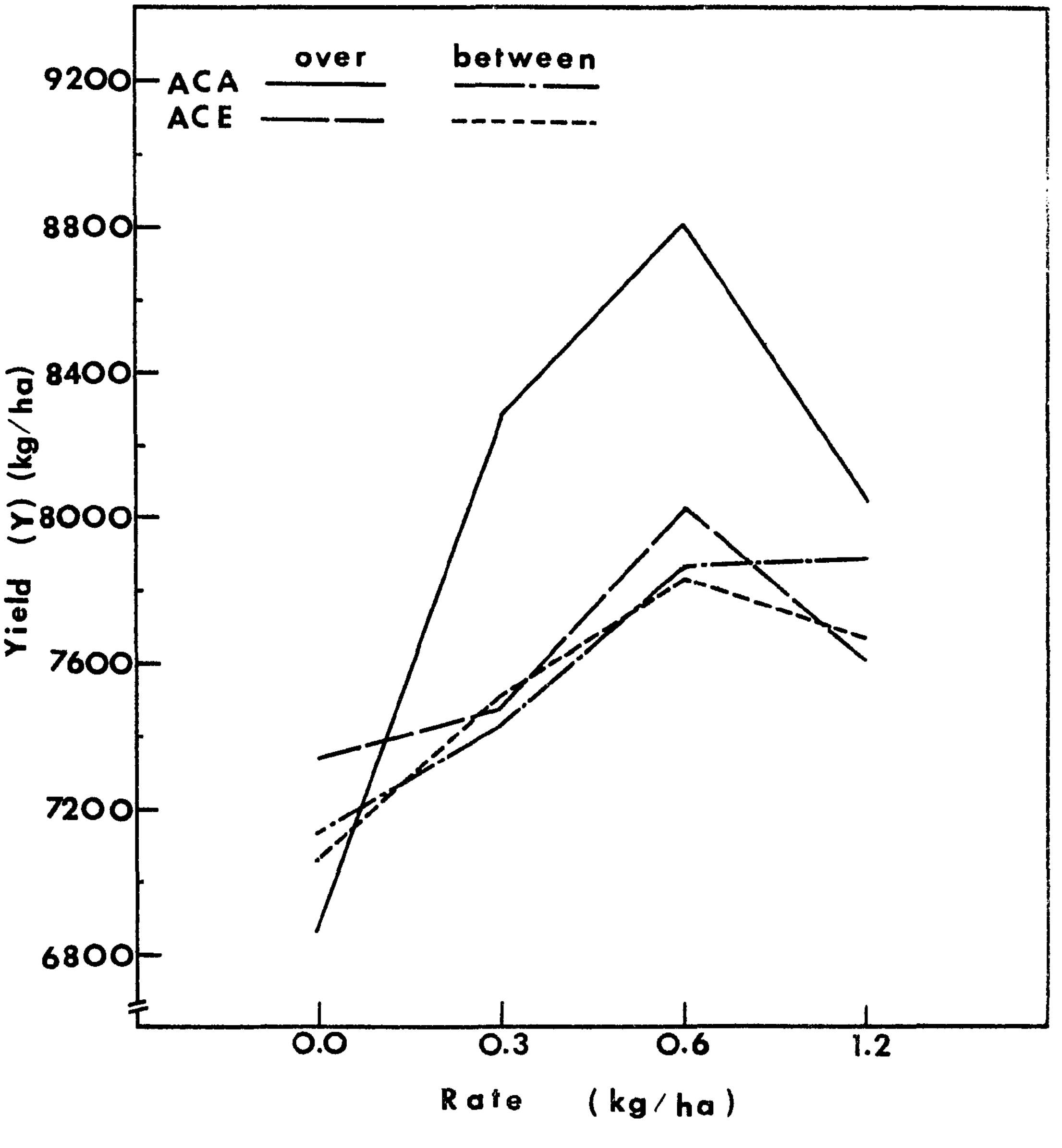

Figure 22. Effects of chemical and rate of chemical on Y of corn when planted early and either over or between the chemical in Field C

between chemical and rate when the seed was planted late and over the row of the chemicals are shown in Tables 34, 35, and 36. ACA increased W/E and Y significantly more than did ACE but the effects of the chemicals on E/P and KW/100 were not different (Table 34). The changes in W/E and Y are shown in Figure 23. The main effects of rate of chemical had no effect on E/P, but the 0.3, 0.6, and 1.2 kg/ha rates significantly increased W/E, KW/100, and Y compared with the control treatment (Table 35). The interaction between chemicals and rates was significant for W/E, KW/100, and Y (Table 36). At the two high rates, ACA increased W/E more than did ACE. The interaction for KW/100 was due to the greater effect of ACE than ACA at the 0.6 kg/ha rate. The interaction for Y was due to a rather large and uniform effect of ACA at the 0.3, 0.6, and 1.2 kg/ha rates compared with a more variable response to ACE.

The results of the main effects of chemicals, rates, and the interaction between chemicals and rates when the seed was planted late and between the injected rows of liquid chemicals are shown in Tables 37, 38, and 39. ACA increased W/E more than did ACE (Table 37). There were no significant differences in the other attributes due to the main effect of chemical. The main effect of rate of chemical did not significantly affect E/P and W/E, but the chemicals significantly increased KW/100 more than did the control (Table 38).

Table 36. The interaction between chemicals and rates for E/P, W/E, KW/100, and Y of corn when planted late and over the chemical in Field C

Chemical	Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0	0.990 a	152.30 c	30.23 b	7089 ef
	0.3	0.988 a	162.13 b	33.40 a	7806 bc
	0.6	0.988 a	169.30 a	33.40 a	7986 b
	1.2	0.998 a	168.18 a	33.33 a	8424 a
ACE	0	0.990 a	152.53 c	30.05 b	6916 f
	0.3	0.998 a	159.23 b	33.23 a	7380 de
	0.6	0.990 a	161.63 b	33.85 a	7615 cd
	1.2	0.993 a	158.88 b	33.25 a	7445 d

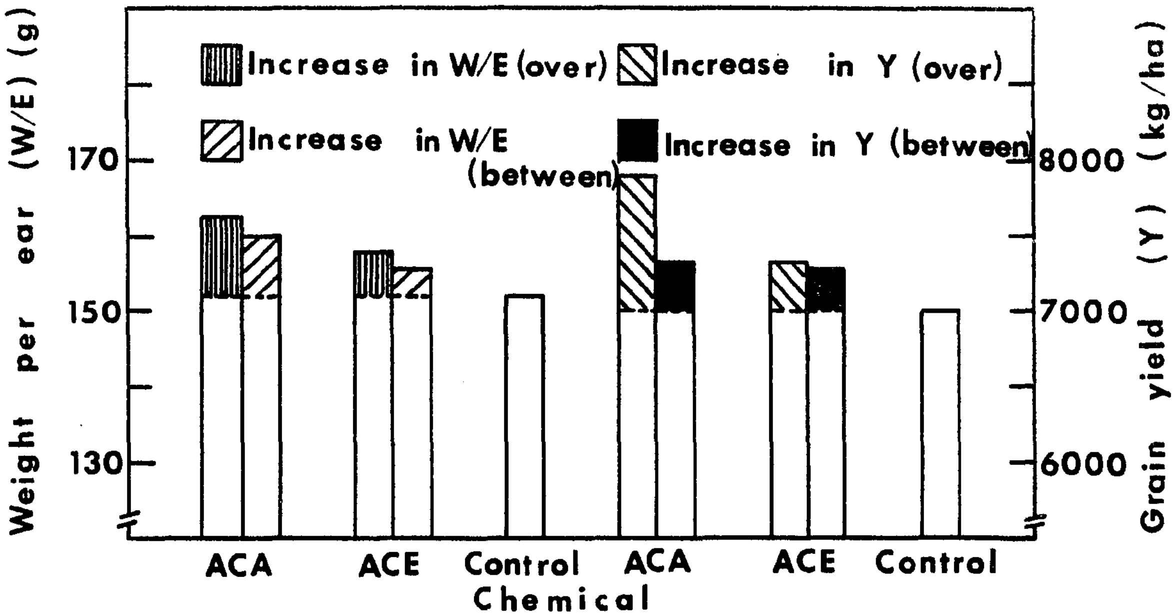

Figure 23. Effects of chemical (ACA and ACE) on W/E and Y of corn when planted late and either over or between the chemical in Field C (averaged across rate of application)

Table 37. The main effects of chemical (ACA and ACE) on E/P, W/E, KW/100, and Y of corn when planted late and between the chemical in Field C

Chemical	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0.989 a	160.20 a	32.47 a	7324 a
ACE	0.993 a	157.74 b	32.35 a	7286 a

Table 38. The main effects of rate of chemical on E/P, W/E, KW/100, and Y of corn when planted late and between the chemical in Field C

Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
0	0.985 a	153.44 a	29.78 b	7032 c
0.3	0.994 a	159.78 a	33.16 a	7315 b
0.6	0.994 a	160.11 a	33.29 a	7378 ab
1.2	0.991 a	162.56 a	33.41 a	7494 a

Table 39. The interaction between chemicals and rates for E/P, W/E, KW/100, and Y of corn when planted late and between the chemical in Field C

Chemical	Rate (kg/ha)	E/P	W/E (g)	KW/100 (g)	Y (kg/ha)
ACA	0	0.983 a	153.20 d	29.70 b	7002 c
	0.3	0.993 a	160.18 abc	33.28 a	7338 ab
	0.6	0.988 a	164.20 ab	33.35 a	7405 ab
	1.2	0.993 a	164.23 a	33.55 a	7553 a
ACE	0	0.988 a	153.68 d	29.85 b	7063 c
	0.3	0.995 a	159.38 bc	33.05 a	7292 b
	0.6	1.000 a	157.03 cd	33.23 a	7352 b
	1.2	0.990 a	160.90 abc	33.28 a	7436 b

The highest rate (1.2 kg/ha) of chemical significantly increased the yield as compared with the low rate (0.3 kg/ha) and the low rate was greater than the control. The interaction between chemical and rate was significant for W/E and Y. ACA at the high rate was more effective in increasing W/E and Y as compared with ACE at the same rate (Table 39), but in general, the interaction between chemical and rate on W/E and Y did not appear to be very important. The effects of ACA and ACE either over the row or between the row of late planted corn are shown in Figure 24.

In the combined analyses of variance with planting date (P), method of planting (M), chemical (C), and rate (R), the following interactions were significant: E/P - none; W/E - C x R, M x R, M x C, and P x M x C x R; KW/100 - none; Y - P x R, C x R, M x R, M x C, M x C x R, and P x M x C x R.

Experiment 6

In this experiment, liquid chemicals ACE and ACA at different rates (two rates of ACE at 0.3 and 0.6 kg/ha and three rates of ACA at 0.3, 0.6, and 1.2 kg/ha) were premixed with anhydrous ammonia and injected as a sidedressing into the soil at three different stages of corn growth (4th, 8th, and 12th leaf stages). The main effects of time of application, rate of chemical, and the interaction between times and rates were examined on number of ears per plant (E/P), weight per ear (W/E), and grain yield (Y).

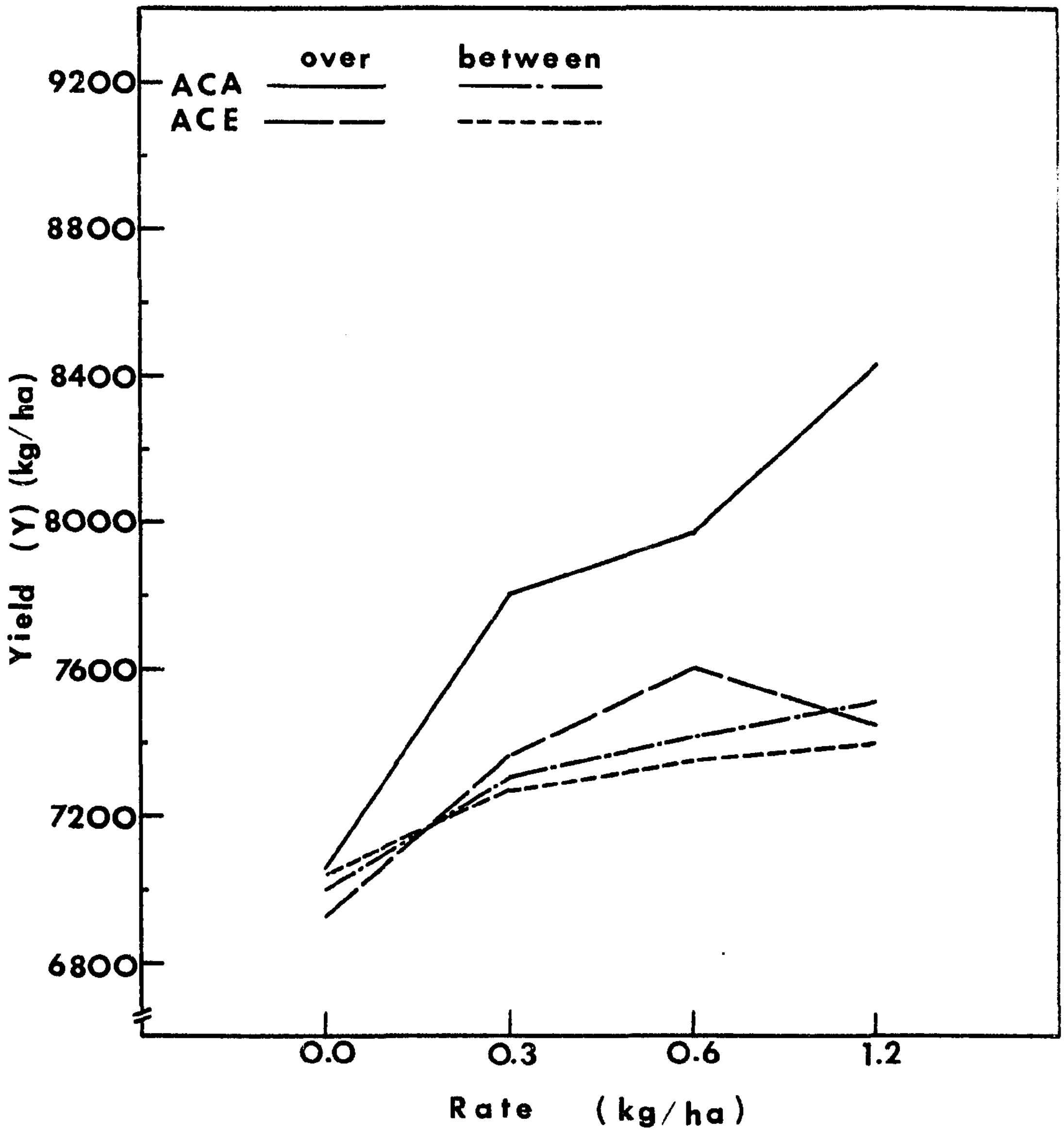

Figure 24. Effects of chemical and rate of chemical on Y of corn when planted late and either over or between the chemical in Field C

The main effects of time of sidedressing on E/P, W/E, and Y are shown in Table 40. There were no significant differences due to time of sidedressing on E/P and Y. However, there was a significant difference on W/E as the result of time of application.

Comparison of the main effects of rate of chemical on E/P, W/E, and Y are shown in Table 41. There were no significant differences on E/P, W/E, and Y as the result of sidedressing either chemical at any rate. The interactions between times of sidedressing and chemicals and rates for E/P, W/E, and Y are shown in Table 42, although the interactions were not statistically significant. The general trend was that sidedressing the chemicals early (4th leaf stage) was most effective in increasing Y. The table also indicates that the major component of yield affected by these chemicals was W/E, which agrees with the results of Experiment 5.

Table 40. The main effects of time of sidedressing chemical (ACA and ACE) on E/P, W/E, and Y of corn in Field D

Time (stage)	E/P	W/E (g)	Y (kg/ha)
4th leaf	0.952	176.15	10,347
8th leaf	0.954	171.38	10,001
12th leaf	0.978	165.99	9,929
L.S.D.$_{(.05)}$	NS[a]	2.27	NS

[a]NS = nonsignificant in this and the following tables.

Table 41. The main effects of rate of chemical (ACA and ACE) on E/P, W/E, and Y of corn in Field D

Chemical	Rate (kg/ha)	E/P	W/E (g)	Y (kg/ha)
ACA	0.3	0.938	171.39	10,106
	0.6	0.965	170.25	10,094
ACE	0.3	0.973	167.60	9,977
	0.6	0.967	174.87	10,458
	1.2	0.970	167.60	10,086
Control	0	0.950	165.34	9.833
L.S.D.$_{(.05)}$		NS	NS	NS

Table 42. The interaction between times of sidedressing and rates of chemical on E/P, W/E, and Y of corn in Field D

Time (stage)	Chemical	Rate (kg/ha)	E/P	W/E (g)	Y (kg/ha)
4th leaf	ACE	0.3	0.893	183.88	10,417
		0.6	0.955	169.10	10,218
	ACA	0.3	0.978	172.50	10,268
		0.6	0.965	185.25	10,857
		1.2	0.983	174.80	10,433
	Control	0	0.935	171.38	9,883
8th leaf	ACE	0.3	0.950	172.53	10,367
		0.6	0.943	178.20	10,300
	ACA	0.3	0.960	169.13	9,833
		0.6	0.960	175.90	10,042
		1.2	0.968	163.43	9,666
	Control	0	0.933	169.13	9,800
12th leaf	ACE	0.3	0.970	157.78	9,800
		0.6	0.998	163.45	9,767
	ACA	0.3	0.985	161.18	9,843
		0.6	0.795	163.45	10,467
		1.2	0.960	164.58	10,159
	Control	0	0.983	155.53	9,817
L.S.D.$_{(.05)}$			NS	NS	NS

DISCUSSION

The responses of some field crops to foliar applied chemical growth regulators such as CLPA, TIBA, SADH, and CCC have been reported by Wittwer and Murneck (1946), Anderson et al. (1965), Brown et al. (1973), and Zur et al. (1972), respectively. My study was on the effects of some chemicals containing acetate on vegetative growth and yield of corn and soybeans.

Results from the growth chamber experiments indicated that the application of acetates (MEAC, ETAC, BUAC, or NAAC) enhanced early vegetative development and, in turn, more dry matter was accumulated. All four of the chemicals, with different sources of acetate, were effective in increasing the parameters measured. The amount of response was similar for the four chemicals, although the optimum rate varied with the chemical. BUAC had the lowest optimum concentration (1.25×10^{-3} M) and the optimum concentration for the others was either 2.5 or 5×10^{-3} M. The optimum concentration generally was similar for each of the five parameters measured. The data also showed that the rate-response curve was quadratic and that rates above the optimum became less stimulatory.

The similarities of the responses from the four chemicals indicated that the active component of the chemicals was the acetate ion. The main basis for this conclusion is that NAAC was equally as effective as the esters and the component in common is acetate, derived from esters by hydrolysis. The esters were used because they might release small amounts of acetate over a long period of time in comparison with NAAC and, thereby, produce responses of greater magnitude than that obtained with NAAC. The growth chamber experiments did not support this presumption. It also was proposed that the response might differ between the highly water soluble MEAC and the slightly water-soluble BUAC. The data indicated that BUAC was effective at a lower concentration than were MEAC and ETAC, but the magnitudes of the responses were similar for the three esters.

Preliminary field tests conducted in 1979 by Dr. I. C. Anderson, Department of Agronomy, Iowa State University, on corn at the 6th leaf stage indicated that foliar applications of ethyl acetate increased grain yield and the optimum rate was 1.0 liter per hectare. I conducted experiments in the field during 1980 on corn and soybeans using more chemicals and treatments at various stages of plant growth. Both vegetative and reproductive attributes were measured in the corn experiments. For corn, the chemicals were applied at the 4th, 8th, and 12th leaf stage of development at four rates (0, 0.2, 0.4, and 0.8 kg/ha). Mature plant height, width of the ear node leaf, ears per plant, weight per ear and grain yield were measured. In general, ears per plant was not affected by the treatments. The greatest effect on vegetative size and grain yield was obtained at the 4th leaf stage, followed in order by 8th and 12th leaf stages. Within each stage of application, the main effect of the four chemicals was similar except that plant height was increased less by NAAC than by the esters. The response to rate of chemical within each stage of application indicated that the 0.4 kg/ha was slightly better than the 0.2 and 0.8 kg/ha and these three rates produced responses that usually were significantly greater than those of the control. Within a stage of application, there were some interactions between rates and chemicals. Grain yield with BUAC did not decrease between the 0.4 and 0.8 kg/ha rates as much as it did with MEAC and NAAC. In the growth chamber experiments, BUAC had the lowest optimum rate, whereas in the field experiments, the optimum rate with BUAC appeared to be higher than that of the three other chemicals.

As in growth chamber experiments, the four chemicals had similar effects on the attributes measured in the field. The chemicals affected both vegetative size and grain yield. In general, the effect of a specific treatment on vegetative size and grain yield was similar, but not as similar as in the growth chamber experiments. This may be a real effect or it could be due to greater variation in the field. The field results support the concept that the active component was the acetate ion and not the ester or the primary alcohol obtained upon hydrolysis of the ester. Foliar application of the chemicals at the 4th leaf stage at the optimum rate increased grain yield 8-10%, at the 8th leaf stage 7-9%, and at the 12th leaf stage 3-5% for the various chemicals.

Experiment 4 used soybeans in Field B as a test crop to study the effects of MEAC, ETAC, and BUAC on grain yield. NAAC was not used because of the lack of an adequate number of plots. The rates of each chemical were 0, 0.2, 0.4, and 0.8 kg/ha. The foliage of soybeans was sprayed at stages V_3, R_1, and $R_{2.5}$.

The treatment at V_3 and R_1 stages yielded significantly more than the $R_{2.5}$ stage, indicating greater effects of the chemicals at early application. There were no significant differences between the action of the three chemicals at any stage of application. At V_3 and R_1, the 0.2, 0.4, and 0.8 kg/ha rates were significantly greater than the control, but at $R_{2.5}$, there was no difference due to rate. The yield response to rate appeared to be quadratic.

Previous studies (Ott, 1975; Khosravi, 1980) have shown that about 0.1 kg/ha of zinc acetate added to anhydrous ammonia applied to corn increased grain yield. Khosravi (1980) compared zinc acetate (ACA) with ammonium acetate (ACE) and found similar stimulatory effects of the two chemicals on vegetative size and grain yield. He also found that most of the increase in grain yield was due to greater weight per kernel rather than the number of kernels or ears per plant. In my study, I compared planting corn soon after the chemicals had been injected into the soil with planting one month later to test the stability of the chemicals in the anhydrous band. Another comparison was planting the corn row over the anhydrous band with planting one-half the distance between the bands (Field C). In a related study, rates of the two chemicals were sidedressed with anhydrous ammonia in the middle of the corn rows at three stages of corn growth to determine at which stage of growth the chemicals have biological activity (Field D). The effects of the treatments on ears per plant, weight per ear, kernel weight, and yield were measured.

In Experiment 5, the influence of date of planting and placement of the chemicals was studied. The mean yield of the early planted corn was 237 kg/ha greater than the late planted corn, but the mean differences for the control plots was only 65 kg/ha. This result indicated that the chemicals had a more desirable effect if the corn was planted soon after application of the chemicals. Another indication that the chemicals were more effective when applied near time of planting was that kernel weight was significantly greater for the early planted corn than for the late planted corn.

The overall mean grain yield for the ACA treatments was

262 kg/ha greater than that of ACE and this was associated with a greater weight per ear. The difference in the effectiveness of ACA compared with ACE was associated with placement. The mean yield advantage of ACA was 391, 76, 487, and 38 kg/ha for early planted - over the band, early - between the band, late - over, and late - between, respectively. Another comparison of the difference in effectiveness of ACA compared with ACE follows; it shows the difference in yield of the control and the mean yield of the 0.3, 0.6, and 1.2 kg/ha rates for ACA and ACE for the four dates of planting and placement treatments. The values are kg/ha of grain difference between the chemical and the appropriate control.

	Early and over the band	Early and between the bands	Late and over the band	Late and between the bands
ACA minus control	1510	587	983	430
ACE minus control	363	601	564	297

ACA under the corn row increased yield more than did ACA between the corn rows. For ACE, placement did not appear to have much effect on response. The values also show the usual response with ACA to be greater than with ACE.

The response to rate of chemical appeared to be quadratic as was found in the experiment with foliar application of NAAC and the acetate esters. In general, the greatest quadratic response appeared to occur with ACA under the row and the least with ACE between the rows.

The yield increase, as a result of the chemicals, was due mainly to greater weight per ear. The greater weight per ear was due mainly to greater weight per kernel as had been reported by Khosravi (1980).

In Experiment 6, where ACA and ACE were sidedressed at the 4th, 8th, and 12th leaf stage to determine effect of growth stage on response of chemical (Field D), the coefficient of variability of yield was relatively large (7%) and the results were less conclusive than expected. The plots in this experiment were 6 rows wide in order to accommodate a commercial anhydrous applicator and, in addition to being large-sized plots, the slope of the land was more bidirectional than Field C.

Weight per ear progressively decreased with delay in application. From the results in Experiment 5 this would indicate less action of chemicals as application was delayed. Also, the data for the 4th leaf stage show responses from ACA and ACE similar to that obtained in Experiment 5.

The studies with ACA and ACE indicated that both chemicals had similar effects on corn, although ACA produced larger and more consistent yield responses. The active ingredient in ACA is zinc acetate which is soluble in alkaline solutions of ammonium under conditions where there are 5 to 6 ammonium molecules associated with each zinc acetate molecule

(L. Ott, American Oil Co., Chicago, Illinois, personal communication). Dr. Ott also believes that when acetate is injected into the soil with anhydrous ammonia, a reaction with zinc oxide in the soil could form the more stable ammoniacal zinc acetate. Another method of obtaining a yield response with ACA is to spray it on ammonium nitrate granules before sidedressing a high rate of the granules as a band beside the corn row (Khosravi, 1980). One can interpret the conditions needed for a response from acetate in ammoniacal solution as either: (1) conditions conducive to maintaining a stable molecule of zinc acetate and it is zinc acetate which is biologically active or, (2) conditions conducive to protecting the acetate ion from being used by the soil microflora before the corn roots have an opportunity to take up the acetate ion.

The other group of acetate yielding chemicals I investigated was MEAC, ETAC, BUAC, and NAAC. All four acetates appeared to be equally effective in the growth chamber studies, but in the field where leaf surfaces are dirty and have bacteria, where they are wet with dew frequently, and where rain washes off water soluble ions, it was assumed that the more lipophyllic esters would be more effective and, secondly, the esters should supply acetate to the plant over a longer period of time than would NAAC. The results with field plots of corn and soybeans indicated that all four chemicals were equally effective in increasing yield and that the active component was the acetate ion.

A number of lines of evidence indicate that the effects of MEAC, ETAC, BUAC, and NAAC are similar to the effects of ACA and ACE on corn.

1. The quantity of acetate for optimum yield is similar, that is, about 0.1 kg/ha for ACA or ACE and 0.4 kg/ha when broadcast sprayed on foliage of plants which only intercepts a fraction of the spray solution.

2. The quantity of acetate is so small that it must be acting on plant hormones or altering normal patterns of metabolism by affecting enzyme action.

3. Both groups of chemicals show quadratic responses with a definite tendency toward inhibitory effects at super-optimal concentration.

4. Both groups of chemicals have the maximum effect if the corn plants receive the chemicals at the 4-8 leaf stage.

5. Both groups of chemicals cause the ear node leaf to be wider. I found this for the esters and Dr. I. C. Anderson, Department of Agronomy, Iowa State University, and Dr. L. Ott, American Oil Co., Chicago, Illinois, have reported this effect of ACA in unpublished reports.

6. Both groups of chemicals stimulate leaf growth at the seedling stage. I found this for the esters and Dr.

I. C. Anderson found similar effects of ACA in greenhouse studies.

7. Both groups of chemicals increase weight per ear but have little effect on ears per plant.

The preceding analogies indicate that the active ingredient in ACA is the acetate ion and not the zinc acetate molecule. I do not consider these analogies as proof that the active ingredient in ACA is acetate. A factional experiment with rates of ACA and of one of the esters should be helpful in determining identity of action.

There is little evidence in the literature indicating the mechanism by which catalytic quantities of acetate could affect vegetative growth and much less that it could affect grain yield when applied at the early vegetative phase of growth. Animals and many bacteria can use acetate as a source of energy. Plants do not contain measurable amounts of free acetate (Bonner, 1950). Plants metabolize much active acetate such as acetyl Co A in the citric acid cycle and in fatty acid metabolism, but there is no evidence of important metabolic pathways with free acetate in higher plants. Plants, tissues of plants and cell cultures of plants take up free acetate and incorporate the acetate into fatty acids, which indicates that plants can metabolize acetate (Rinne and Canvin, 1971; Stearn and Morton, 1975; Negishi, 1976; Griener et al., 1975; Wilson and Kates, 1978).

Rychter et al. (1979) found that acetic acid, acetaldehyde and some other two-carbon chemicals increased respiration of potato slices. The quantity of chemical used was much below substrate levels (increased amount of CO_2 produced). The two-carbon chemicals were not consumed by aerobic tissue slices. These workers presented evidence that the effect of the chemicals was to stimulate catalytically noncyanide-sensitive respiratory pathways. Speeding carbon flow through the citric acid cycle by partially uncoupling or shunting the obligatory terminal electron transport system of mitochondria could be an advantage in generating carbon skeletons for amino acid synthesis in an energy-rich photosynthetic plant. Ohlrogge (1975) has proposed that the mechanism by which dinitrophenol increases grain yield of corn is to uncouple terminal electron transport in the mitochondria.

SUMMARY

Growth chamber experiments were conducted in April 1979. Four acetate chemicals were sprayed on the foliage of corn seedlings at the 5th leaf stage at four rates. Results showed that application of acetates enhances early vegetative growth and thus, in turn, more dry matter accumulated compared with controls. The amount of response was similar for the four chemicals. This indicated that the active component of the four chemicals was the acetate ion.

In 1980, field studies were carried out to investigate the effects of acetates applied to corn and soybeans at various stages of growth. Results indicated that the greatest effect on vegetative size and grain yield of corn was obtained when the treatment was applied at the 4th leaf stage followed in order by the 8th and 12th leaf stages. As in the growth chamber experiment, the four chemicals had similar effects on the attribute measured in the field. The field results supported the concept that the active component was the acetate ion and not the ester or primary alcohol. Soybeans sprayed at early stages yielded significantly more than when sprayed at later stages. This indicated greater effect of the chemicals at early application. The amount of yield response was similar for the chemicals, indicating that the active component was the acetate ion.

Studies of the effect of the chemicals ACA and ACE on

components of yield of corn showed a more desirable effect if corn was planted soon after application of the chemicals. Corn planted soon after the chemicals were applied resulted in significantly greater weight per kernel than the late planted corn. Results also indicated that corn planted over the band of ACA increased yield more than did ACA between the corn rows. The yield increase, as a result of the chemicals, was due to greater weight per ear. The greater weight per ear was due mainly to greater weight per kernel.

In another study, ACA and ACE were sidedressed at the 4th, 8th, and 12th leaf stages to determine the effects of growth stage on response of chemicals. Weight per ear progressively decreased with delay in application, indicating a greater response from the chemical applied at the early stage.

The results of the experiments indicate that the yield response from NAAC, MEAC, ETAC, BUAC, ACA, and ACE was due to the acetate component of the chemicals. The concentration of acetate needed for optimum response indicates that acetate is acting through its effect on hormones or on regulation of metabolic pathways.

LITERATURE CITED

Anderson, I. C., H.A.L. Greer, and J. W. Tanner. 1965. Response of soybeans to triiodobenzoic acid. Plant Growth Symposium Proceedings. International Minerals and Chemical Corporation, Skokie, Illinois.

Bauman, R. W., and A. J. Norden. 1971. Effect of growth regulators on vegetative and reproductive characteristics of six peanut genotypes. Am. Peanut Res. Educ. Assoc. J. 3: 75-80.

Bonner, J. 1950. Plant biochemistry. Academic Press Inc., New York.

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.

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 hypogea* L.). Crop Sci. 13: 507-510.

Clapp, J. G., Jr. 1973. Responses of 'Bragg' soybean to TIBA (2,3,5-triiodobenzoic acid). Agron. J. 65: 41-43.

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.

Griener, G., H. J. Hope, and C. Willemot. 1975. Sodium-1, 2-^{14}C acetate incorporation in roots of frost-hardy and less hardy alfalfa varieties under hardening conditions. Plant Physiol. 55: 906-912.

Hallock, D. L., and M. W. Alexander. 1970. Response of Florigiant and Virginia bunch 46-2 peanuts to TIBA in Virginia. Am. Peanut Res. Educ. Assoc. J. 2: 22-32.

Hartzook, A., and E. Goldin. 1970. Effect of 2,3,5-triiodobenzoic acid (TIBA) on the morphology of three peanut varieties grown in the field. Israel J. Agric. Res. 20: 169-171.

Khosravi, G. 1980. The effect of hormones and chemical growth regulators on ear development and grain yield of nonprolific corn (Zea mays L.). Unpublished Ph.D. dissertation. Library, Iowa State University, Ames, Iowa.

Krishnamoorthy, H. N., and M. J. Khun. 1972. Effect of morphactin on growth and development of maize and peanut. Indian J. Plant Physiol. 15: 21-29.

Miller, N. A., and W. C. Ashby. 1978. The effect of phenylmercuric acetate on the leaf water balance of Zea mays L. Bot. Gaz. 139(2): 211-214.

Mitlehner, A. W. 1977. Economic value of growth regulants in horticulture. Plant Growth Regulators 159: 60-67.

Negishi, T. 1976. Incorporation of (1-^{14}C) acetate into phospholipids by soybean seedlings. J. Am. Oil Chem. Soc. 53(2): 77-79.

Ohlrogge, A. J. 1975. A biostimulant in corn production. An abstract of a paper presented at a meeting of the Plant Growth Regulator Working Group, August 27-29, 1975, Chicago, Illinois.

Ott, L. E. 1974. Process for producing ammonical solution of zinc alkanoates. U.S. Patent No. 3,854,923.

Ott, L. E. 1975. Plant nutrients. U.S. Patent No. 3,909,229.

Ott, L. E. 1976. Fertilizing method. U.S. Patent No. 3,997,319.

Rhue, R. D., and C. D. Grogan. 1977. Screening corn for Al tolerance using different Ca and Mg concentrations. Agron. J. 69: 755-760.

Rinne, R. W., and D. T. Canvin. 1971. Fatty acid biosynthesis from acetate and CO_2 in the developing soybean cotyledon. Plant Cell Physiol. 12: 387-393.

Rychter, A., H. W. James, C. K. Chin, and C. Frankel. 1979. Effect of ethanol, acetaldehyde, acetic acid, and ethylene on changes in respiration and respiratory metabolites in potato tubers. Plant Physiol. 64: 108-111.

Stearn, E. M., Jr., and W. T. Morton. 1975. Biosynthesis of fatty acids from acetate in soybean suspension cultures. Lipids 10(10): 597-601.

Steel, R.G.D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York.

Wilson, A. C., and M. Kates. 1978. Incorporation of ($1-^{14}C$) acetate into lipids of soybean cell suspensions. Lipids 13(7): 504-510.

Wittwer, S. H. 1971. Growth regulants in agriculture. Outlooks in Agric. 6: 205-207.

Wittwer, S. H., and A. E. Murneck. 1946. Further investigations on the value of "hormone" sprays and dusts for green bush snap beans. Proc. Am. Soc. Hort. Sci. 47: 285-293.

Zur, M., A. Marani, and B. Karadavid. 1972. Effect of growth retardants CCC and CMH on cotton. Cotton Grow. Rev. 49: 250-257.

ACKNOWLEDGMENTS

I wish to express my sincerest appreciation to my major professor, Dr. Irvin C. Anderson, for his academic guidance and assistance in preparation of this dissertation.

I remain very grateful to the other members of my committee, Drs. Clifford E. LaMotte, Robert H. Shaw, David K. Whigham, and Donald G. Woolley, for their scholarly advice and patience in reviewing this manuscript.

Two persons I shall never forget are Dr. Suraphol Sanugansri and Dr. Banjerd Boonsue, because they helped make my dream come true.

Grateful thanks to the Rockefeller Foundation for its financial support throughout my study and to Kasetsart University for granting me a study leave.

My thanks also go to Professor David F. Cox and Dr. Apichart Pongsrihadulchai for their statistical advice, to Dr. Jacob Secor for his sincere and cheerful help during my study, to Mr. Kim Pin Ong for his valuable suggestions in the preparation of this manuscript, to Mr. Nabil E. El-Halawani for the technical drawing, and to Mrs. Ina Couture for her patient and excellent assistance in the final preparation of this manuscript.

Special thanks to many of the graduate students and faculty at Iowa State University for their understanding, friendly support and enthusiasm during my study.

Lastly, I wish to express my very special appreciation to my wife, Rattana, and my beloved son, Tandorn, for their wonderful cooperation and encouragement during my course of study. Together we shared the pain and joy.