1980

The effect of hormones and chemical growth regulators on ear development and grain yield of nonprolific corn (Zea mays L.)

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THE EFFECT OF HORMONES AND CHEMICAL GROWTH REGULATORS ON EAR DEVELOPMENT AND GRAIN YIELD OF NONPROLIFIC CORN (ZEA MAYS L.)

Iowa State University Ph.D. 1980

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The effect of hormones and chemical growth regulators on ear development and grain yield of nonprolific corn (*Zea mays* L.)

by

Gholamreza Khosravi

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Department: Agronomy
Major: Crop Production and Physiology

Approved:

In Charge of Major Work

For the Major Department

For the Graduate College

Iowa State University
Ames, Iowa

1980
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INTRODUCTION

Increased interest in expanding the world's food production has been a stimulatory factor in the use of chemical growth regulators in the field of agriculture. To obtain more efficient productivity, manipulation of crop production processes with chemicals has been considered to be very important and development of chemicals for practical use has been accelerated. In the past decade there has been a rapid growth in the use of regulants that have proven profitable to the growers and manufacturers and beneficial to the consuming public (Mitlehner, 1977).

In 1968, there were sales of 650 million dollars of plant growth regulators and herbicides. Growth regulators accounted for 5% of the total, or 17 million dollars worth of business (Huffman, 1972). Wittwer, in 1968, predicted a potential market of 50 to 75 million dollars worth of business for plant growth regulators by 1975.

In the study of the relationship between hormone structure and plant response, some limitations are involved. For example, the stage of plant development, timing of chemical treatment application, the environment, the responses that should be measured, and finally differences in phenotype and genotype are all factors that have to be considered and these variables certainly make the plant regulator research and development more complex. Nevertheless, along with progress in many branches of agriculture, the research with growth regulators has been fruitful and undoubtedly there is an integrated, interdependent role for growth regulators in the future of crop production.
Yield obviously is the ultimate goal in growing any crop. Thus, the economic importance of hormones is their ability to increase crop yields. There have been numerous reports considering increased yield due to the use of hormones especially in the horticultural field, where hormones have been used for many years. The use of plant growth regulators on agronomic crops is in its infancy. The treatment of wheat with CCC (2-chloroethyltrimethylammonium chloride) was introduced in 1959, and has been used in Europe since 1964. It has not been used on wheat in the United States (Wittwer, 1970). Alar was the first plant growth regulator to be cleared on food crops in the United States in 1967, and TIBA (2,3,5-triiodobenzoic acid) has also been cleared for use on soybeans (Wittwer, 1970). A plant growth regulator called Polaris is used to enhance sugar content of sugar cane. Some plant growth regulators are used as defoliators in cotton and in soybean as a harvest aid.

Interest in the synthesis of growth regulating chemicals has been generated by the discovery of naturally occurring hormones. Auxins, and more specifically indole-3-acetic acid (IAA) have probably received the greatest attention. Research in this area led to such auxin analogs as naphthaleneacetic acid (NAA) and to its commercial application. The subsequent discoveries of other natural plant hormones such as gibberellins (GA), cytokinins (Cy) and abscisic acid (ABA) led to similar evolution of analogs and their commercial application in the field of agriculture.

This study was undertaken to further determine the influence of hormones and chemical growth regulators on ear development and grain yield of nonprolific corn (Zea mays L.) cultivars.
In 1978, the objectives of this study were to determine:

1. The effects of indole-3-acetic acid (IAA) and abscisic acid (ABA) on percent of filled kernels (PFK), and dry weight (DW) of first ear of 'Pioneer 3780' when hormones were injected into the 14th internode.

2. The effects of indole-3-acetic acid (IAA), gibberellic acid (GA), and N\(^6\)-benzyladenine (BA) on:
   a. percent of filled kernels (PFK) and dry weight (DW) of first ear;
   b. second and third ear length (from the tip of the husk to the point of attachment of the shank to the stalk) and cob length;
   c. dry weight of second and third ears of 'Pioneer 3780' when hormones were injected into the 12th internode.

In 1979, the objectives of this study were to determine:

1. The effects of indole-3-acetic acid (IAA), Naphthalenacetic acid (NAA), gibberellic acid (GA), and N\(^6\)-benzyladenine (BA) on:
   a. percent of filled kernels (PFK) and dry weight (DW) of first ear;
   b. second and third ear length and cob length;
   c. dry weight of second and third ears of 'Pioneer 3780' when hormones, in lanolin paste, were applied to first ear and at conjunction point of first ear and its internode.

2. The effect of zinc acetate (ACA) and acetate (ACE) on vegetative growth (plant height, leaf length, leaf width), and components of yield of 'Pioneer 3780' when applied as a band placement in the soil at early stages of corn growth (5th leaf stage).
3. The effect of zinc acetate (ACA) and acetate (ACE) when injected into the soil with anhydrous ammonia on vegetative growth (plant height, leaf length, leaf width), and components of yield of 'Pioneer 3780' with two methods of application (close to the row and far from the row application) used before planting.
LITERATURE REVIEW

The control of form or function in one part of a plant by another part is considered to be a correlative event. Apical dominance is a general term which is used to describe the correlative influence of the apex, or dominant shoot, on the growth and orientation of lateral organs such as buds, leafy shoots, stolons, branches and leaves (Phillips, 1969a).

Considering the inhibition of lateral growth by the apex, it has been assumed that the same basic mechanism of inhibition exists in all species irrespective of age or stage of development of the lateral shoot. However, suggestions have been made over the years that control of lateral bud growth probably involves complex interactions between nutritional factors, anatomical structure, stage of development, growth promoters, and growth inhibitors (Woolley and Wareing, 1972).

Besides the obvious relevance to basic research into plant morphogenesis and hormone action, the control exerted by apically located organs profoundly affects agricultural as well as ecological interests. In economically important crops, such as tomatoes (*Lycopersicum esculentum* L.) or tobacco (*Nicotiana tabacum* L.), much labor is expended removing or inhibiting the lateral shoots which results from an incomplete apical dominance. On the other hand, bud break is encouraged in many cereal crops and commercial flowering plants (Rubenstein and Nagao, 1976).

In contrast to the extensive literature on dicotyledons, there is a general lack of clarity in the understanding of bud growth control in the grasses. One of the main reasons for this is that the apical meristem in grasses is not readily accessible until after inflorescence emergence and
the axillary buds are protected by their subtending leaf sheath. But, as Gustafson (1946) stated, the pattern of earshoot development of corn (*Zea mays* L.) plants is apparently similar to fruit set in the inflorescence of tomato plants, in which flower buds formed first within an inflorescence have more hormone and are more likely to set fruit than those formed later. The second, third, and fourth flower set have progressively less hormone and less chance of setting fruit.

In corn, evidence indicates that the inhibition of lower ear shoot development by the dominant upper ear shoot(s) is a form of apical dominance (Earley et al., 1974; Harris et al., 1976), and this probably is controlled by a delicate interaction between hormones (Harris et al., 1976) as well as nutritional factors (Earley et al., 1974). It is clear from the studies of Gregory and Veale (1957), and of Shein and Jackson (1971) that nutritional conditions affect the response of axillary buds to hormone treatments, and yet inhibited buds do not appear to be deficient in nitrogen, potassium or phosphorus (Phillips, 1968). It would, therefore, seem possible that mineral nutrition may be affecting the production of some hormonal factor (Phillips, 1969b) which interacts with other hormones in the phenomenon of apical dominance.

Despite the fact that most scientists agree that special diffusible plant hormones such as auxins, abscisic acids (ABA), cytokinins (Cy), gibberellins (GA), etc., are involved in correlative events and apical dominance phenomenon, the mode of action of these substances has not been satisfactorily resolved in corn or any other plant species (Wickson and Thimann, 1958; Bauman, 1960).
Auxins have been implicated as inhibitory factors in apical dominance since the early work of Thimann and Skoog (1933). They showed that auxin or diffusates from broad bean (*Vicia faba* L.) apices could substitute for the apex as an inhibitor of lateral bud growth. Naphthaleneacetic acid (NAA) or indole-3-acetic acid (IAA) also prevented DNA synthesis and cell division in lateral buds of spiderwort (*Tradescantia* sp.) and soybean (*Glycin max* L. Merrill) (Naylor, 1958).

The endogenous regulation of apical dominance by auxin in coleus (*Coleus blumei* L.) was questioned by Jacobs et al. (1959) when the concentration of auxin, which substituted for the apex as far as vascular regeneration was concerned, was unable to inhibit lateral bud outgrowth. Coleus, however, does not show a complete form of apical dominance under the conditions of high light intensity used by Jacobs et al. (1959). It may be that buds on young plants or on plants under high light conditions are already growing rapidly and are only partially, or not at all, regulated by auxin from the apex (Rubenstein and Nagao, 1976).

One of the theories for the regulation of lateral buds by auxin is that auxin may act indirectly either by interacting with some factor from the roots, or by mobilizing essential substances away from the lateral bud toward the area of highest auxin concentration (the apex). Husain and Link (1966) have shown that the apex is a site of nutrient accumulation in intact plants and that after decapitation, the lateral buds become new sites for accumulation. They showed that auxin on decapitated internodes could direct the transport of $^{32}$P to the site of hormone application. The ability of auxin to direct transport seemed to be related to its basipetal transport, since a ring of triiodobenzoic acid (TIBA) (20 μM)
applied below the auxin prevented $^{32}\text{P}$ accumulation. It was also discovered that GA (2.0 μM) or cytokinin (4.7 μM) applied with auxin resulted in greater $^{32}\text{P}$ accumulation (Seth and Wareing, 1964, 1967).

Ions, nitrogenous substances and soluble carbohydrates have been shown to accumulate at regions where IAA was applied (Mitchell and Martin, 1937; Stuart, 1939; Brunsetter et al., 1948). These experiments, however, took place over several days, and it is possible that the primary effect of IAA was to induce a region of rapid growth to which nutrients were attracted to form new cell materials.

Shorter term experiments over some 24 hours to reduce the growth effect have been carried out by Booth et al. (1962), Seth and Wareing (1964), Davies et al. (1966), Bowen and Wareing (1971), and Patrick and Wareing (1973). These workers applied IAA in lanolin to decapitated internodes of pea (*Pisum sativum* L.), kidney bean (*Phaseolus vulgaris* L.), or aspen (*Populus robusta*) and found that the transport of $^{14}\text{C}$-sucrose or $^{32}\text{P}$ orthophosphate to the treated internodes was greatly increased compared to the control plants, which were treated only with plain lanolin. Phillips (1968), using a similar system, has shown enhanced accumulation of endogenous nitrogen, phosphorus and potassium in the IAA-treated regions. It was concluded that IAA probably acts by a rather specific and direct effect upon the transport process itself, rather than by establishment of a sink. However, it is still possible that application of the hormone causes an increased rate of metabolism and biosynthesis in neighboring tissue, before there are any visible signs of growth, and thereby establishes a "metabolic sink".
Hew et al. (1967) have presented somewhat different results. They found that $^{14}$C-labeled photosynthates from a primary leaf are translocated primarily to the roots of decapitated plants, even if the cut ends of the internodes were treated with auxin (30 $\mu$M) or GA (0.13 $\mu$M). Distribution patterns of $^{14}$C-photosynthates were also identical when intact and decapitated controls were compared.

The general concept of auxin induced transport is adequate to explain the distribution of nutrients in plants. For example, the accumulation of metabolites in young leaves and developing fruits might well be related to their capacity to produce auxin. Also, certain correlation effects, such as apical dominance and the competition for nutrients, which brings back to mind the diversion theory of Went (1936), can be interpreted in terms of auxin-induced transport. Tucker (1977) found that, during summer, the more rapidly growing buds of the rogue tomato plants contained much higher levels of IAA than were found in those of the normal plants. Such an observation did not lend support to the direct theory of apical dominance, but rather suggested that IAA acts in some other manner, such as auxin-induced transport.

Correlations between auxin content and growth have been shown in a variety of ways. Some results of Scott and Briggs (1960) showed that the growth rate in pea stems dwindles from the apex toward the base of the plant, as does the auxin content. The correlation with time is illustrated by some data of Hatcher (1959). The auxin content in apple (Malus domestica Bork.) twigs rises in the spring as growth gets underway, and it subsequently declines through the growing season; trailing after it is a decline in the growth rate until autumn.
Correlations between auxin content of tissues and growth rates have frequently been found, but there are also many instances in which no such correlation was observed. In their data for pea stems, Scott and Briggs (1960) observed a slight decline in diffusible auxin down the stem over the region of declining growth rate, but extractable auxin showed no appreciable change over the whole region from the rapidly growing stem apex to the point where growth had essentially stopped. They deduced that the auxin obtained from peas by diffusion is more relevant to the growth-regulating action than that obtained by extraction. In contrast, Went (1942) reported that in oat (*Avena sativa* L.) coleoptiles, the extractable auxin correlated well with growth rate, whereas the diffusible auxin correlated instead with the tropistic reactions.

Since phytohormones play a significant role in regulation of processes of plant growth and development (Chailakhyan, 1969; Cleland, 1971), a number of investigations have been devoted to study the effects exerted by different compounds possessing hormonal activity on structure, composition, and synthesis of the plant cell wall (Leopold, 1968; Cleland, 1971). There are data indicating the ability of auxin to induce changes in the rate of synthesis of polysaccharide fractions for entering the cell wall in plants. Thus, it was demonstrated using $^{14}$C-glucose that the stimulating influence of IAA (20 to 50%) on synthesis of cell wall components is a direct hormonal effect of auxin, and not a result of cell elongation (Baker and Ray, 1965). It has been demonstrated that inhibitors which depress the action of auxin inhibit incorporation of labeled precursors into the composition of cell walls (Ray and Baker, 1962). According to the data of Japanese investigators, the activities of B-1,3-glucanase, B-1,6-
glucanase and hemicellulase in barley (Hordeum vulgare L.) coleoptiles increased after 3 hours of auxin action (Masuda, 1968; Tanimoto and Masuda, 1971).

Auxin-induced elongation of plant cells is mediated by a fundamental alteration in the cell wall (Cleland, 1971). An enhanced decrease in the non-cellulosic glucose component of wall polysaccharids occurs in oat coleoptile segments as a rather specific response to IAA application (Loescher and Nevins, 1972). The extent to which the wall is modified bears an inverse relationship to the amount of growth induced at various IAA concentrations (Loescher and Nevins, 1974). It is noteworthy that such a relationship exists when coleoptiles are subjected to low IAA levels, which stimulate growth, as well as those high concentrations, which suppress growth. The decrease in a particular non-cellulosic glucose component in response to IAA imparts to the wall its enhanced capacity to extend.

Cooil and Bonner (1957), investigating growth of oat coleoptile sections, showed that endogenous growth, as well as auxin-induced growth, is inhibited by concentrations of calcium chloride between 1 and 10X10^{-3}M. This inhibition can be reversed quickly by supplying potassium ions to the sections, or slowly by placing them in calcium-free solution of sucrose and IAA. Tagawa and Bonner (1957) were able to show that both IAA and potassium ions increase the deformability of the tissue, primarily increasing its plastic component, and that calcium ions reverse these effects. The role of auxin in loosening the wall is to reduce the number of calcium bridges or other cross linkages between pectin chains by promoting methylation of the carboxyl groups.
Patrick and Wareing (1970) determined the effect of IAA on protein levels and net incorporation of $^{14}$C-leucine by internode tissue in the seedlings of dwarf bean over the 12 hours after decapitation. Results showed that after 12 hours, the protein level in the lanolin controls had declined to 30-50% of the initial value, whereas pretreatment with IAA maintained the initial level. Net incorporation of $^{14}$C-leucine was 5 times greater in the IAA treated tissue than in the lanolin controls. Their data suggested that IAA maintains the initial protein level by regulating the rate of protein turnover. Whether this is by increased synthesis or decreased degradation is not clear.

Matchett and Nance (1962) showed that $^{14}$C introduced into cell-wall constituents of pea stems is subject to metabolic turnover. Turnover is increased in test tissues which are supplied with growth-promoting levels of IAA and decreased by growth-inhibiting levels of mannitol and galactose.

Stimulatory effects of IAA on the mitotic rate in various plant tissues have been described by numerous investigators (Snow, 1935; Naylor et al., 1954; Chouinard, 1955). These observations did not reveal whether auxin primarily induced DNA synthesis, or whether it merely stimulated mitosis in cells which had already undergone DNA doubling, or whether it affected both processes. Das et al. (1956) showed that combined treatments with IAA and kinetin promote DNA synthesis, because they caused the descendants of certain cells to divide continually.

Many investigators have studied and compared the effect of indole compounds with other hormones on different crops. Harris et al. (1976) treated two nonprolific and two prolific single crosses of corn with solutions containing known plant growth regulators, ABA, $GA_3$, kinetin, and
indole-3-butyric acid (IBA). None of the hormones injected were particu­larly effective in stimulating grain productivity. However, the IBA treatment induced extreme kernel abortion and poor cob development in second ears of both prolific hybrids. Relative to controls, these ears showed average reductions of 53%, 48%, and 31% in kernel numbers, grain weight, and cob weight, respectively.

Schlienger et al. (1977) showed that the elongation rate of wheat (Triticum aestivum L.) coleoptiles treated with IAA and ABA was already affected during the first 8 hours of culture. Growth stimulation by IAA was nearly proportional to its concentration up to $10^{-4}$M, while ABA always induced a significant inhibition.

Unfortunately, direct treatment of lateral buds have yielded equivocal results. IAA may induce growth of lateral buds of pea (Libbert, 1954), or not (Thimann, 1937). Menil and Von Guttenberg (1954) have pointed out that only relatively high concentration of exogenously applied auxin inhibit the lateral buds of bean, and they, therefore, questioned whether endogenous levels of auxin are that high. Jacobs et al. (1959) later demonstrated that IAA added in the amount sufficient to replace the level of native auxin was not sufficient to maintain the correlative inhibition of lateral buds of coleus.

Mullins (1970) showed that the applications of ethylene, IAA, benzyladenine (BA), or mixtures of IAA, GA, and BA to decapitated internodes of bean seedlings increased the accumulation of $^{14}$C-activity in the stump. He suggested three factors with respect to the mode of action of growth regulators on assimilate translocation. First, accumulation of label in treated tissues may be the result of a growth response. Second, effects of
growth substance on assimilate translocation may be related to their effects on internode senescence, and third, direct effects of growth regulators on the translocation mechanism. Pretreatment of internodes for 24 hours with a mixture of IAA, GA, and BA followed by a further delay of 4 hours, for translocation of label, resulted in a greater fresh weight of internode segment tissue than in controls which were treated with water.

Seth and Wareing (1967) showed that, although kinetin and GA alone appeared to have little effect upon the transport of metabolites from the leaf to the fruit, or within decapitated bean plants, when applied in conjunction with IAA, they considerably enhanced the effects of IAA. Further, when the three hormones were applied together, the accumulation produced was still greater than with IAA alone or a combination of IAA with either GA or kinetin.

A synthetic auxin, NAA, has been shown to have effects similar to IAA on plant growth and development. Bowen and Wareing (1971) studied the effect of synthetic auxins such as NAA, 2,4-D, and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) upon the transport of $^{32}$P-orthophosphate and $^{14}$C-sucrose in 'Canadian Wonder' bean, 'Meteor' dwarf pea, 'Tall Single' sunflower (Helianthus annus L.), and 'Pineapple' coleus. The result of applying these hormones on the upward movement of $^{14}$C-sucrose led to a significant increase in sucrose accumulation when compared to the lanolin control in bean and coleus. In pea and sunflower, 2,4,5-T and NAA treatments brought about a significant increase in accumulation of label derived from $^{14}$C-sucrose, when compared to the lanolin control, whereas 2,4-D did not. Hormone-directed transport of $^{32}$P-orthophosphate experiments in bean showed that all synthetic auxins increased $^{32}$P-orthophosphate accumulation
in the decapitated apex. In pea, 2,4-D was the only hormone treatment which did not cause increased accumulation of label. In neither coleus nor sunflower did a hormone treatment cause as much accumulation of $^{32}P$ orthophosphate in the decapitated internode as the plain lanolin treatment.

Sacher (1967) made a comparative study on the effect of the NAA, auxin, kinetin and a mixture of auxin and kinetin applied in vivo on synthesis amongst the subcellular fractions of sections of endocarp from 'Kentucky Wonder Pole' beans. NAA caused considerable enhancement of incorporation of labeled precursors into RNA and protein of all subcellular fractions, and induced net synthesis of RNA and protein. The effect of kinetin alone on synthesis of RNA, or of kinetin and auxin-induced synthesis of RNA, was variable, with either stimulation or inhibition observed in different experiments.

Naphthalenacetic acid has been shown to inhibit monocarpic senescence in soybean (James et al., 1965). For bean endocarp tissue sections, evidence has been presented that the primary action of NAA in preventing senescence is on the synthesis of RNA (Sacher, 1963; Sacher, 1965; Sacher, 1967).

Noodén et al. (1979) found that foliar applications of NAA or BA delayed the seed induced foliar senescence in soybeans. They showed that BA is more effective in preventing leaf yellowing with less retardation of abscission; therefore, there is a tendency to shed greenish leaves. In contrast, NAA retards yellowing less, but abscission more, so that petioles and yellow leaves hang on longer than normal. When they applied them together, the combination of 50μM NAA and BA essentially suppressed leaf
yellowing and abscission. The plants treated with NAA plus BA stayed green long after the buds turned brown (at least 2 months beyond normal podded plants). The treatment with NAA plus BA did not retard fruit development, nor did it change seed yields.

The influence of the achenes upon the growth of the strawberry (*Fragaria vesca* L.) was studied by Nitsch (1950), who reported that removal of the achenes completely stops further growth of the fleshy part. Partial removal, however, results in fruits of abnormal shape. Synthetic growth substances β-naphthalenacetic acid and IBA restored the growth of the receptacle and normal shape and size in the absence of the achenes. He concluded that the achenes are the source of auxin necessary for normal fruit development. Similarly it was reported that during the various stages of grape (*vitis* sp.) berry development, different levels of growth substances were detected (Coombe, 1960; Nitsch et al., 1960; Nijjar and Bhatia, 1969).

Singh et al. (1976) reported that NAA, GA, and 2-(2,4,5-trichlorophenoxy) propionic acid (2,4,5-TP) applications at 100 and 250 ppm to mango (*Mangifera indica* L.) fruits accelerated fruit ripening. Fruit size and quality were enhanced only by GA.

Abscisic acid is recognized as a naturally occurring plant hormone of major importance in the regulation of plant growth and development. It has been implicated in such plant growth processes as senescense, abscission of leaves, flowers, and fruits; rest and dormancy of seeds, buds, and tubers; and inhibition of vegetative growth (Sondheimer et al., 1968; Addicott and Lyon, 1969).
Addicott and Lyon (1969) showed that exogenous application of ABA can inhibit stem and bud growth. Hillman (1970), applying growth regulators to the decapitated stem of bean, found that ABA (0.1 μM) increased the inhibitory action of IAA plus kinetin. ABA alone had a small promotive effect on bud growth.

The importance of ABA as an endogenous regulator of apical dominance is suggested by its presence and fluctuation in homogenates. An extractable inhibitor from broad bean was shown by the work of Kefford (1955) to accumulate at higher concentrations in the lateral buds than in the apex. Dörffling (1966) extracted internodes above the cotyledons of pea and assayed the activity using lateral bud growth and oat coleoptile growth. He found at least two substances which inhibited growth in both assays and whose effects could be reversed by 0.01 μg/bud GA.

Auxin may induce the production of a secondary inhibitory substance in the manner first suggested by Snow (1939). Evidence in support of this theory has been put forward by Tucker (1976) who showed that for the tomato, auxin synthesized in the apex and travelling basipetally, may induce the formation of ABA in or near the lateral buds, and it is this hormone which brings about bud inhibition. This is in agreement with the work by Eliasson (1975), who found that for Quaking Aspen (Populus tremula) and pea, a high auxin level in growing stems maintains a high level of ABA, which prevents the outgrowth of the lateral bud.

Tucker (1977) found lower levels of ABA in the apical region, axillary buds and stems of the rogue tomato plants for both winter and summer sowings and concluded that the lesser apical dominance in rogue plants is due to lower levels of ABA in rogue plants compared to normal tomato plants.
The inhibitory effects of ABA have been suggested to be accomplished through an effect on GA metabolism. Thus, several studies have shown that ABA application can cause reductions in endogenous GA levels (Rudnicki et al., 1972), perhaps by inhibiting GA interconversion or biosynthesis per se (Wareing et al., 1969). It has been suggested that one general effect of ABA might be to increase the conversion of biologically active GA$_5$ into less active products (Nadeau et al., 1972). Taylor and Railton (1977) showed that wilting etiolated-dwarf pea seedling resulted in significant reductions in the conversion of bio-active GA$_{20}$ into its less biologically active derivative, GA$_{29}$.

There is evidence which indicates that the plant hormone ABA has an important role in the natural regulation of plant water status through its effects on stomatal operation. Not only does the concentration of this hormone increase rapidly with water stress (Wright, 1969; Millborrow and Noddle, 1970; Zeevaart, 1971; Loveys and Kriedemann, 1973), but it has also been shown that exogenously applied ABA can mimic the effects of water stress in causing closure of stomata, prevention of the opening of closed stomata, and reducing the transpiration from excised leaves and intact plants (Little and Eidt, 1968; Mittelheuser and Van Steveninck, 1969; Tucker and Mansfield, 1971; Talha and Larsen, 1975; Uehara et al., 1975).

Wright (1969) reported an increase in the ABA content of wheat leaves following a period of wilting and suggested suppression of physiological processes following water stress might be regulated by an increase in ABA.

Talha and Larsen (1975) treated intact corn plants with foliar sprays of ABA at concentrations from $10^{-9}$M to $10^{-4}$M. Even the lowest concentration caused a reduction of the transpiration rate as measured between 1
and 33 hours after spraying. After 5.5 days, the transpiration rate of plants treated with $10^{-9}$M and $10^{-8}$M was nearly back to normal, whereas transpiration of plants treated with $10^{-4}$M was only about 2/3 of their normal rate.

Quarrie and Jones (1977) conducted experiments to compare effects of ABA and water stress treatments on leaf morphology and floral development in a spring wheat. In both experiments the treated plants produced smaller leaves and fewer spikelets per ear. Both ABA and water stress decreased the mean cell size, reduced the number of stomata per leaf, and increased the production of trichomes in all the leaves sampled. It was concluded that ABA could mediate many of the responses of wheat plants to prolonged water stress.

Attempts have been made to understand the mechanism(s) of action of ABA in eliciting inhibition of plant growth. Several effects on cellular metabolism have been reported, including a reduction in rates of protein and nucleic acid synthesis, although these can not be detected until after 2 or more hours of ABA treatment (Millborrow, 1974).

Sodek and Wright (1969), Deleo and Sacher (1970), and Leshem (1971) have established that RNase activity in many plant parts may be modified by ABA and cytokinin. Cytokinin has a repressing effect on RNase activity and ABA has an enhancing effect. Also, the influence of ABA on various other enzymes has been documented in the literature (Addicott and Lyon, 1959).

Cram and Pitman (1972), and Van Steveninck (1972) have suggested that ABA may function as a hormonal regulator of ion-transport processes in plant cells. The most rapid and dramatic effect in this respect is the
inhibitory action of ABA on $K^+$ uptake by guard cells (Cummins et al., 1971; Arntzen et al., 1973). Reports on the effect of ABA on ion transport into other plant tissues are somewhat inconsistent. Mansfield and Jones (1971) found ABA inhibited $K^+$ uptake by leaves; Cram and Pitman (1972) reported that it stimulated $K^+$ uptake into roots. Migliaccio and Rossi (1977) reported that ABA stimulates the translocation of chloride and sulphate in excised corn roots and supported the hypothesis that the principal action of ABA is the stimulation of ion release into the xylem.

Cold-acclimation of plants has been shown to be associated with changes in their hormonal balance (Irving and Lanphear, 1963). In maple tree (Acer negundo L.), an induction of hardiness was found to be related more to the build-up of ABA than to a reduction of GA levels (Irving, 1969). In winter wheat, increased cold-hardiness was associated with a large decrease in GA content (Reid et al., 1974). Wareing et al. (1968) suggested the possibility that ABA acts as an antagonist to GA by affecting the latter's biosynthesis.

King (1976) showed that there was no clear relationship between ABA content and the growth of grains in various spikelet or floret positions of wheat. Application of ABA to the ear had no effect on grain growth rate, but led to an earlier cessation of grain growth and hastened the drying of the grain. It is suggested that the accumulation of ABA at the later stages of grain growth (up to 40-fold) prevents precocious germination and premature hydrolysis of starch reserves of the morphologically mature, but still unripe, grain. He showed that early in development, the content of ABA per grain is quite low. Also, its subsequent
increase paralleled dry matter accumulation, a result which does not suggest an inhibitory action of ABA on grain growth.

The recognition that gibberellins, as well as auxins, are synthesized in young leaves and are transported down the stem has led to the idea that these hormones also play a regulatory role in apical dominance (Jacobs and Case, 1965; Pharis et al., 1970). There are conflicting reports on the interaction between the action of gibberellins and auxins in plants (Galston, 1957; Brian and Hemming, 1958; Kato, 1958; Brian, 1959; Galston and McCune, 1961; Kefford and Goldacre, 1961; Kefford, 1962; Kuraishi and Muir, 1962; Sastry and Muir, 1963; Scott et al., 1967; Tanimoto et al., 1967; and Phillips, 1971a).

Gibberellic acid treatment synergistically enhanced IAA-induced elongation of excised stem segments of either dwarf or normal peas (Tanimoto et al., 1967). It also showed a synergistic effect and reduced the lag period of tryptophan-induced elongation. This reduction in the lag period suggested that GA promoted the conversion of tryptophan to auxin (Tanimoto et al., 1967).

Galston (1957), Brian and Hemming (1958), and Galston and McCune (1961), in separate experiments on pea plants, suggested that GA increased the concentration of a phenolic inhibitor of the IAA-oxidase system, thereby producing greater auxin concentration in tissue, which in turn promotes cell elongation.

Kefford (1962) proposed that the contribution of exogenous GA to elongation of the rice (*Oryza sativa* L.) coleoptile was dependent upon the auxin status of the coleoptile. This proposed scheme of GA action being dependent on auxin was also put forward by Kefford and Goldacre (1961).
Phillips (1971a) has attempted to clarify the role of exogenously applied GA$_3$ by showing that it can be a modifying factor in auxin-regulated apical dominance. He suggested that GA synthesized in the apex normally stimulates growth in the elongation internodes and may not reach the axillary buds. If, however, there is excess GA, it may reach the buds and enhance their growth.

However, reports by Purves and Hillman (1959), Hillman and Purves (1961), and Kato (1961) proposed that auxin and GA made independent contributions to cell enlargement in etiolated pea epicotyl and stem sections because GA promoted growth in the presence of inhibitory concentrations of IAA, and the antiauxin, p-chlorophenoxyisobutyric acid, and other compounds inhibited auxin-induced growth, but did not inhibit gibberellin-induced growth.

Devlin (1969) and Lang (1970) stated that gibberellins and auxins act both independently and together depending on the plant species, condition, tissue under consideration, site of application, and the kind of response being measured. Cutter (1972) reported that the interacting effects of auxins and GA may differ according to the stage of development of the buds at the time of treatment, and this view is supported by evidence for the sequential roles for different growth regulators during lateral bud outgrowth (Ali and Fletcher, 1970).

Catalano and Hill (1969) showed that the effects of treating intact plants with GA and kinetin were inconsistent; in some cases no growth was observed, while in others there was stimulation of growth.

Most often, stimulation of growth has been recorded with application of GA. Catalano and Hill (1969) reported stimulation of growth in
lateral buds of tomato plants by 270 μM GA. Ali and Fletcher (1970) stimulated bud growth of 7-day-old soybean plants, after a 1 to 3 day lag, using 26 μM GA applied directly to the cotyledonary buds. Phillips (1971a) found that when GA is applied close to the bean lateral bud elongation will result.

Since bud growth is stimulated by GA applied through the roots of bean and this acceleration is reduced by kinetin or IAA, Shein and Jackson (1971) proposed that GA is, in fact, an endogenous regulator whose effects are modulated by levels of other inhibitory compounds.

Gibberellins are considered primarily to stimulate cell enlargement. However, there have been many reports where cell division was observed in beans (Feucht and Watson, 1958; Greulach and Haesloop, 1958; Moh and Alan, 1967), peas (Sommer, 1961), pigbean (Hyoscyamus niger) Sachs and Lang, 1957), and onion (Allium cepa) anthers (Vasil, 1957). Schroeder and Spector (1957) reported that GA stimulated callus formation in excised citron fruit mesocarp.

Leshem et al. (1975) showed that either by direct GA supply or by release of glycoside bound GA, pollination caused partial opening of double-stranded DNA in somatic corn kernel tissues, as evidenced by increased thermal denaturation (Tm) profiles. They showed that this phenomenon is associated with enhanced RNA and protein production. They indicated that in higher plants the act of fertilization and/or pollination induces RNA activity and enhances amino-acid incorporation and concluded that the process may be triggered by GA.

The effect of GA on crop production has been reviewed by Wittwer and Bukovac (1958). These workers suggested that GA may have many potential
uses in the production of crop plants. Alder et al. (1959) reported the effects of GA on corn plants. They found a significant increase in height due to GA treatment, but there was no significant change in the amounts of silage or grain produced.

Cherry et al. (1962) studied the effect of GA on growth and yield of two single cross hybrid corn cultivars. Weekly foliage sprays beginning at the seedling stage decreased the leaf area, but the height of the plant, number of nodes per plant, and height to first ear node were increased. Other GA spray or injection treatments beginning at a later stage, slightly increased height, but had little effect on leaf area or number of nodes per plant. The total yield produced by WF$_9$ X M$_{14}$ was affected less by GA treatments than that of HY$_2$ X 07. The number of ears produced by WF$_9$ X M$_{14}$ was not affected, but GA treatments at weekly intervals decreased the number of first and tiller ears produced by HY$_2$ X 07. The number of second ears produced was decreased by the GA application beginning at the time of anthesis. The early GA treatments at weekly intervals reduced ear length and cob weight. Generally, the GA treatments tended to increase stover weight. The greatest increase in stover was obtained from plants that were treated near the end of the growing season. Grain yields were slightly increased by spraying with GA near anthesis. The 1-mg injection treatment into the second ear sheaths increased yield of WF$_9$ X M$_{14}$. Skirde and Crossman (1964) were able to show that GA$_3$ temporarily increased the height of corn plants, improved their development and, as a seed treatment, increased the germination rate below 20°C.

Gale et al. (1974) treated dwarf, semi-dwarf and tall wheat varieties with GA supplied with culture solution daily at a rate of 3mg/l. Applied
GA increased photosynthetic rate and the maximum increase was 17% in the variety with the lowest control rate.

An increase in leaf area and other photosynthetic surfaces has been suggested (Brian and Grove, 1957) as the explanation for increases in yield up to 40% in crops such as celery (*Apium graveolens* Dulce) and forage grasses following a single application of gibberellin. GA has been shown to affect immediate increases in photosynthetic rates in tomatoes (Coulombe and Paquin, 1959), corn, beans and clover (*Trifolium pratense*) (Treharne and Stoddart, 1968). Numerous other plants (Marth et al., 1956; Gray, 1957; Coleman, 1958; and Peterson, 1958) have shown dry weight increased from GA.

The report by Noggle (1958) that GA does not enhance the rate of CO₂ fixation per unit of leaf tissue support the increased leaf area hypothesis as the explanation for dry matter increases. He concluded that GA does promote overall leaf expansion and elongation with a wide variety of species.

Likholat et al. (1973) stated that growth regulators such as GA with a positive sign of action on plant growth and development intensify processes of energy metabolism. This view was supported by Yakushkina and Starikova (1977), who reported that GA increases energetic exchange in corn seedlings.

N⁶-benzyladenine is a potent cytokinin which exhibits some physiological effects in common with that of kinetin (the natural cytokinin), that is, cell division and cell enlargement (Powell and Griffith, 1960; Ali and Fletcher, 1971; Guern and Usciati, 1972; and Usciati et al., 1972),
leaf growth (Scott and Lieverman, 1956), inhibition of leaf senescence and preservation of chlorophyll (Fletcher, 1969; Adedipe et al., 1971), acceleration of chloroplast differentiation and increased photosynthetic enzyme activity (Harvey et al., 1974), bud release from apical dominance (Usciati et al., 1972), and increased protein synthesis (Pozsar et al., 1967).

Cytological and biochemical changes in lateral buds released from apical dominance by cytokinins have been studied extensively. Chick pea (Cicer arietinum) lateral buds treated with 1 μM BA exhibited increased cell division within an hour, whereas increased elongation first occurred two hours after treatment (Guern and Usciati, 1972; Usciati et al., 1972). Buds of soybean exhibited increases in cell division within 24 hours of cytokinin treatment (Ali and Fletcher, 1971).

Jewiss (1972), Langer et al. (1973), and Clifford and Langer (1975) reported that local application of kinetin and BA promote tiller bud elongation on barley. It was suggested by Clifford and Langer (1975) that cytokinins act by diverting assimilates to the buds.

Schaeffer and Sharpe (1970) showed that axillary buds of tobacco, under apical suppression, are stimulated by BA applied in a lanolin paste or in aqueous solution. Sustained growth increased with BA concentration up to 1 mg BA/ml lanolin. Sachs and Thimann (1964, 1967) showed escape from apical dominance and the stimulation of bud growth on intact plants of peas with cytokinin application.

Investigations into the relationship between endogenous cytokinin and apical dominance have yielded contradictory results. Tucker and Mansfield (1972, 1973), for example, reported that cytokinin levels
decreased in lateral buds of cocklebur (*Xanthium* sp.) following release from apical dominance, while studies in peas have suggested that cytokinin supplies may be limiting in inhibited lateral buds (Lee et al., 1974).

Cytokinins are reported to have a variety of effects on chloroplast development. For example, BA has been reported to stimulate division of mature chloroplast in tobacco (Laetsch and Basson, 1972). Harvey et al. (1974) found that the chloroplasts of etiolated cucumber (*Cucumis sativus*) cotyledons had crystalline prolamellar bodies, whereas those treated with BA had a well-developed plastid membrane system. After 4 hours exposure to light, grana were formed in the chloroplasts of BA treated cotyledons, but not in the control. The specific activities of ribulose 1,5-diphosphate carboxylase, and NADP-dependent glyceraldehyde 3-phosphate dehydrogenase increased 75 and 50% respectively during BA treatment in the dark, while there was little change in the controls. They concluded that BA stimulates structural differentiation of the chloroplast and enhances activities of photosynthetic enzymes, even in the dark.

Feierabend (1969) showed that dark grown rye (*Secale cereale* L.) exhibits a considerable increase in ribulose diphosphate carboxylase and NADP-dependent glyceraldehyde 3-phosphate dehydrogenase 3 days after kinetin treatment. Activity of the former enzyme is also increased within 24 hours of BA treatment of mature bean leaves (Treharne et al., 1970).

Feierabend and deBoer (1978) studied the effect of cytokinins in plastid biogenesis in etiolated rye leaves. The cytokinin supply had a much greater influence on plastid biogenesis than on leaf growth in general. The activities of several chloroplastic enzymes were increased 200% to 400% after kinetin treatment of cytokinin depleted leaves. The
activity of ribulose-1,5 bisphosphate carboxylase and the amount of fraction-I protein showed a seven-fold increase.

Mothes and Engelbrecht (1959) sprayed solutions of kinetin directly onto leaves of tobacco and reported that the retention of chlorophyll is localized to the areas of the blade to which kinetin is supplied. They found that labelled amino acids migrate to, and accumulate in the treated parts of tobacco leaves, and suggested that the treated areas act as loci for the accumulation of metabolites.

Kinetin appears to enhance RNA synthesis, but not DNA synthesis (Osborne, 1962; Jensen et al., 1964). Osborne (1962) suggested that the primary action of kinetin might be the regulation of synthesis of a particulate RNA fraction. Further evidence (Salunkhe et al., 1962, and Sugarira et al., 1962) suggested that kinetin may effect the synthesis of ribosomal and soluble RNA's.

Carpenter and Cherry (1966) treated cotyledons from 3-day-old peanut (Arachis hypogaea) seeds with BA ranging from 0.09 to 9.0x10^{-3}M. In the presence of 0.09, 0.2, and 0.4x10^{-3}M BA, ^{32}P incorporation into nucleic acid fractions was enhanced, while at 2.0, 4.0, and 9.0x10^{-3}M, incorporation was inhibited. From their studies, it was concluded that BA may promote or inhibit nucleic acid synthesis, as judged by ^{32}P accumulation.

Pozsar et al. (1967) brushed half leaves of 'Pinto' bean daily for 6 days with BA and kinetin solution of 30 and 50 ppm respectively. The incorporation of labelled glycine into the acid insoluble fraction was determined in leaf disks floated for 4 hours on 100 ml of a solution of ^{14}C-glycine with activity of 0.5 μc/ml. Protein synthesis was increased in both kinetin and BA-treated half leaves as measured by the increase of
incorporation of glycine into the protein fraction. Concentrations of protein and RNA were also increased as a consequence of these cytokinin effects. The influence of BA was analogous to that of kinetin and was more pronounced in every respect. They showed that the effect of BA on leaf growth is also a cytokinin-like effect.

Terry and Polley (1977) studied the kinetics of RNA synthesis after 24 hours in cultured pea root segments. They found that kinetin stimulated a 2 to 4-fold enhancement in the rate of RNA synthesis after 24 hours. They interpreted the results to indicate a stimulation in the rate of RNA synthesis due to kinetin treatment prior to any other known response.

Usciati et al. (1972) showed that incorporation of $^3$H-uridine into RNA was stimulated 90 minutes after BA application and that RNA levels in the bud doubled within 12 hours, while DNA levels doubled after 24 hours. Schaeffer and Sharpe (1970) showed that in tobacco, DNA and RNA content per bud increased between 18 to 24 hours after 2 to 3 μM cytokinin was applied to the lateral buds. $^3$H-thymidine incorporation into the DNA of lateral buds was accelerated between 6 to 24 hours after BA treatments.

Increased synthesis and methylation of fatty acids have been shown to be some of the earliest events occurring in the lateral bud after cytokinin application (Schaeffer and Sharpe, 1971, 1974). They showed $^{14}$C-acetate incorporation into lipids occurred 3 hours after BA application in chick pea and the rate doubled by 6 hours; dry weight of the bud doubled only after 18 to 24 hours. They also found that more label from $^{14}$C-methyl methionine was diverted to phosphatidyl choline than into $^{14}$CO$_2$ about 12 hours after BA applications to tobacco buds.
The effect of BA on protein synthesis is thought to be mediated by a cytokinin-receptor (Fox and Erion, 1975). Tobacco pith, as a non-growing tissue, may possess only very few such receptors. To be affected by cytokinins, corn polysomes are assumed to contain these cytokinin receptors.

Klämbt (1976) showed that cytokinins stimulate the protein synthesis of in vitro systems prepared from tobacco pith and/or one-day-old corn shoots. The maximal stimulation was found at a cytokinin concentration of $10^{-7}$ to $10^{-6}$M and was 20 to 30% higher than the control level.

It has been suggested that increased longevity and a decrease in respiration due to BA treatment may be a consequence of enhanced nucleic acid and protein metabolism (Fletcher and Osborne, 1965; Fletcher, 1969). Conservation of ATP rather than inhibition of respiration has been suggested for some plants (MacLean and Dedolph, 1964).

Retardation of leaf senescence in intact bean plants is one of the numerous growth regulating effects of BA. Fletcher (1969) and Adedipe et al. (1971) suggested that this effect is associated with either a maintenance or an enhancement of chlorophyll synthesis.

Mothes et al. (1959, 1961) showed that when kinetin was applied to one half of a tobacco leaf, senescence of the leaf tissue in this region is delayed, and there is movement within the leaf of labelled amino acids and other metabolites toward the region of kinetin application. They referred to this phenomenon as "kinetin-induced directed transport."

Dostal et al. (1965) supported the evidence for the hypothesis that BA is functional by means of affecting an increase in the amount of organic phosphate, particularly in the adenosine triphosphate fraction. Adedipe and Fletcher (1970) found that the retardation of the leaf senescence by
BA in intact bean plants is associated with increased utilization of metabolites, indicating a more rapid turnover of the adenosine phosphates. It was concluded that this effect was brought about by a regulatory coordination of metabolic processes in relation to energy production and utilization.

Seth and Wareing (1964) found that there is synergistic interaction between IAA, GA and cytokinin, and indicated that they are probably acting through the same system and are involved in the well-known phenomenon that metabolites move actively towards growth centers.

Developing soybean cotyledons have been shown to be able to incorporate acetate into fatty acids and water soluble constituents (Rinna and Canvin, 1971). Oleic acid was the first fatty acid to be detected with $^{14}$C and the $^{14}$C distribution pattern with time was consistent with it being the precursor of linoleic and linolenic acids. They showed that the cotyledons fixed $^{14}$CO$_2$ by either dark or light fixation reactions, but little $^{14}$C was incorporated into lipids.

Wilson and Kates (1978) showed that suspension cultures of soybean cells incorporated [1-$^{14}$C] acetate very rapidly into the fatty acid moities of phospholipids and glycolipids when incubated at 26°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.

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 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 incorporate [1-\(^{14}\)C] acetate into phospholipids mainly phosphatidylethanolamine in the cotyledon and phosphatidyl choline in the axis.

The initial incorporation of \(^{14}\)C-acetate into the 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 the fatty acids of alfalfa roots at 22°C was approximately twice that at 1°C. At 22°C, the percentage of labeling in individual fatty acids remained relatively constant throughout the incorporation, whereas, at 1°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.

Phenylmercuric acetate (C\(_6\)H\(_5\)HgOCoCh\(_3\)) has been reported to reduce transpiration by causing closure of stomata (Zelitch and Waggoner, 1962a, 1962b; McClurkin, 1974; and Miller and Ashby, 1978). This compound has been sprayed on many species including tobacco, beans, sunflower, loblolly pine (*Pinus taeda*), and corn, with reported transpiration reductions as high as 50%.
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 the control plants 4 bars. The transpiration was reduced by 54%.

Rychter et al. (1979) examined the effect 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 to 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 $\alpha$-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 a 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 $C_1$-$5$ alkyl and most preferably $C_1$ alkyl. The zinc salts of formic, acetic, propionic, butanoic, pentanoic and hexanoic acids that
are capable of reacting with ammonia and being soluble in aqua ammonia are suitable for forming the compositions.

Zinc acetate (ACA) has been especially preferred 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, wt.% zinc. The solution contains at least about 4, preferably 6 or more mols of ammonia per mol of zinc and at least about 10 wt.% water. Solutions containing from about 10 to about 20 wt.% 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 lbs/acre equivalent. Single cross corn hybrids Wf9 X Hy and N5 X N15 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 the 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 filed tests using zinc-containing solutions and zinc-free liquid ammonia as fertilizer for corn by pre-planting applications in soils classified as zinc-sufficient, and by side dressing application in zinc-deficient soils showed (Ott, 1976) 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 eight test plots out of ten in favor of the ammonia-zinc combination versus ammonia only. At the other two plots, no significant difference in yield was noted.

In a series of experiments (unpublished data, I. C. Anderson, Iowa State University) using zinc acetate in the corn fields of a group of farmers in Iowa, Anderson found an average yield improvement of 7 bushels per acre and increased leaf width in treated plots compared to controls.

Based on the current literature, this study was undertaken to further determine the influence of hormones and chemical growth regulators on ear development and grain yield of nonprolific corn cultivars.
MATERIALS AND METHODS

This research was conducted during the growing seasons of 1978 and 1979 at the Iowa State University Agronomy Experimental Station located about 10 miles west of Ames.

Hormone Experiments in 1978

'Pioneer 3780', a single cross nonprolific cultivar of corn (*Zea mays* L.), was planted during the middle of May, 1978, at a population rate of 50,000 plants/ha, and row spacing of 1.01m. After emergence (May 22, 1978), a section of the field containing 352 seedlings in four rows was randomly selected and marked. The experiment was completely randomized block design with 22 treatments each containing 8 plants replicated 2 times. The first 8 treatments were injected into the 14th stem internode and the others into the 12th stem internode.

The chemical treatments were as follows.

1) $10^{-2}$ M IAA (indoleacetic acid)  
2) $10^{-3}$ M IAA  
3) $10^{-4}$ M IAA  
4) $10^{-5}$ M IAA  
5) $10^{-2}$ M ABA (abscisic acid)  
6) $10^{-3}$ M ABA  
7) $10^{-4}$ M ABA  
8) $10^{-5}$ M ABA  
9) Control (no injection)  
10) $10^{-2}$ M IAA  
11) $10^{-3}$ M IAA  
12) $10^{-4}$ M IAA  
13) $10^{-5}$ M IAA  
14) $10^{-2}$ M GA (gibberellic acid)  
15) $10^{-3}$ M GA  
16) $10^{-4}$ M GA  
17) $10^{-5}$ M GA  
18) $10^{-2}$ M BA (benzyladenine)  
19) $10^{-3}$ M BA  
20) $10^{-4}$ M BA  
21) $10^{-5}$ M BA  
22) Control (no injection)
Preparation of different concentrations of hormones

Preparation of different concentrations of each hormone was done at the crop physiology laboratory located in the Agronomy Building at Iowa State University, a few hours before injection into the plants. Hormones IAA, ABA, BA, and GA had been stored frozen until used. For each hormone, the highest concentration \(10^{-2}\text{M}\) was made considering the molecular weight of the hormone and the volume of the solution which was needed to inject the total number of plants in the corresponding treatments and the volume necessary in dilution processes to make other concentrations, \(10^{-3}\text{M}\), \(10^{-4}\text{M}\), and \(10^{-5}\text{M}\), of that particular hormone. The hormones were dissolved in 50% ethanol. Since the solubility of hormones was not identical, the solutions were heated and stirred as required using a hot plate magnetic stirrer (Corning PC 351).

The objective was to place the hormones in contact with the developing ear shoot at an early stage, before ear shoot emergence. Since application of the treatments was to be made prior to appearance of the top ear shoot, it was necessary to predict the node at which the top ear shoot would develop. Leaves were counted on each plant while the first leaf was still intact, and the fifth leaf was marked by clipping off about five centimeters (cm) of the leaf tip. Later, before the fifth leaf had dropped, the tenth leaf was clipped on each plant. Except for the control, each of the treatments was injected by syringe into the stem internode. The first 8 treatments (IAA, ABA) were injected into the 14th stem internode on July 17, 1978. One milliliter (ml) of the solution containing hormone in 50% ethanol was injected into each plant (8 ml per
treatment). Treatments 10 to 22 (IAA, GA, and BA) were injected into the 12th stem internode in order to be as close as possible to the second ear shoot. The injection was done on July 18, 1978, at a rate of 1 ml per plant (8 ml per treatment).

There were some problems involved in the injection of the hormones into the stem internode. One major problem was blockage of the needle of the syringe, which hindered the process, but did not make the injection impossible. This problem was solved by attempting to find a suitable place in the stem internode in which the needle could penetrate the stem and the solution could be discharged without difficulty. Another unusual development was the formation of a faded black spot around the point of injection, probably due to the ethanol (50%) which was one of the constituents of the solution.

The attributes measured on each of the eight plants within each treatment were as follows:

1. percent of filled kernels (PFK) and dry weight (DW) of the first ear (top ear) in the first nine treatments (IAA, ABA, and control);
2. percent of filled kernels and DW of the top ear in treatments 10 to 22;
3. Ear length (EL), cob length (CL), and DW of the second and third ears in treatments 10 to 22 (IAA, GA, BA, and control).

At harvest on October 10, 1978, the top ears of all treatments (treatments 1 to 22) were picked by hand and the ten ears of each treatment were placed in a linen bag and labelled for further processes.
Later, the PFK was judged on each ear (visual judgment) and recorded. The indices for PFK determination were based on the percentage of the cob length that was covered by kernels. For example, index number 1 was used if the cob was completely covered by filled kernels, 0.9 was used if 90% of the cob was covered by filled kernels, etc. Dry weight of the top ears in each treatment was obtained after putting all bags into a forced air drier at 60°C for 3 days.

To measure EL, CL, and DW of the second and third ears in treatments 10 to 22, the plant was cut off using a knife after harvesting the top ear. The eight plants in each treatment were packed together, labeled, and removed from the field to where facilities were available to measure second and third EL and CL. The measurements were done using a ruler while the ears were still on each plant. After measurement, the second and third ears were cut off the plant separately, put into bags, labeled, and put into a drier for 3 days at 60°C before weighing.

Hormone and Liquid Growth Chemical Experiments in 1979

During the growing season of 1979, two types of experiments were conducted: a) an experiment with hormones applied in lanolin paste; b) experiments with liquid growth chemicals, zinc acetate (ACA) and acetate (ACE).

Part A. Experiment with hormones applied in lanolin paste

'Pioneer 3780' was planted on May 20, 1979. The population rate was 50,000 plants/ha with row spacing of 1.01m. After emergence on May 26,
1979, a section of the field containing 156 seedlings in two rows was randomly selected and marked. The experimental design was a completely randomized block design with 13 treatments each containing six plants replicated two times.

The treatments used in this experiment were as follows:

1) Control
2) $10^{-4}$M NAA (Naphtaleneacetic acid)
3) $10^{-3}$M NAA
4) $10^{-2}$M NAA
5) $10^{-4}$M IAA (Indoleacetic acid)
6) $10^{-3}$M IAA
7) $10^{-2}$M IAA
8) $10^{-4}$M GA (Gibberellic acid)
9) $10^{-3}$M GA
10) $10^{-2}$M GA
11) $10^{-4}$M BA (Benzyladenine)
12) $10^{-3}$M BA
13) $10^{-2}$M BA

Preparation of hormones

Preparation of different concentrations for each hormone was done at the crop physiology laboratory located in the Agronomy Building at Iowa State University. Hormones IAA, NAA, GA, and BA had been bought previously and stored in the freezer. For each hormone, the highest concentration ($10^{-2}$M) was made considering the molecular weight of the hormone and the volume of the solution necessary to mix with lanolin paste for treating the number of plants in each treatment and the volume required for the dilution processes to make other concentrations ($10^{-3}$M and $10^{-4}$M) of that particular hormone.

An analytical scale, Torbal Model EA-1, was used to weigh the amount of hormone required. The weighed amount was then poured into an Erlenmeyer flask and diluted with the appropriate amount of heated lanolin.
One ml of lanolin paste containing hormone was rubbed on the surface of the top ear of each plant and also at the conjunction point of ear and stem at the stage of ear development when ears were beginning to emerge from the sheath.

The attributes measured in this experiment were as follows:
1. percent of filled kernels (PFK) and dry weight (DW) of the first ear (top ear);
2. ear length, CL, and DW of the second and third ears in each treatment.

At harvest on October 13, 1979, the top ears in each treatment were picked by hand and the six ears of each treatment were placed in a bag and labeled for further processes. Later, the percent of filled kernels was judged on each ear (visual judgment) and recorded. The indices for PFK determination were based on the percentage of the cob length that was covered by kernels. For example, index number 1 was used if the cob was completely (100%) covered by filled kernels, 0.9 was used if 90% of the cob was covered by filled kernels, etc. Dry weight of the top ears in each treatment was obtained after drying in a forced air dries for 3 days at 60°C.

To measure the EL, CL, and DW of the second and third ears in each treatment, the plant was cut off after harvesting the top ear. The six plants in each treatment were packed together, labeled, and carried out of the field, where the facilities were available to measure second and third ear shoot and cob length. The measurements were done while the ears were still on each plant. After measurement, the second and third ears were cut off separately, put into bags, labeled, and put into a forced
air drier for 3 days at 60°C. The dry weight of second and third ears in each treatment was then recorded.

**Part B. Experiments with liquid growth chemicals, zinc acetate (ACA), and acetate (ACE)**

These liquid growth chemicals were used in three fields collectively called Field A located at the Agronomy and Agricultural Engineering Experimental area and Field B and Field C located at the Bruner Farm.

**Field A**  
Field A was about 107 meters long and 11 meters wide (1177 m²). 'Pioneer 3780' was planted on May 28, 1979, at a population rate of 50,000 plants/ha, with row spacing of 1.01 m, and emerged on June 3, 1979.

Chemical treatments of zinc acetate ACA, a solution containing 33% zinc acetate in 5N NH₄OH, and acetate ACE, a solution containing 16% acetic acid in 5N NH₄OH were as follows:

1 = zero milliliter (ml) of ACA, control  
2 = 8 ml of ACA  
3 = 16 ml of ACA  
4 = 24 ml of ACA  
5 = 32 ml of ACA  

1 = zero milliliter (ml) of ACE, control  
2 = 8 ml of ACE  
3 = 16 ml of ACE  
4 = 24 ml of ACE  
5 = 32 ml of ACE
The experimental design was a randomized block design with five different rates of each of the liquid chemicals of ACA and ACE replicated ten times. The length of each replication for each treatment was 10.67 m.

The seedlings were treated at the 5th leaf stage on June 26, 1979, as follows. For control treatments in both ACA and ACE, 2.2 kg of ammonium nitrate (NH$_4$NO$_3$) was weighed and distributed by hand machine (band placement) along each control row at a distance of 5 cm from the seedlings. The depth of the band placement was approximately 3.8 cm. The rate of fertilizer application was 20.6 g per linear meter of row. Preparation of treatments 2, 3, 4, and 5 with ACA was done by weighing 2.2 kg of NH$_4$NO$_3$ for each treatment, spreading it on a plastic sheet and adding 8, 16, 24, and 32 ml of ACA for each treatment respectively. Each solution was thoroughly mixed with the NH$_4$NO$_3$ and applied (band placement) by a hand machine along the rows that had been assigned randomly to each treatment. Application was made at a distance of 5 cm from seedlings and at a depth of 3.8 cm. Preparation of treatments 2, 3, 4, and 5 with ACE was the same as those described for ACA.

The effect of the liquid growth chemicals on vegetative growth (height of the plant and leaf width) and grain yield was measured. On July 13, 1979, plant height measurements were taken using 10 plants randomly selected from each replication. The uppermost leaves on each plant were pulled upward and the height was measured from the ground level to the tip of the leaves and recorded. Leaf width measurements were done on September 5, 1979. Ten plants in each replication were randomly selected and the widest part of each ear node leaf was measured and recorded.
At harvest on October 19, 1979, five replications of each treatment were picked by hand. The length of the harvested area in each replication was 9.1 m. In each harvested replication, the number of plants and the number of harvested ears were counted and recorded. Total fresh weight of the ears in each replication was determined. Ten ears were then chosen randomly and weighed as a sample for determination of moisture content. The selected 10 ears then were put into a bag, marked, and put into a forced air drier for 3 days at a temperature of 60°C. The sample 10 ears were weighed again after drying and the difference in weight was considered to be the amount of water. The total grain yield (kg/ha) was calculated at 15.5% moisture.

Field B  Field B consisted of four main plots, each 53.5 m long and four rows wide. Either ACA or ACE was applied in alternate main plots. Four rates of each chemical with 5 replicates were used in each main plot. The total area of Field B was 856 m². 'Pioneer 3780' was planted on June 6, 1979, at a population rate of 50,000 plants/ha with row spacing of 1.01 m. Seedlings emerged on June 11, 1979.

The following volume of ACA or ACE was sprayed on 2.2 kg of fertilizer 18-9-5 (N,P₂O₅,K₂O) with 20.6 g of fertilizer applied per linear meter of row at the 5 leaf stage on July 2, 1979, as described for Field A.

1 = zero milliliter (ml) of ACA, control
2 = 8 ml ACA
3 = 16 ml ACA
4 = 24 ml ACA
The experimental design in each main plot was a randomized block design with four treatments (different rates of chemical) replicated five times. The length of each replication of treated area was 10.67 m. The statistical analysis which was used was ACA and ACE as main plots with ten replicates of 4 rates of chemicals.

Plant height was measured on July 13, 1979, and leaf width on September 6. The plots were harvested on October 31, 1979, using a procedure similar to that described for Field A.

Field C In this experiment, different concentrations of the two liquid growth chemicals, ACA and ACE, were applied on May 27, 1979 using two methods:

a) an application close to the corn rows in which the liquid chemicals were premixed with anhydrous ammonia and injected into the soil 10 cm from the row where the corn plants would grow. The depth of injection was 20 cm;

b) an application far from the corn row in which the liquid chemicals in anhydrous ammonia were applied far (40 cm) from the plant row.

In this experiment, anhydrous ammonia (NH₃) was applied at a rate of 168 kg/ha. The liquid chemicals were applied on May 25, 1979, five days before planting date, as described earlier. 'Pioneer 3780' was planted on May 30, 1979, at a population rate of 52,000 plants/ha. Emergence was on June 4, 1979.

1 = zero milliliter (ml) of ACE, control
2 = 8 ml ACE
3 = 16 ml ACE
4 = 24 ml ACE
Chemicals and methods of application were as follows.

<table>
<thead>
<tr>
<th>Liquid chemical</th>
<th>Rate of liquid chemical kg/ha</th>
<th>Method of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>zinc acetate (ACA)</td>
<td>0.0</td>
<td>close to the row</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>acetate (ACE)</td>
<td>0.0</td>
<td>far from the row</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td></td>
</tr>
</tbody>
</table>

The design of the experiment was a randomized block design with treatments replicated 3 times with each plot consisting of two rows wide with a row spacing of 1.01 m.
Plant height, leaf width, leaf length, plants per plot, ears per plant, average ear grain weight, grain yield per hectare, number of rows per ear, weight of 1000 kernels, and number of kernels per unit area ($m^2$) were the responses measured in this experiment.

Plant height was measured at two different stages: once on July 26, 1979, when the plants were making rapid vegetative growth, and again on August 28, 1979. Ten plants in each replication for each treatment were randomly selected and measured. At the first measurement, the uppermost leaves on each plant were pulled upward and the height was measured from the ground level to the tip of the longest leaf and recorded. For the second measurement of plant height, the height was obtained from ground level to the lowest branch of the tassel and recorded.

Leaf width measurement was done on August 28, 1979. Ten plants in each replication for each treatment were randomly selected, and the width of the ear node leaf at its widest part was measured and recorded. At the same time, leaf length of the ear node leaf was measured on the same ten plants which were randomly selected for measuring leaf width. Leaf length was measured from the base of the leaf blade to the tip of the leaf.

At harvest on October 13, 1979, before picking the ears, 18.3 m in each plot (9.15 m in each row) was marked and the number of plants counted in each plot and population per hectare calculated. Ears from plants in each plot were picked by hand, counted and weighed. Ears per plant were calculated by dividing the number of ears by the number of plants. Average ear grain weight was calculated by dividing the grain weight of
the ears, adjusted to 15.5% moisture, in each plot by the number of ears in that plot.

After determination of the total fresh weight of the grain of each treatment, ten ears were selected and weighed as a sample for determination of moisture content. The selected ears were dried at 60°C for 3 days. Grain yield at 15.5% moisture was calculated assuming grain weight was 7/9 of grain plus cob weight.

The bags containing ten ears were used to determine number of rows of kernels per ear. From each bag, five ears were randomly selected and the number of the rows of kernels on each ear was counted and recorded.

To determine the weight of 1000 kernels for each treatment, two kernel rows on each of the ten ears in the bags were shelled by placing the tip of the cob at the bottom of a bucket and using a medium size screw driver to push the two rows out from each cob. Two hundred kernels were counted from each sample and weighed. Weight per 1000 kernels was calculated at 15.5% moisture.

The number of kernels per unit area (m²) was determined by dividing the grain yield by kernel weight.

Statistical analysis of data was by Fisher's F-test with mean separation by Duncan's Multiple Range Test (Steel and Torrie, 1960).
RESULTS

Hormones Injected into the 14th Stem Internode - 1978

In this experiment, hormones (IAA and ABA) were injected into the 14th stem internode, each at four rates \( (10^{-2}, 10^{-3}, 10^{-4}, \text{ and } 10^{-5}M) \). One ml of each rate was injected into the treated plants. The attributes measured were percentage of filled kernels (PFK) and dry weight (DW).

There were no significant differences between the attributes measured due to the main effect of hormones, and the interaction between rate and hormone. The main effect of the hormones on PFK and DW is shown in Table 1.

Table 1. The main effects of the hormones IAA and ABA on PFK and DW of the first ear when hormones were injected into the 14th stem internode

<table>
<thead>
<tr>
<th>Compound</th>
<th>PFK (%)</th>
<th>DW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAA</td>
<td>0.85 a</td>
<td>164 a</td>
</tr>
<tr>
<td>ABA</td>
<td>0.85 a</td>
<td>162 a</td>
</tr>
</tbody>
</table>

\(^a\)Means in each column followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

As shown in Table 1, both IAA and ABA had the similar effects of PFK and DW and were not significantly different from each other.

The interaction between hormone and rate showed no special trend in treated plants for both hormones (IAA and ABA) considering PFK, whereas DW of the first ear of treated plants was lowest at highest concentration...
(10^{-2}M) of both IAA and ABA and increased with decreased concentrations up to 10^{-4}M for IAA and up to 10^{-5}M for ABA (Table 2). It was evident that the concentration ranges of 10^{-3}M to 10^{-4}M were the most effective treatments causing the greatest DW of the first ear in IAA treatment and generally the lower concentrations of ABA, especially 10^{-5}M; however, in none of the cases were these trends significant.

Table 2. The effect of the hormones IAA and ABA at different rates on PFK and DW of the first ear when the hormones were injected into the 14th stem internode.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>PFK (%)</th>
<th>DW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAA</td>
<td>10^{-2}</td>
<td>0.86 a</td>
<td>152 a</td>
</tr>
<tr>
<td></td>
<td>10^{-3}</td>
<td>0.84 a</td>
<td>174 a</td>
</tr>
<tr>
<td></td>
<td>10^{-4}</td>
<td>0.85 a</td>
<td>175 a</td>
</tr>
<tr>
<td></td>
<td>10^{-5}</td>
<td>0.85 a</td>
<td>157 a</td>
</tr>
<tr>
<td>ABA</td>
<td>10^{-2}</td>
<td>0.86 a</td>
<td>146 a</td>
</tr>
<tr>
<td></td>
<td>10^{-3}</td>
<td>0.85 a</td>
<td>165 a</td>
</tr>
<tr>
<td></td>
<td>10^{-4}</td>
<td>0.86 a</td>
<td>164 a</td>
</tr>
<tr>
<td></td>
<td>10^{-5}</td>
<td>0.85 a</td>
<td>174 a</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>0.79 a</td>
<td>149 a</td>
</tr>
</tbody>
</table>

^2Means within each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Compounds Injected into the 12th Stem Internode - 1978

In this experiment, the compounds BA, GA, and IAA were injected into the 12th stem internode, at a rate ranging from $10^{-5}$M to $10^{-2}$M. Each treated plant received 1 ml of the hormone solution. Dry weight and PFK of the first ear and DW, ear length (EL), and cob length (CL) of the second and third ears were the attributes measured.

The main effect of the compounds on DW and PFK of the first ear was similar to that of the previous experiment where hormones injected into the 14th stem internode indicated that there were no significant differences between attributes measured due to the main effect of compounds, and interaction between compound and rate.

The main effects of compounds BA, GA, and IAA were similar and not significantly different from each other (Table 3). However, the trend showed an increased PFK and DW in BA and GA treated plants over IAA treatments.

Table 3. The main effects of the compounds BA, GA, and IAA on PFK and DW of the first ear when compounds were injected into the 12th stem internode

<table>
<thead>
<tr>
<th>Compound</th>
<th>PFK (%)</th>
<th>DW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>0.89 a</td>
<td>169 a</td>
</tr>
<tr>
<td>GA</td>
<td>0.89 a</td>
<td>168 a</td>
</tr>
<tr>
<td>IAA</td>
<td>0.85 a</td>
<td>165 a</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*
There were no significant interactions among attributes due to the different rates of each compound (Table 4), but both PFK and DW followed a decreased trend with decreasing rates of compounds BA and GA.

Table 4. The effect of the compounds BA, GA, and IAA at different rates on PFK and DW of the first ear when compounds were injected into the 12th stem internode.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>PFK (%)</th>
<th>DW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>$10^{-2}$</td>
<td>0.91 a</td>
<td>171 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.90 a</td>
<td>170 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.89 a</td>
<td>167 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-5}$</td>
<td>0.86 a</td>
<td>167 a</td>
</tr>
<tr>
<td>GA</td>
<td>$10^{-2}$</td>
<td>0.90 a</td>
<td>169 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.89 a</td>
<td>170 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.88 a</td>
<td>168 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-5}$</td>
<td>0.87 a</td>
<td>167 a</td>
</tr>
<tr>
<td>IAA</td>
<td>$10^{-2}$</td>
<td>0.86 a</td>
<td>164 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.85 a</td>
<td>165 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.86 a</td>
<td>165 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-5}$</td>
<td>0.86 a</td>
<td>167 a</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>0.86 a</td>
<td>165 a</td>
</tr>
</tbody>
</table>

Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Benzyladenine was the most effective compound in increasing DW, EL, and CL of the second ear and was significantly different from the other compounds (Table 5). GA was the second most effective compound and was significantly greater than the IAA for DW. GA and IAA had similar effects on EL and CL (Table 5). The changes in DW, EL, and CL of the second ear due to the main effect of compounds is shown in Figures 1 and 2.

Table 5. The main effects of the compounds BA, GA, and IAA on DW, EL and CL of the second ear when compounds were injected into the 12th stem internode.

<table>
<thead>
<tr>
<th>Compound</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>24 a</td>
<td>27.9 a</td>
<td>14.6 a</td>
</tr>
<tr>
<td>GA</td>
<td>21 b</td>
<td>23.4 b</td>
<td>11.3 b</td>
</tr>
<tr>
<td>IAA</td>
<td>19 c</td>
<td>22.1 b</td>
<td>10.7 b</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*

The interaction between compounds and rates was significant for all attributes. The contribution of BA to increased DW, EL, and CL of the second ear was due to its higher rates. In contrast to that, IAA influenced those attributes mostly at its lower rates. The effect of GA on EL and CL of the second ear was greatest at its lowest rate and the effect on DW was somewhat inconsistent with the highest and lowest rate both contributing to increased DW (Table 6).
Figure 1. Effects of IAA, BA, and GA on DW of the second ear when compounds were injected into the 12th stem internode after averaging across rates of application.
Figure 2. Effect of IAA, BA, and GA on EL and CL of the second ear when compounds were injected into the 12th stem internode after averaging across rates of application
Ear length (EL) and cob length (CL)
of the second ear (cm)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Increase in (EL)</th>
<th>Increase in (CL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6. The effect of the compounds BA, GA, and IAA at different rates on DW, EL, and CL of the second ear when compounds were injected into the 12th stem internode.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>$10^{-2}$</td>
<td>26 a</td>
<td>30.3 a</td>
<td>15.2 ab</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>25 a</td>
<td>30.0 a</td>
<td>16.8 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>24 ab</td>
<td>24.9 bcd</td>
<td>13.1 bcd</td>
</tr>
<tr>
<td></td>
<td>$10^{-5}$</td>
<td>21 cd</td>
<td>26.2 abc</td>
<td>13.6 abc</td>
</tr>
<tr>
<td>GA</td>
<td>$10^{-2}$</td>
<td>24 ab</td>
<td>21.3 de</td>
<td>10.8 cde</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>19 de</td>
<td>22.1 cde</td>
<td>11.0 cde</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>20 de</td>
<td>21.3 de</td>
<td>7.2 f</td>
</tr>
<tr>
<td></td>
<td>$10^{-5}$</td>
<td>22 bc</td>
<td>28.9 ab</td>
<td>16.2 ab</td>
</tr>
<tr>
<td>IAA</td>
<td>$10^{-2}$</td>
<td>19 de</td>
<td>19.7 e</td>
<td>8.6 ef</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>18 e</td>
<td>19.3 e</td>
<td>8.9 ef</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>18 e</td>
<td>27.1 ab</td>
<td>14.3 abc</td>
</tr>
<tr>
<td></td>
<td>$10^{-5}$</td>
<td>20 cde</td>
<td>22.5 cde</td>
<td>11.3 cde</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>18 e</td>
<td>20.5 e</td>
<td>8.7 def</td>
</tr>
</tbody>
</table>

Superscript Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

The data in Table 6 are shown in Figures 3, 4, and 5 indicating the changes in DW, EL, and CL of the second ear due to the effect of different rates of each compound.

Benzyladenine had the same effects on DW, EL, and CL, of the third ear as it had on the second ear. The effect of BA was significantly
Figure 3. Effect of different rates of BA, GA, and IAA on the DW of the second ear when compounds were injected into the 12th stem internode.
Dry weight (DW) of the second ear (g)
Figure 4. Effect of different rates of BA, GA and IAA on the EL of the second ear when compounds were injected into the 12th stem internode
Ear length (EL) of the second ear (cm)
Figure 5. Effect of different rates of BA, GA and IAA on the CL of the second ear when compounds were injected into the 12th stem internode
different from other compounds. IAA was the second most active compound increasing the DW of the third ear. Gibberellins and IAA had the same effect on EL and CL of the third ear (Table 7). The changes in DW, EL and CL of the third ear due to the main effect of the compounds is shown in Figures 6 and 7.

Table 7. The main effects of the compounds BA, GA, and IAA on DW, EL, and CL of the third ear when compounds were injected into the 12th stem internode.

<table>
<thead>
<tr>
<th>Compound</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>0.68 a</td>
<td>18.8 a</td>
<td>4.0 a</td>
</tr>
<tr>
<td>GA</td>
<td>0.20 c</td>
<td>15.8 b</td>
<td>2.62 b</td>
</tr>
<tr>
<td>IAA</td>
<td>0.33 b</td>
<td>16.3 b</td>
<td>2.84 b</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*

The interaction between compound and its rates was significant for DW and EL of the third ear but not for the CL. The contribution of BA to increased DW and EL was due to a stimulation at its higher rates and, in contrast, IAA influenced those attributes at its lower concentrations. For GA, the lowest rate was the most effective rate in increasing the DW and CL of the third ear. The influence of rates of GA on EL of the third ear was inconsistent with the effect similar to those for the second ear (Table 8). The contribution of each compound at different rates on DW, EL and CL of the third ear is shown in Figures 8, 9, and 10, respectively.
Figure 6. Effect of IAA, BA, and GA on DW of the third ear when compounds were injected into the 12th stem internode after averaging across rates of application.
Increase in DW

Dry weight (DW) of the third ear (g)

<table>
<thead>
<tr>
<th>Compound</th>
<th>IAA</th>
<th>BA</th>
<th>GA</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase</td>
<td></td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increase in DW
Figure 7. Effect of IAA, BA and GA on EL and CL of the third ear when compounds were injected into the 12th stem internode after averaging across rates of application.
Ear length (EL) and cob length (CL) of the third ear (cm)

Compound

Control  CA  BA  IAA

Increase in (EL)
Increase in (CL)
Figure 8. Effect of different rates of BA, GA and IAA on the DW of the third ear when compounds were injected into the 12th stem internode
Dry weight (DW) of the third ear (g)
Figure 9. Effect of different rates of BA, GA and IAA on the EL of the third ear when compounds were injected into the 12th stem internode.
Ear length (EL) of the third ear (cm)
Figure 10. Effect of BA, GA and IAA on the CL of the third ear when compounds were injected into the 12th stem internode.
Cob length (CL) of the third ear (cm)

Rate (%) 10-2 10-3 10-4 10-5

Cob length (CL) of the third ear (cm)

IAA  
CA  
BA  

0.0 0.1 0.2 0.3 0.4 0.5 0.6
Table 8. The effect of the compounds BA, GA, and IAA at different rates on DW, EL, and CL of the third ear when compounds were injected into the 12th stem internode.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>10^{-2}</td>
<td>1.03 a</td>
<td>18.3 ab</td>
<td>4.04 a</td>
</tr>
<tr>
<td></td>
<td>10^{-3}</td>
<td>0.97 a</td>
<td>20.8 a</td>
<td>5.20 a</td>
</tr>
<tr>
<td></td>
<td>10^{-4}</td>
<td>0.39 c</td>
<td>17.3 ab</td>
<td>2.40 a</td>
</tr>
<tr>
<td></td>
<td>10^{-5}</td>
<td>0.33 c</td>
<td>18.3 ab</td>
<td>4.30 a</td>
</tr>
<tr>
<td>GA</td>
<td>10^{-2}</td>
<td>0.14 de</td>
<td>16.3 ab</td>
<td>1.87 a</td>
</tr>
<tr>
<td></td>
<td>10^{-3}</td>
<td>0.19 de</td>
<td>14.8 b</td>
<td>2.85 a</td>
</tr>
<tr>
<td></td>
<td>10^{-4}</td>
<td>0.13 e</td>
<td>13.4 b</td>
<td>2.26 a</td>
</tr>
<tr>
<td></td>
<td>10^{-5}</td>
<td>0.35 c</td>
<td>18.7 ab</td>
<td>3.51 a</td>
</tr>
<tr>
<td>IAA</td>
<td>10^{-2}</td>
<td>0.18 de</td>
<td>14.6 b</td>
<td>1.96 a</td>
</tr>
<tr>
<td></td>
<td>10^{-3}</td>
<td>0.17 de</td>
<td>15.1 b</td>
<td>2.31 a</td>
</tr>
<tr>
<td></td>
<td>10^{-4}</td>
<td>0.40 c</td>
<td>17.8 ab</td>
<td>4.16 a</td>
</tr>
<tr>
<td></td>
<td>10^{-5}</td>
<td>0.57 b</td>
<td>17.6 ab</td>
<td>2.92 a</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>0.21 d</td>
<td>15.5 ab</td>
<td>2.62 a</td>
</tr>
</tbody>
</table>

Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Experiments in 1979

Part A. Compounds mixed in lanolin paste

In this experiment, four compounds (BA, GA, IAA, and NAA) each at 3 different rates mixed in lanolin paste were used. The compounds were rubbed on the surface of the first ear and at the conjunction point of the ear and stem internode.

No significant differences were found between the PFK and DW of the first ear as the result of applying different compounds, and the interaction between compounds and the rates used.

The main effects of compounds on DW and PFK were similar and there were no significant differences between them (Table 9).

Table 9. The main effects of the compounds BA, GA, IAA and NAA on DW and PFK of the first ear when compounds were mixed in lanolin paste and rubbed on the first ear.

<table>
<thead>
<tr>
<th>Compound</th>
<th>PFK (%)</th>
<th>DW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>0.79 a</td>
<td>197 a</td>
</tr>
<tr>
<td>GA</td>
<td>0.80 a</td>
<td>200 a</td>
</tr>
<tr>
<td>IAA</td>
<td>0.80 a</td>
<td>197 a</td>
</tr>
<tr>
<td>NAA</td>
<td>0.79 a</td>
<td>199 a</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

The interaction between each compound and the rates used for that compound was not significantly different (Table 10).
The results obtained for the main effect of compounds on DW, EL, and CL of the second ear were similar to the results obtained in the 1978 experiment. Benzyladenine again was the most effective compound influencing the DW, EL and CL of the second ear. It was significantly different from other compounds in increasing DW and CL and had similar effect to GA on the second EL. GA was the second most active compound in increasing the DW and CL of the second ear. IAA and NAA exerted similar effects of DW, WL, and CL (Table 11). The changes in DW, EL, and CL of the second ear due to the main effect of compounds are shown in Figures 11 and 12.

The interaction between compounds and rates was significant for all attributes measured. The highest rate of BA \((10^{-2}\text{M})\) contributed significantly to the effect of this compound on DW of the second ear as did the highest rate of GA, whereas with IAA and NAA the lower rates had the greatest DW. For EL the effects of BA and GA were stimulatory but with little effect of rates of compound, whereas with IAA and NAA the low rates were definitely more stimulatory than the high rates. For CL, rates of BA had no effect, the highest rates of GA were stimulatory and in contrast, the low rates of IAA and NAA tended to be greater than the high rate. In other words, the lower rates of IAA and NAA had stimulatory effects on variables measured, whereas the higher concentrations had inhibitory effects and caused an overall decrease in value for the responses measured compared to BA and GA, but was greater than untreated plants (Table 12). The contribution of each compound at its different rates on DW, EL, and CL of the second ear is shown in Figures 13, 14, and 15, respectively.
Table 10. The effect of the compounds BA, GA, IAA, and NAA at different rates on PFK and DW of the first ear when compounds were mixed in lanolin paste and rubbed on the first ear.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>PFK (%)</th>
<th>DW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>$10^{-2}$</td>
<td>0.80 a</td>
<td>194 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.79 a</td>
<td>198 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.79 a</td>
<td>200 a</td>
</tr>
<tr>
<td>GA</td>
<td>$10^{-2}$</td>
<td>0.79 a</td>
<td>200 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.80 a</td>
<td>201 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.81 a</td>
<td>201 a</td>
</tr>
<tr>
<td>IAA</td>
<td>$10^{-2}$</td>
<td>0.84 a</td>
<td>195 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.77 a</td>
<td>198 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.78 a</td>
<td>199 a</td>
</tr>
<tr>
<td>NAA</td>
<td>$10^{-2}$</td>
<td>0.80 a</td>
<td>197 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>0.80 a</td>
<td>199 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>0.79 a</td>
<td>201 a</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>0.80 a</td>
<td>200 a</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*

Table 11. The effect of the compounds BA, GA, IAA, and NAA on DW, EL, and CL of the second ear when compounds were mixed in lanolin paste and rubbed on the first ear.

<table>
<thead>
<tr>
<th>Compound</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>37 a</td>
<td>26.7 a</td>
<td>17.0 a</td>
</tr>
<tr>
<td>GA</td>
<td>32 b</td>
<td>27.2 a</td>
<td>9.9 b</td>
</tr>
<tr>
<td>IAA</td>
<td>30 bc</td>
<td>18.3 b</td>
<td>7.9 c</td>
</tr>
<tr>
<td>NAA</td>
<td>29 c</td>
<td>17.4 b</td>
<td>7.3 c</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*
Figure 11. Effect of IAA, BA, GA and NAA on DW of the second ear when compounds were used in lanolin paste after averaging across rates of application.
Figure 12. Effect of IAA, BA, GA and NAA on EL and CL of the second ear when compounds were used in lanolin paste after averaging across rates of application
Increase in (EL)
Increase in (CL)

Ear length (EL) and cob length (CL) of the second ear (cm)

Compounds:
- IAA
- BA
- GA
- NAA
- Control
Figure 13. Effect of different rates of BA, GA, IAA and NAA on DW of the second ear when compounds were used in lanolin paste.
Dry weight (DW) of the second ear (g)
Figure 14. Effect of different rates of BA, GA, IAA and NAA on EL of the second ear when compounds were used in lanolin paste
Ear length (EL) of the second ear (cm)

[Graph showing trends for different categories labeled NAA, IAA, CA, and BA]
Figure 15. Effect of different rates of BA, GA, IAA, and NAA on CL of the second ear when compounds were used in lanolin paste.
Table 12. The effect of the compounds BA, GA, IAA, and NAA at different rates on DW, EL, and CL of the second ear when compounds were mixed in lanolin paste and rubbed on the first ear.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>$10^{-2}$</td>
<td>40 a</td>
<td>28.2 ab</td>
<td>17.8 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>34 bc</td>
<td>27.0 ab</td>
<td>17.0 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>34 bc</td>
<td>25.0 b</td>
<td>16.1 a</td>
</tr>
<tr>
<td>GA</td>
<td>$10^{-2}$</td>
<td>36 bc</td>
<td>30.0 a</td>
<td>12.0 b</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>35 bc</td>
<td>26.3 b</td>
<td>9.2 bc</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>26 bc</td>
<td>25.3 b</td>
<td>8.6 c</td>
</tr>
<tr>
<td>IAA</td>
<td>$10^{-2}$</td>
<td>22 f</td>
<td>14.9 d</td>
<td>6.6 cd</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>31 d</td>
<td>19.3 c</td>
<td>7.9 c</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>37 ab</td>
<td>20.7 c</td>
<td>9.1 bc</td>
</tr>
<tr>
<td>NAA</td>
<td>$10^{-2}$</td>
<td>22 f</td>
<td>15.0 d</td>
<td>6.6 cd</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>31 d</td>
<td>18.4 c</td>
<td>7.4 cd</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>33 cd</td>
<td>18.7 c</td>
<td>8.0 c</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>23 f</td>
<td>12.0 d</td>
<td>4.7 d</td>
</tr>
</tbody>
</table>

Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

The main effect of the compounds on DW, EL, and CL of the third ear followed the same pattern as they did for the second ear. Like the effect on second ear, BA was the most effective compound in influencing DW, EL, and CL of the third ear and significantly different from the other compounds. GA was the second most active compound in increasing values of the attributes measured. IAA and NAA exerted similar effects on DW, EL,
and CL of the third ear (Table 13). The main effect of each compound on DW, EL and CL of the third ear is shown in Figures 16 and 17.

Table 13. The main effects of the compounds BA, GA, IAA and NAA on DW, EL, and CL of the third ear when compounds were mixed in lanolin paste and rubbed on the first ear.

<table>
<thead>
<tr>
<th>Compound</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>1.60 a</td>
<td>22.1 a</td>
<td>10.6 a</td>
</tr>
<tr>
<td>GA</td>
<td>1.40 b</td>
<td>18.7 b</td>
<td>7.0 b</td>
</tr>
<tr>
<td>IAA</td>
<td>1.33 bc</td>
<td>14.3 c</td>
<td>5.3 c</td>
</tr>
<tr>
<td>NAA</td>
<td>1.30 c</td>
<td>12.9 c</td>
<td>5.1 c</td>
</tr>
</tbody>
</table>

Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

To find out which concentrations of each compound contributed more to the main effects of compounds on DW, EL and CL of the third ear, the different rates of each compound were plotted against DW (Figure 18), EL (Figure 19), and CL (Figure 20). The interaction between compound and rate was significant for all attributes. In BA and GA treated plants, the higher rates of these compounds were the ones which contributed most in increased DW, EL, and CL of the third ear. In contrast to BA and GA, for the IAA and NAA treatments the values for the attributes measured increased with decreased rates of the compounds. In other words, higher concentrations of BA and GA increased the responses and had stimulatory
Figure 16. Effect of IAA, GA, GA, and NAA on DW of the third ear when compounds were used in lanolin paste after averaging across rates of application.
1.8

Increase in DW

Dry weight (DW)
of the third ear (g)

0.0

1.2

1.6

I A A

B A

G A

N A A

C ontrol

Compound
Figure 17. Effect of IAA, BA, GA and NAA on EL and CL of the third ear when compounds were used in lanolin paste after averaging across rates of application
Increase in EL
Increase in CL

Ear length (EL) and cob length (CL) of the third ear (cm)

Compound:
- IAA
- BA
- GA
- NAA
- Control
Figure 18. Effect of different rates of BA, GA, IAA, and NAA on DW of the third ear when compounds were used in lanolin paste
Dry weight (DW) of the third ear (g)

Rate (M)

10^{-4} 10^{-3} 10^{-2}
Figure 19. Effect of different rates of BA, GA, IAA and NAA on EL of the third ear when compounds were used in lanolin paste
Ear length (EL) of the third ear (cm)
Figure 20. Effect of different rates of BA, GA, IAA and NAA on CL of the third ear when compounds were used in lanolin paste
effects, whereas for IAA and NAA it was the lower concentration that caused more growth and more dry weight of the third ear (Table 14).

Table 14. The effect of the compounds BA, GA, IAA, and NAA at different rates on DW, EL, and CL of the third ear when compounds were mixed in lanolin paste and rubbed on the first ear.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Rate (M)</th>
<th>DW (g)</th>
<th>EL (cm)</th>
<th>CL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>$10^{-2}$</td>
<td>1.80 a</td>
<td>25.6 a</td>
<td>11.0 a</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>1.72 ab</td>
<td>20.6 ab</td>
<td>10.5 ab</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>1.20 de</td>
<td>20.2 ab</td>
<td>10.1 abc</td>
</tr>
<tr>
<td>GA</td>
<td>$10^{-2}$</td>
<td>1.59 abc</td>
<td>20.0 abc</td>
<td>8.1 cd</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>1.45 bcde</td>
<td>18.4 bcd</td>
<td>7.0 de</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>1.30 cde</td>
<td>17.8 bcde</td>
<td>6.0 def</td>
</tr>
<tr>
<td>IAA</td>
<td>$10^{-2}$</td>
<td>1.1 ef</td>
<td>13.0 cdef</td>
<td>4.1 efg</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>1.3 cde</td>
<td>14.4 bcdef</td>
<td>5.5 defg</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>1.5 bcd</td>
<td>15.9 bcdef</td>
<td>6.3 def</td>
</tr>
<tr>
<td>NAA</td>
<td>$10^{-2}$</td>
<td>0.87 fg</td>
<td>11.0 ef</td>
<td>3.5 fg</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>1.40 bcde</td>
<td>12.4 def</td>
<td>4.1 efg</td>
</tr>
<tr>
<td></td>
<td>$10^{-4}$</td>
<td>1.61 abc</td>
<td>15.4 bcde</td>
<td>7.6 cd</td>
</tr>
<tr>
<td>Control</td>
<td>0.0</td>
<td>0.73 g</td>
<td>10.7 f</td>
<td>2.6 g</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*
Part B. Chemical growth regulator experiments

Liquid chemicals ACA and ACE were mixed with fertilizer and applied as band placement along corn seedling rows when seedlings were at the 5th leaf stage. These fields are collectively called Field A and Field B. In another experiment called Field C, the liquid chemicals were mixed with anhydrous ammonia and injected into the soil along the rows before planting time.

In Field A, five rates of each liquid chemical were used (0.0, 8, 16, 24, and 32 ml). The main effect of each compound, the main effect of the rates of compounds and the effect of each compound at its different rates were studied on vegetative growth of the plants (leaf width, and plant height), and on the components that contributed to the final yield (population, the number of ears per plant, weight per ear, and grain yield).

The main effect of liquid chemicals ACA and ACE on leaf width (LW), height of the plant (HT), population (POP), ears per plant (EP), weight per ear (WE) and grain yield (Y) is shown in Table 15. ACA increased LW and WE significantly compared to ACE. The effect on other attributes such as HT, POP, EP, and Y was similar for the two chemicals. The greater WE with ACA was not to the extent to cause significant differences in Y. However, the trend showed an increased Y with ACA over ACE (Figure 21).

Leaf width was lowest at zero rate and increased with increasing rate of chemicals up to 24 ml followed by a decline at the highest rate (32 ml), with 24 ml being significantly different from other rates (Table 16). The HT of the plant was the same for 0.0, 8, 16, and 24 ml and significantly different from the highest rate which showed the lowest HT. There were
Figure 21. Effect of chemicals ACA and ACE on LW, WE, and grain yield in Field A
no differences between POP, EP, WE and Y due to the different rates of chemicals

Table 15. The effect of the chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y of 'Pioneer 3780' corn cultivar in Field A

<table>
<thead>
<tr>
<th>Chemical</th>
<th>LW (cm)</th>
<th>HT (cm)</th>
<th>POP</th>
<th>EP</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>11.04 a</td>
<td>136.6</td>
<td>40,578 a</td>
<td>1.03 a</td>
<td>183.6 a</td>
<td>7439 a</td>
</tr>
<tr>
<td>ACE</td>
<td>10.91 b</td>
<td>136.2 a</td>
<td>39,501 a</td>
<td>1.00 a</td>
<td>175.9 b</td>
<td>7167 a</td>
</tr>
</tbody>
</table>

^Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

Table 16. The effect of different rates of chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y of 'Pioneer 3780' corn cultivar in Field A

<table>
<thead>
<tr>
<th>Rate (ml)</th>
<th>LW (cm)</th>
<th>HT (cm)</th>
<th>POP</th>
<th>EP</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.6 c</td>
<td>138.2 a</td>
<td>40,492 a</td>
<td>1.01 a</td>
<td>178.0 a</td>
<td>7317 a</td>
</tr>
<tr>
<td>8</td>
<td>11.0 b</td>
<td>137.8 a</td>
<td>39,953 a</td>
<td>1.02 a</td>
<td>178.9 a</td>
<td>7317 a</td>
</tr>
<tr>
<td>16</td>
<td>11.1 b</td>
<td>137.2 a</td>
<td>40,592 a</td>
<td>0.99 a</td>
<td>180.5 a</td>
<td>7290 a</td>
</tr>
<tr>
<td>24</td>
<td>11.3 a</td>
<td>136.1 a</td>
<td>39,846 a</td>
<td>1.03 a</td>
<td>178.1 a</td>
<td>7284 a</td>
</tr>
<tr>
<td>32</td>
<td>10.7 c</td>
<td>132.6 b</td>
<td>39,415 a</td>
<td>1.01 a</td>
<td>183.5 a</td>
<td>7307 a</td>
</tr>
</tbody>
</table>

^Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

In studying the main effects of chemical, or the main effects of rates on attributes measured, it is not possible to explain which rate(s) of chemical or which chemical at a specific rate contributes more to the
value obtained for a response. In these cases, studying the interaction between each chemical and its rates is helpful. The interaction between chemical and rate was significant for LW, HT, and WE. In Table 15, it was shown that ACA increased LW and WE significantly more than did ACE. Analyzing ACA at its different rates showed that the 24 ml rate was the most effective rate in increasing LW followed by 16 ml. All concentrations of ACA, especially the highest rate (32 ml), contributed more to increased WE than did ACE. Like ACA, the 24 ml rate of ACE was the most effective contributor in increasing LW followed by 16 and 8 ml. Weight per ear was lowest with 8 ml ACE and there were no differences between the other rates. Height of the corn plants was lowest with the highest rates in both ACA and ACE. No differences were found due to different rates of each chemical for the other attributes such as POP, EP, and Y (Table 17).

Plotting the LW values against different rates of each chemical showed that the smaller LW was associated with the zero rate and followed a trend toward increased LW with increasing the rates up to 24 ml (Figure 22).

In Field B, four rates of each liquid chemical were used (0.0, 8.0, 16, and 24 ml). The main effect of each chemical, the main effect of the rates of chemicals and the effect of each chemical at its different rates were examined on vegetative growth of the plants (LW, and HT), and on the components of yield (POP, EP, WE, and Y).

The results obtained due to the main effect of liquid chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y were generally similar to that of Field A (Table 18). Again, ACA significantly increased WE compared to ACE and this increase was to the extent that it caused a significant
Table 17. The effect of different rates of chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y of '3780 Pioneer' corn cultivar in Field A²

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Rate (ml)</th>
<th>LW (cm)</th>
<th>HT (cm)</th>
<th>POP</th>
<th>EP</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>0.0</td>
<td>10.64 d</td>
<td>138.1 a</td>
<td>41,569 a</td>
<td>1.00 a</td>
<td>180.0 a</td>
<td>7503 a</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
<td>11.09 bc</td>
<td>136.8 ab</td>
<td>40,707 a</td>
<td>0.98 a</td>
<td>184.5 a</td>
<td>7330 a</td>
</tr>
<tr>
<td></td>
<td>16.0</td>
<td>11.25 b</td>
<td>139.3 a</td>
<td>41,353 a</td>
<td>0.98 a</td>
<td>184.6 a</td>
<td>7510 a</td>
</tr>
<tr>
<td></td>
<td>24.0</td>
<td>11.48 a</td>
<td>135.7 abc</td>
<td>40,276 a</td>
<td>1.03 a</td>
<td>181.0 a</td>
<td>7483 a</td>
</tr>
<tr>
<td></td>
<td>32.0</td>
<td>10.73 d</td>
<td>133.0 bc</td>
<td>38,984 a</td>
<td>1.00 a</td>
<td>188.1 a</td>
<td>7370 a</td>
</tr>
<tr>
<td>ACE</td>
<td>0.0</td>
<td>10.57 d</td>
<td>138.3 a</td>
<td>39,415 a</td>
<td>1.02 a</td>
<td>176.0 a</td>
<td>7131 a</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
<td>10.96 c</td>
<td>137.6 a</td>
<td>39,199 a</td>
<td>1.07 a</td>
<td>173.3 b</td>
<td>7304 a</td>
</tr>
<tr>
<td></td>
<td>16.0</td>
<td>11.09 bc</td>
<td>136.4 abc</td>
<td>39,630 a</td>
<td>1.01 a</td>
<td>176.5 a</td>
<td>7071 a</td>
</tr>
<tr>
<td></td>
<td>24.0</td>
<td>11.25 b</td>
<td>136.4 abc</td>
<td>39,415 a</td>
<td>1.04 a</td>
<td>175.2 a</td>
<td>7084 a</td>
</tr>
<tr>
<td></td>
<td>32.0</td>
<td>10.68 d</td>
<td>312.2 c</td>
<td>39,846 a</td>
<td>1.01 a</td>
<td>178.8 a</td>
<td>7244 a</td>
</tr>
</tbody>
</table>

²Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Figure 22. Effect of different rates of chemicals ACA and ACE on LW in Field A
increase in Y (Figure 23). There were no significant effects of the chemicals on POP and EP as were the results in Field A. Unlike the results in Field A, there was a significant increase in HT due to ACA, but no difference in LW (Table 18).

Table 18. The effect of the chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y of 'Pioneer 3780' corn cultivar in Field B

<table>
<thead>
<tr>
<th>Chemical</th>
<th>LW (cm)</th>
<th>HT (cm)</th>
<th>POP</th>
<th>EP</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>10.42 a</td>
<td>119.1 a</td>
<td>47,734 a</td>
<td>0.96 a</td>
<td>157.8 a</td>
<td>7262 a</td>
</tr>
<tr>
<td>ACE</td>
<td>10.43 a</td>
<td>117.2 b</td>
<td>47,761 a</td>
<td>0.97 a</td>
<td>151.5 b</td>
<td>6979 b</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*

Comparing attributes POP and EP in Table 18 with the same attributes in Table 15 indicates a slight increase in percentage of barren plants due to the higher POP in Field B.

The results due to the main effect of rates of chemicals in this experiment were similar to those obtained in Field A (Table 19). Leaf width of the treated plants was greater than LW of the control plants. There were no significant effects of rates on POP, EP, WE, and Y. Plants treated with 16 and 24 ml were significantly taller than those treated with 0.0 and 8 ml (Table 19).

Considering the effect of each chemical at its different rates on the attributes measured makes it possible to find out which concentration of a specific compound contributes more to the value obtained for that
Figure 23. Effect of chemicals ACA and ACE on WE and grain yield in Field B
Table 19. The effect of different rates of chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y of 'Pioneer 3780' corn cultivar in Field B.

<table>
<thead>
<tr>
<th>Rate (ml)</th>
<th>LW (cm)</th>
<th>HT (cm)</th>
<th>POP</th>
<th>EP</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9.99 b</td>
<td>116.7 b</td>
<td>47,222 a</td>
<td>0.96 a</td>
<td>156.9 a</td>
<td>7070 a</td>
</tr>
<tr>
<td>8</td>
<td>10.64 a</td>
<td>116.2 b</td>
<td>47,384 a</td>
<td>0.97 a</td>
<td>155.3 a</td>
<td>7103 a</td>
</tr>
<tr>
<td>16</td>
<td>10.53 a</td>
<td>12.07 a</td>
<td>48,461 a</td>
<td>0.95 a</td>
<td>153.2 a</td>
<td>7038 a</td>
</tr>
<tr>
<td>24</td>
<td>10.54 a</td>
<td>119.0 a</td>
<td>47,922 a</td>
<td>1.00 a</td>
<td>153.2 a</td>
<td>7271 a</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*

attribute (Table 20). The interaction between compound and rate was significant for LW, HT, WE and Y. The 8, 16, and 24 ml rates of both ACA and ACE significantly increased LW as compared to the zero ml rate. Height of the plants was increased by the higher rates of ACA, whereas, for ACE, the rate did not affect HT. There was no influence of rate on POP and EP.

In Table 18, it was shown that ACA increased Y more than did ACE, and now in Table 20, it is shown that the highest rate of ACA (24 ml) is the most effective rate contributing to the increased Y of ACA treated plants and generally that WE and Y were higher for different rates of ACA as compared to the same rate of ACE treated plants.

In Field C, different concentrations of the two liquid growth chemicals (0.0, 0.15, 0.30, 0.60, and 1.20 kg/ha), ACA and ACE, were applied using two methods: a) an application close to corn rows (10 cm) in which the chemicals were premixed with anhydrous ammonia and injected into the
Table 20. The effect of different rates of chemicals ACA and ACE on LW, HT, POP, EP, WE, and Y of 'Pioneer 3780' corn cultivar in Field B.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Rate (ml)</th>
<th>LW (cm)</th>
<th>HT (cm)</th>
<th>POP</th>
<th>EP</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>0</td>
<td>9.93 b</td>
<td>116.6 b</td>
<td>47,815 a</td>
<td>0.95 a</td>
<td>157.8 a</td>
<td>7136 ab</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>10.65 a</td>
<td>115.8 b</td>
<td>47,707 a</td>
<td>0.96 a</td>
<td>159.0 a</td>
<td>7256 ab</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>10.53 a</td>
<td>121.9 a</td>
<td>47,599 a</td>
<td>0.96 a</td>
<td>156.4 a</td>
<td>7161 ab</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>10.59 a</td>
<td>122.1 a</td>
<td>47,815 a</td>
<td>0.99 a</td>
<td>158.2 a</td>
<td>7497 a</td>
</tr>
<tr>
<td>ACE</td>
<td>0</td>
<td>10.0 b</td>
<td>116.7 b</td>
<td>46,630 a</td>
<td>0.96 a</td>
<td>156.1 a</td>
<td>7005 b</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>10.63 a</td>
<td>116.7 b</td>
<td>47,061 a</td>
<td>0.98 a</td>
<td>151.7 b</td>
<td>6950 b</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>10.54 a</td>
<td>119.4 ab</td>
<td>49,323 a</td>
<td>0.94 a</td>
<td>150.1 b</td>
<td>6916 b</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>10.49 a</td>
<td>116.0 b</td>
<td>48,030 a</td>
<td>1.00 a</td>
<td>148.2 b</td>
<td>7045 b</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*
soil before time of planting; b) an application far from the corn row (40 cm) in which the chemicals were premixed with anhydrous ammonia and injected into the soil before time of planting.

In this experiment, the main effect of chemicals, the main effect of rates of chemicals, the main effect of the methods of application, and the interaction between chemical and rate, chemical and method, methods of application, and the interaction between chemical and rate, chemical and method, rate and method, and chemical and rate and method were examined on vegetative growth of the plants [(HT, LW, and leaf length (LL)], and on components of yield [POP, EP, number of kernels per unit area (K/m²)], weight of 1000 kernels (KW/1000), number of rows per ear (RE), WE, and Y.

The main effect of chemicals ACA and ACE on height of plant (HT₁, HT₂), LW, and LL is shown in Table 21. There were no differences due to form of chemicals on height of plants at first measurement. Leaf width was also similar for both chemicals. The second measurement of height of the plants which was done two months later, showed greater height and longer leaves for ACE treated plants than for ACA treated plants.

Table 21. The effect of the chemicals ACA and ACE on HT₁, HT₂, LW, and LL of 'Pioneer 3780' corn cultivar in Field C

<table>
<thead>
<tr>
<th>Chemical</th>
<th>HT₁ (cm)</th>
<th>HT₂ (cm)</th>
<th>LW (cm)</th>
<th>LL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>97.7 a</td>
<td>250.8 b</td>
<td>10.24 a</td>
<td>98.0 b</td>
</tr>
<tr>
<td>ACE</td>
<td>96.5 a</td>
<td>254.5 a</td>
<td>10.23 a</td>
<td>99.0 a</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*
Table 22 shows the results due to the main effect of chemicals on yield components such as POP, EP, K/m², KW/1000, RE, WE, and Y. Both chemicals had similar effects on yield components and there were no significant differences between them. In this respect, the results from Field C share some common points with the results obtained for yield components in Fields A and B such as POP and EP. Unlike the results in Field A and B, in this experiment there were no differences in WE due to chemicals whereas in both Fields A and B, WE was significantly greater in ACA treated plants (Tables 15 and 18).

Table 22. The effect of the chemicals ACA, and ACE on POP, EP, K/m², KW, RE, WE, and Y of 'Pioneer 3780' corn cultivar in Field C

<table>
<thead>
<tr>
<th>Chemical</th>
<th>POP (q)</th>
<th>EP (kq/ha)</th>
<th>K/m²</th>
<th>KW/1000</th>
<th>RE (g)</th>
<th>WE (kg/ha)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>52,909 a</td>
<td>1.01 a</td>
<td>2753 a</td>
<td>355.5 a</td>
<td>15.2 a</td>
<td>184.3 a</td>
<td>9762 a</td>
</tr>
<tr>
<td>ACE</td>
<td>51,675 a</td>
<td>1.03 a</td>
<td>2726 a</td>
<td>358.3 a</td>
<td>14.9 a</td>
<td>183.0 a</td>
<td>9740 a</td>
</tr>
</tbody>
</table>

*Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.*

Comparison of the main effect of different methods of application (close and far) on parameters measured for vegetative growth of plants (HT₁, HT₂, LW and LL) is shown in Table 23. At the first measurement there was no significant effect of method of application on plant height, but there was a trend for greater plant height with the close application. At the later stages of growth, significant differences were found between
Table 23. The effect of the methods of application on HT₁, HT₂, LW and LL of the plants in Field C²

<table>
<thead>
<tr>
<th>Application</th>
<th>HT₁ (cm)</th>
<th>HT₂ (cm)</th>
<th>LW (cm)</th>
<th>LL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>97.5 a</td>
<td>254.4 a</td>
<td>10.3 a</td>
<td>99.1 a</td>
</tr>
<tr>
<td>Far</td>
<td>96.7 a</td>
<td>250.9 b</td>
<td>10.1 b</td>
<td>98.0 b</td>
</tr>
</tbody>
</table>

²Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

the two methods of application with the close application being significantly greater in HT₂, LW and LL compared with the far application.

The main effect of the methods of application did not show any differences on POP, EP, K/m², KW/1000 and RE, but WE and Y were significantly increased due to close application of the chemicals. It seems that there is a direct relationship between the effect of close application on increased vegetative parameters and increased WE and yield (Table 24).

Table 24. The effects of the methods of application on components of yield POP, EP, K/m², KW/1000, RE, WE, and Y, in Field C²

<table>
<thead>
<tr>
<th>Application</th>
<th>POP (g)</th>
<th>EP (g)</th>
<th>K/m²</th>
<th>KW/1000 (g)</th>
<th>RE (g)</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>51,786 a</td>
<td>1.03 a</td>
<td>2735 a</td>
<td>356.8 a</td>
<td>15.1 a</td>
<td>185.2 a</td>
<td>9909 a</td>
</tr>
<tr>
<td>Far</td>
<td>51,798 a</td>
<td>1.00 a</td>
<td>2693 a</td>
<td>356.9 a</td>
<td>15.0 a</td>
<td>182.2 b</td>
<td>9593 b</td>
</tr>
</tbody>
</table>

²Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Effects of different rates of liquid growth chemicals on vegetative parameters and yield components are shown in Tables 25 and 26, respectively. Height of the plants at first measurement was most affected by 0.30 and 0.60 kg/ha of the chemicals. The same rates plus the 0.15 rate increased the height of plants again at second measurement and also LW of the plants. Leaf length of the plants was similar at different rates of the chemicals. The changes in HT and LW due to the different rates of chemicals are shown in Figure 24.

### Table 25. The effect of different rates of chemicals ACA and ACE on HT\textsubscript{1}, HT\textsubscript{2}, LW, and LL of the plants in Field C\textsuperscript{2}

<table>
<thead>
<tr>
<th>Rate (kg/ha)</th>
<th>HT\textsubscript{1} (cm)</th>
<th>HT\textsubscript{2} (cm)</th>
<th>LW (cm)</th>
<th>LL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>93.1 b</td>
<td>251.2 bc</td>
<td>9.8 b</td>
<td>98.8 a</td>
</tr>
<tr>
<td>0.15</td>
<td>95.0 b</td>
<td>256.4 a</td>
<td>10.4 a</td>
<td>98.6 a</td>
</tr>
<tr>
<td>0.30</td>
<td>101.7 a</td>
<td>253.8 ab</td>
<td>10.5 a</td>
<td>98.4 a</td>
</tr>
<tr>
<td>0.60</td>
<td>101.8 a</td>
<td>253.1 ab</td>
<td>10.5 a</td>
<td>98.4 a</td>
</tr>
<tr>
<td>1.20</td>
<td>94.0 b</td>
<td>248.8 c</td>
<td>9.9 b</td>
<td>98.4 a</td>
</tr>
</tbody>
</table>

\textsuperscript{2}Means in each column followed by the same letter are not significantly different at the 5\% level, Duncan's Multiple Range Test.

There were no differences due to the effect of different rates of the chemicals on POP, EP, K/m\textsuperscript{2}, and RE. Considering the other yield components, rates 0.30 and 0.60 kg/ha were the most effective in increasing KW/1000, WE, and grain yield. KE/1000 increased with increasing rate of chemicals up to 0.60 and was lowest at 1.20 kg/ha. Weight per ear was
Figure 24. Effect of the different rates of chemicals ACA and ACE on HT\textsubscript{1}, and LW in Field C
highest at 0.60 kg/ha followed by 0.30 kg/ha and again WE also was lowest at the highest rate of the chemicals (1.2 kg/ha). Grain yield increased with increasing rates of chemicals up to 0.60 kg/ha of chemical and reached the lowest point at the highest rate of the chemicals. The changes in these attributes due to the effect of different rates of chemicals followed the same trend, being lowest at the highest rate of chemicals. The contribution of each rate of chemicals to the changes in KW/1000, WE and Y is shown in Figure 25.

Table 26. The effect of different rates of chemicals ACA and ACE on components of yield (POP, EP, K/m², RE, KW/1000, WE, and Y) of the plants in Field C²

<table>
<thead>
<tr>
<th>Rate (kg/ha)</th>
<th>POP</th>
<th>EP</th>
<th>K/m²</th>
<th>RE</th>
<th>KW/1000 (g)</th>
<th>WE (g)</th>
<th>Y (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>51,011 a</td>
<td>1.02 a</td>
<td>2781 a</td>
<td>14.8 a</td>
<td>341.0 b</td>
<td>181.6 bc</td>
<td>9,462 b</td>
</tr>
<tr>
<td>0.15</td>
<td>54,283 a</td>
<td>1.00 a</td>
<td>2768 a</td>
<td>14.9 a</td>
<td>352.0 b</td>
<td>178.3 bc</td>
<td>9,734 ab</td>
</tr>
<tr>
<td>0.30</td>
<td>52,311 a</td>
<td>1.03 a</td>
<td>2731 a</td>
<td>15.3 a</td>
<td>371.9 a</td>
<td>187.8 ab</td>
<td>10,126 a</td>
</tr>
<tr>
<td>0.60</td>
<td>51,773 a</td>
<td>1.01 a</td>
<td>2690 a</td>
<td>15.2 a</td>
<td>379.3 a</td>
<td>194.5 a</td>
<td>10,165 a</td>
</tr>
<tr>
<td>1.20</td>
<td>52,081 a</td>
<td>1.02 a</td>
<td>2726 a</td>
<td>15.1 a</td>
<td>346.2 b</td>
<td>176.1 c</td>
<td>9,268 b</td>
</tr>
</tbody>
</table>

²Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.

The interaction between chemical and rate (Chem x R), chemical and method of application (Chem x App), rate and method of application (R x App), and chemical and rate and application (Chem x R x App) for all responses measured is shown in Table 27. In Table 27, negative sign (-) indicates that there was no interaction and a positive sign (+) indicates the existence of significant interaction for the responses measured.
Figure 25. Effect of different rates of chemicals ACA and AC on KW/1000, WE, and grain yield in Field C
Table 27. The interaction between Chem x R, Chem x App, R x App, and Chem x R x App for HT$_1$, HT$_2$, LW, LL, POP, EP, WE, KW/1000, K/m$^2$m RE, and Y in Field C$^2$. $^Z$

<table>
<thead>
<tr>
<th>Responses</th>
<th>Chem x R</th>
<th>Chem x App</th>
<th>R x App</th>
<th>Chem x R x App</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT$_1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HT$_2$</td>
<td>-</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>LW</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POP</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WE</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KW/1000</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K/m$^2$</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE</td>
<td>-</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Y</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^Z$ = significant interaction; - = no interaction.

Significant interactions between Chem x App and Chem x R x App for HT$_2$, between R x App for LW, and between Chem x App and Chem x R x App for RE are shown in Tables 28, 29, and 30 respectively.
Table 28. The interaction between Chem x App, and Chem x R x App for HT<sub>2</sub>
in Field C<sup>z</sup>

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Rate</th>
<th>Application</th>
<th>HT&lt;sub&gt;2&lt;/sub&gt; (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>254.1 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>247.5 b</td>
</tr>
<tr>
<td>ACA</td>
<td>0.0</td>
<td>C</td>
<td>249.4 b</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>F</td>
<td>249.5 b</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>C</td>
<td>255.7 a</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>F</td>
<td>256.7 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>C</td>
<td>257.7 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>F</td>
<td>247.2 b</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>C</td>
<td>258.1 a</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>F</td>
<td>242.4 C</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>C</td>
<td>249.6 b</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>F</td>
<td>241.9 c</td>
</tr>
<tr>
<td>ACE</td>
<td>0.0</td>
<td>C</td>
<td>255.2 ab</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>F</td>
<td>250.7 b</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>C</td>
<td>257.4 a</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>F</td>
<td>256.1 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>C</td>
<td>256.5 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>F</td>
<td>253.8 b</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>C</td>
<td>254.7 ab</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>F</td>
<td>257.3 a</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>C</td>
<td>250.1 b</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>F</td>
<td>253.7 b</td>
</tr>
</tbody>
</table>

<sup>z</sup>Means in each column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Table 29. The interaction between R x App for LW in Field C

<table>
<thead>
<tr>
<th>Rate (kg/ha)</th>
<th>Application</th>
<th>LW (cm)</th>
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</thead>
<tbody>
<tr>
<td>0.0</td>
<td>C</td>
<td>9.80 b</td>
</tr>
<tr>
<td>0.0</td>
<td>F</td>
<td>9.87 b</td>
</tr>
<tr>
<td>0.15</td>
<td>C</td>
<td>10.49 a</td>
</tr>
<tr>
<td>0.15</td>
<td>F</td>
<td>10.33 a</td>
</tr>
<tr>
<td>0.30</td>
<td>C</td>
<td>10.49 a</td>
</tr>
<tr>
<td>0.30</td>
<td>F</td>
<td>10.43 a</td>
</tr>
<tr>
<td>0.60</td>
<td>C</td>
<td>10.76 a</td>
</tr>
<tr>
<td>0.60</td>
<td>F</td>
<td>10.24 a</td>
</tr>
<tr>
<td>1.20</td>
<td>C</td>
<td>10.01 ab</td>
</tr>
<tr>
<td>1.20</td>
<td>F</td>
<td>9.83 b</td>
</tr>
</tbody>
</table>

Means in the column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
Table 30. The interaction between Chem x App and Chem x R x App for RE in Field C^2

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Rate</th>
<th>Application</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>C</td>
<td>15.0 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>15.3 a</td>
<td></td>
</tr>
<tr>
<td>ACE</td>
<td>C</td>
<td>15.2 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>14.7 b</td>
<td></td>
</tr>
<tr>
<td>ACA</td>
<td>0.0</td>
<td>C</td>
<td>14.5 b</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>F</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>C</td>
<td>14.8 b</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>F</td>
<td>15.6 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>C</td>
<td>15.7 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>F</td>
<td>15.3 a</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>C</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>F</td>
<td>15.4 a</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>C</td>
<td>14.8 b</td>
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<tr>
<td></td>
<td>1.20</td>
<td>F</td>
<td>15.3 a</td>
</tr>
<tr>
<td>ACE</td>
<td>0.0</td>
<td>C</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>F</td>
<td>14.2 b</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>C</td>
<td>15.4 a</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>F</td>
<td>13.7 c</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>C</td>
<td>15.0 a</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>F</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>C</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>F</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>C</td>
<td>15.2 a</td>
</tr>
<tr>
<td></td>
<td>1.20</td>
<td>F</td>
<td>15.3 a</td>
</tr>
</tbody>
</table>

^Means in the column followed by the same letter are not significantly different at the 5% level, Duncan's Multiple Range Test.
DISCUSSION

Effect of Hormones on First Ear Growth and Development

The effect of different hormones on the growth and development of the first ear is shown in Tables 1, 3 and 9 when hormones were either injected into the 14th stem internode, 12th stem internode, or mixed in lanolin paste and applied onto the surface of the first ear and the conjugation point of the ear shank and stem, respectively. Results on the effect of hormones on PFK and DW of the first ear showed no significant differences between treated plants and control regardless of the method of application and placement of the hormones. Application of IAA and ABA into the 14th stem internode (Table 2) brought about neither adverse effects nor stimulatory effects on the development of the first ear, nor did BA, GA and IAA (Table 4), nor the same hormones plus NAA (Table 10).

Considering the pattern of earshoot development of corn along with the phenomenon of apical dominance is helpful in discussing the results presented in Tables 1, 2, 3, 4, 9, and 10. Generally, each of the eight or so nodes below about the 5th or 6th nodes from the top of the corn plant has an axillary vegetative bud that is initiated acropetally (from the base of the plant upward) and transformed into an earshoot basipetally (from the top downward) at intervals of about 0.5 to 2 days. The earshoots develop into one or more functional ears and always in a basipetal pattern (Sass, 1960). The yield of grain per plant is not limited by lack of potential ears, but by failure of one or more of the earshoots to develop into sizable ears.
The basipetal pattern of earshoot development and the production of grain by the nonfunctional earshoots when functional earshoots are removed suggest that growth-promoting substances are synthesized in the upper part of the plant (probably in the leaves and tassel) and move down the stalk into the earshoots. The first earshoot is seemingly in the most favorable position to receive growth-promoting substances. Competition by the earshoots for growth-promoting substances and nutrients from the upper part of the plant favors growth of the earlier developed upper earshoots, which become functional. Dominance of the functional earshoots over the growth of lower earshoots, therefore, is believed to be due to the sink provided by the functional earshoots for growth-promoting substances and nutrients, which deprives the nonfunctional earshoots of these substances. This type of dominance appears to be only "positional dominance" which has no influence in determining the number of nonfunctional earshoots per plant, but does have a direct influence in keeping them nonfunctional by depriving them of growth-promoting substances.

It appears that cobs and kernels require different growth-promoting substances for their development. Fertilization of ovules of the first ear apparently triggers the synthesis of the substances physiologically active in the growth of the kernels and cobs of functional ears.

The reason that application of different hormones did not affect the development of the first ear can be related to the fact that many investigators have recognized the immature grain of corn as a good source of plant growth substances. Beauchesne (1961) has confirmed that several different types of growth substances are present in the grains. The level of IAA increases rapidly in the first ear near the time of silking and it is low in
the nonfunctional lower earshoots. King (1976) found that, early in development, the content of ABA per grain starts increasing in parallel to dry matter accumulation (up to 40 fold), a result which does not suggest an inhibitory action of ABA on grain growth. Avery et al. (1942), Wittwer (1943), and Hinsvark et al. (1954) have reported a similar relationship between the concentration of IAA and the rate of growth of immature corn kernels of functional earshoots. The relationship between the concentration of IAA and the rate of growth of apical buds and axillary buds in dicotyledonous plants has been reported by Thimann and Skoog (1934), and Avery et al. (1936, 1937). They showed that functional earshoots and apical buds of dicotyledonous plants have high concentrations of IAA, whereas nonfunctional ear shoots or axillary buds have little or no IAA. Crane (1964) showed the maximum activity of cytokinins in corn kernels two weeks following pollination.

Because of dramatic changes at the time of ear development and fertilization and the natural occurrence of different growth substances at probably adequate amounts, it seems unlikely that exogenously applied hormones could have affected the processes of ear growth and development since there already would have been enough growth regulators to carry on the processes. The results of this experiment confirm those reported by the foregoing investigators about the increase in the levels of different endogenous hormones at the time of ear development, and therefore, makes the effect of exogenously applied hormones negligible. These results also confirm reports by Harris et al. (1976) and Sorrells et al. (1978) who found no significant increase in grain yield of the first ear due to the effect of applied hormones.
The effect of compounds at different rates on the DW of the first ear (Tables 2, 4, and 10) showed a trend toward decreased DW at higher concentrations of ABA, IAA and NAA. It is noteworthy that such a relationship has been shown by other authors. Low IAA levels stimulate growth, whereas those at high concentrations suppress growth (Loescher and Nevins, 1974). It has been shown that the inhibitory effects of IAA at high concentrations may be due to induction of the production of a secondary inhibitory substance. Tucker (1976) showed that auxin synthesized in the apex may induce the formation of ABA. The inhibitory effects of ABA at high concentrations (Table 2) may have been accomplished through an effect on GA metabolism, and suppression of subsequent physiological processes, as has been suggested by Wright (1969) and Rudnicki et al. (1972).

The trend toward increased PFK and DW (Table 3) with BA and GA compared to IAA treatment indicates that despite the existence of large amounts of these growth substances in developing seeds, there is a complex and delicate interaction between hormones and nutritional factors that causes differential growth responses. Slight increases in the DW of the first ear by GA confirm the result by Cherry et al. (1962) who showed a slight grain yield increase by spraying GA near the time of anthesis.

Slight increases in DW and PFK of the first ear due to BA application (Table 3) exhibits some physiological effects of this compound, which is a potent cytokinin, such as: more leaf growth, thereby increasing the source of photosynthates, as suggested by Scott and Lieverman (1956), and inhibition of leaf senescence as suggested by Fletcher (1969) and Adedipe et al. (1971).
Effect of Hormones on Second Ear Development

In this part of the experiment the effect of hormones BA, GA, and IAA when they were injected into the 12th stem internode and the effect of the same hormones plus NAA when they were applied in lanolin paste on the surface of the first ear were studied on the growth and development of the second ear. Despite the significant effect of hormones in increasing the grain yield and the consistency in the order of effectiveness of the compounds in increasing grain yield, EL, and CL, BA>GA>IAA>NAA (Tables 5 and 11) and regardless of the method of application, the basipetal pattern of earshoot development was evident by the decrease in grain yield per ear from the top ear downward as suggested by Collins and Russell (1965). The failure of the plants to produce normal second ears might have been due to the result of failure of complete silk emergence during the pollen-shedding period, rather than the failure of formation of the floral organs.

Data in Table 5 and Figures 1 and 2 showed significant increases in DW of the second ear due to application of either BA or GA with BA being the most effective. The percent of increase in DW due to BA and GA over IAA was 12.6 and 11%, respectively. Ear length and CL of the second ear was most affected by BA followed by GA and IAA. In Table 11 and Figures 11 and 12, the order of effectiveness of the hormones was the same as shown in Table 5. The data in Table 11 showed a more pronounced effect of hormones in increasing DW of the second ear and this may be due to the slow release of hormones in lanolin paste. The percent of increase in DW of the second ear was 13.1, 11, and 10.3 for BA, GA, and IAA, over NAA,
respectively. The trend for increase in EL and CL for the compounds was similar to the data in Table 5.

The results obtained from the effects of hormones on second ear development clearly showed that the reason for failure of lower ear development in corn is due to the lack of necessary amount of hormones and nutrients because of the positional dominance of the first ear. The increase in DW, EL and CL of the second ear indicated that the application of hormones could partially compensate for the inhibitory effect of the apical dominance of the top ear which grows to the extent of depriving lower ears of growth factors. The application of growth regulators could be thought of as having somewhat similar effects on the growth of lower ears as does the removal of the first ear. Thimann and Skoog (1934) showed that removing the first earshoot of one-ear hybrids generally released the inhibition of the second nonfunctional earshoot and the newly developing second earshoot apparently maintains dominance over the growth of the lower nonfunctional earshoot in a manner similar to the way the upper axillary branches of decapitated dicotyledonous plants restrict the growth of the lower axillary buds. Although the hormones stimulated second ear development, the grain yield was small compared to that of normal ear development. The small grain yield indicated that the ovules did not completely produce silk or reach the silking emergence stage and become fertilized or if the silk emerged, it was not at the proper time of the pollen-shedding period as suggested by Sass and Loeffel (1959), or it might be due to the time or the amount of the added hormones that were not adequate to sustain growth.
Earley et al. (1974) suggested that meristematic cells of cobs and ovules of nonfunctional earshoots rapidly lose their capacity to grow after silking of functional earshoots. My data confirm the results reported by Earley et al. (1974) in that applied hormones could not bring about improved grain yield in lower ears. They stressed the age or stage of development of earshoots as a most important factor in determining the amount of growth of nonfunctional earshoots after functional earshoots have been removed or in the case of my experiment, the time of application of hormones. The adequacy of the ovules also confirms the results reported by Sass (1960) that the failure of complete development of the second ear is not ascribed to inadequate ovule development by the time of anthesis, but to factors associated with competition prior to and after anthesis.

Some rather important points can be inferred from the data in Tables 6 and 12. Since all of the hormones, whether injected into the stem internode or applied onto the ear surface, stimulated growth and development of the second ear, the following conclusions can be made.

A. The effect of the growth substances is not restricted to the point of application (e.g., by creating a metabolic sink), but extends throughout the stem and may be directly affecting the process of phloem transport itself. This agrees with the results reported by Seth and Wareing (1964).

B. The results show a synergistic interaction between the hormones applied and the endogenous hormones and that they are probably acting through the same system and are involved in the well-known phenomenon that metabolites move actively towards growth centers. The
fact that all substances have been observed to have effects when applied alone to various parts of corn suggests that where such responses were obtained the other factors were probably present in the plant.

C. The increasing basipetal inhibition of growth of the nonfunctional earshoots compared to the top ear seems to negate the theory that the functional earshoot inhibits the growth of the nonfunctional earshoots by synthesizing and releasing IAA down the stalk. If the auxin production theory were correct, inhibition of the growth of nonfunctional earshoots should be the same or should decrease basipetally rather than increase basipetally, as is the case. Furthermore, the stimulation of second ear and even third ear by applying IAA and NAA supports the concept that IAA stimulates growth as proposed for other plants by Skoog et al. (1942), Bonner (1949), Cheng (1972). These scientists associate growth of plant tissue with the involvement of auxins in the synthesis of essential nucleic acids, proteins, and enzymes. On this basis, the failure of cobs and fertilized ovules of nonfunctional earshoots to grow normally may be due to a deficiency of auxins as a result of dominance of the functional earshoots for these growth promoting substances.

D. Incomplete fertilization of the ovules on the cob can be considered the main reason for limited DW increase of nonfunctional earshoot. If complete fertilization had taken place, this process of fertilization of ovules by itself would have been the main factor to trigger the synthesis of the substances physiologically active in
the growth of the kernels and in that case cobs of this newly functional earshoot apparently would have provided the fertilized ovules with an adequate supply of a precursor to sustain kernel development.

The effect of IAA at its different rates when injected into the internode confirms the trend that was observed for the effect of IAA on DW of the first ear. The stimulatory effect of BA and GA at the greatest concentrations on DW of the second ear and the inhibitory effect of IAA at high concentrations on DW, EL, and CL of the second ear is shown in Figures 3, 4 and 5.

The effect of different concentrations of each hormone when applied in lanolin paste is shown in Figures 13, 14 and 15. Again, BA and GA increased the DW, EL, and CL of the second ear at their higher concentrations and in contrast, IAA and NAA had inhibitory effects on these attributes at their higher rates and stimulatory effects at their lower concentrations. The exact mechanism of inhibition of IAA and NAA at higher concentrations can not be determined in this study; however, the results may be considered in terms of a correlative inhibitor. Most available evidence indicates that ABA is synthesized in mature leaves and transported acropetally (Hoad, 1973), thus it is possible that descending IAA at high concentrations and ascending ABA interact and cause an inhibitory effect.

The stimulatory action of BA and GA in my study agrees with the fact that both GA and BA have generally been found to counteract the dominating influence of an active growth center. My results agree with those reported by Wickson and Thimann (1958) who demonstrated cytokinins are
active in the initial release of axillary buds and, therefore, these com-

pounds may be more important at the time of earshoot initiation, and also

with the report of Hew et al. (1967) that GA can interact with IAA in the

enhancement of metabolite translocation. Phillips (1971b) has attempted to

clarify the role of exogenously applied GA, showing that it can be a

modifying factor in inhibitory effects of inhibitors. He suggested that

GA synthesized in the apex normally stimulates growth in the elongating

internodes and may not reach the axillary buds. If, however, there is ex-

cess GA it may reach the buds and enhance their growth, as is the case in

this experiment. Also, the increased growth in second ear confirms the

results reported by Catalano and Hill (1969), who showed that GA applied

to the lateral buds of plants caused a greater stimulation of bud growth,
especially if these buds had been pre-treated by kinitin.

Effect of Hormones on Third Ear Development

The effect of the hormones BA, GA, and IAA and the effect of the same

hormones plus NAA on DW, EL and CL of the third ear is shown in Tables 7

and 13, respectively. The significant increase in DW of the third ear due
to BA and IAA but not GA is clearly shown in Figure 6. Figure 16 shows
the significant effect of BA and all other hormones in increasing DW of the
third ear. Figures 7 and 17 show the effects of hormones in increasing EL
and CL of the third ear.

Although the hormones increased the development of the third ear,
they were not able to transfer the third ear from a nonfunctional form
to a functional form. In other words, the increased inhibition of the
basipetal pattern of development of earshoots on the corn plant was much stronger than the effects brought about by the application of hormones.

For grain yield, there is only a basipetal compensatory relationship between functional earshoots and nonfunctional earshoots; however, this compensatory relationship does not come into play unless one or more of the functional earshoots fail to develop as has also been discussed in other plants by Jacobs and Bullwinkel (1953). In my experiment, there was no removal of the top ear, but I attempted to compensate for the inhibitory effect of apical dominance by the top ear by application of growth regulators. Data in Tables 7, 8, 13, and 14 show that although there was a stimulatory effect of hormones, this stimulation was not to the extent to change the natural pattern of earshoot development. The results showed that the lack of growth regulators and nutrients in the third ear was more severe compared to the second ear. These results are in agreement with those reported by Earley et al. (1974), Harris et al. (1976) and Sorrells et al. (1978), in which they were not able to increase the growth and development of the nonfunctional lower ears. But, in this experiment, I found somewhat different results considering the fact that hormones, especially BA, increased EL and CL of the third ear; however, in the literature, there was no report of measurements of the EL or CL of the lower ears. In addition to lack of adequate amounts of essential growth regulators in nonfunctional third ears, the failure of the third earshoot to grow and produce grain might be related to its inability to reduce nitrates and synthesize protein more rapidly, as suggested by Noodén and Thimann (1963) and Oaks et al. (1972).
The trend of effect of hormones on third ear development followed the same pattern as was observed in the second ear with BA being the most effective compound in increasing all attributes measured.

Results in Figures 8, 9, 10, 18, 19 and 20 showed the similar trend of the effect of different rates of the compounds used. Again, similar to the effects on second ear, attributes measured decreased with increasing rates of IAA and NAA (Tables 8 and 14), however, for BA, the responses increased with increased rate of compound. GA had an inconsistent effect on the DW of the third ear when injected into the plant tissue. This inconsistency of the effect of GA application to intact plants also has been reported by Catalano and Hill (1969).

Effect of Chemicals ACA and ACE on Plant Growth and Yield Components

The effects of the liquid chemicals ACA and ACE were studied on vegetative growth and yield components of corn using different rates of chemicals and different methods of application in three fields collectively called Fields A, B, and C.

The results in Table 15 indicated a significant increase in LW and WE due to ACA compared to ACE. Also, there was a trend toward a greater grain yield with ACA than with ACE; however, it was not significant. This result confirms those reported (unpublished data) by I. C. Anderson (Agronomy Dept., ISU, 1974), who found increased leaf width and a slight increase in grain yield due to ACA application. As shown in Table 15, there were no differences between ACA and ACE on HT, POP, and EP. The results from Field B (Table 18) showed an increase in HT of plants and WE. This increase in WE in
Field B was to the extent that it caused significant increase in grain yield with ACA treated plants compared to ACE treated plants.

The reason for the increase in LW, WE and grain yield (Figure 21) in Field A and the increase in WE and grain yield (Figure 23) in Field B might be related to the fact that ACA, a solution which contains 33% zinc acetate, is an organic zinc chelate that is available to the corn seedlings at early stages of growth without creating any fixation problems for zinc which occurs when zinc is applied directly to the soil (Ott, 1974). By application of ACA, zinc will be absorbed by the plants much easier and probably gets to the meristematic growing points of the plant and may produce more tryptophan which is the precursor of IAA. The other reason that can be proposed is that ACA treated plants by having wider leaves and taller heights have more photosynthetic area, resulting in a larger source of photosynthates produced. The increased WE, which led to more grain yield per/ha, is logically due to more photosynthates available to the ear; however, it is not clear from this study whether this increase in WE and grain yield is due to prolongation of filling period or due to the increased rate of photosynthetic translocation.

The data in Tables 17 and 20 indicate that LW increased with increasing rate of chemicals up to 24 ml and again decreased at the higher rates of chemicals. Figure 22 shows that the response of seedlings was limited to a range of concentrations of chemicals in which adverse effects were caused by chemicals beyond a certain concentration.

In Field C, where ACA and ACE were applied in anhydrous ammonia, the components of yield (Table 22) were affected similarly by ACA and ACE. However, ACE had a greater effect on height of the plants during the
second measurement and on LL than did ACA (Table 21). Apparently, increased height and leaf length due to ACE treatment did not cause an increase in grain yield. The reason that ACE caused increased LL and HT might be due to its conversion to ACA by reacting with the zinc already available in the soil.

The effect of the different rates of chemicals followed the same trend as in Field A and B (Figures 24 and 25). Figure 24 indicates that the response increased with each increment of the rate up to 0.60 kg/ha of chemical and was followed by a decline at the highest rate (1.2 kg/ha). This indicates that the beneficial response of the plant to the chemical is limited to a certain range of concentration and beyond that rate the chemicals cause adverse effects on the plant.

In Field C, two methods of application were used: a) a close application in which the chemicals were injected close (10 cm) to the row, and b) a far application in which the chemicals were applied (40 cm) far from the seedling row. The results in Table 23 show the effect of the method of application on vegetative growth of the plant. The first measurement of height was greater for the close application although not significantly different. The height at second measurement and LW and LL were significantly greater for the close application compared to the far application. The increased LW, LL, and HT eventually resulted in increased WE, grain yield and K/m² (Table 24) for the close application compared to the far application of the chemicals. The results obtained in Tables 30 and 31 can be interpreted as an effect of availability of the chemicals at earlier stages of growth. The seedlings treated with the close application of chemicals had an earlier opportunity to reach the available
chemicals in the soil and establish vigorous root and vegetative organs. This advantage of the close application of chemicals was reflected in greater WE and grain yield.

The reasoning behind the effect of ACA on vegetative growth of the plants and greater WE and grain yield presented earlier could be indirectly related to changes in in vivo of growth regulators. This indirect relationship could be discussed as follows:

A. By application of ACA, zinc increased tryptophan of meristematic areas and tryptophan transforms to IAA, so the ACA treated plants could have more IAA content. The relationship between the concentration of IAA and rate of growth of apical and axillary buds has been reported by Thimann and Skoog (1934) and Avery et al. (1936, 1937). Patrick and Wareing (1970) suggested that IAA affects the process of phloem translocation rather directly. According to them, IAA prevents senescence of the transport tissue and plays an essential role in maintaining this tissue in a functional condition, rather than in actively stimulating the transport processes as suggested by Mullins (1970).

B. Another possibility is that plants with increased growth rates due to ACA application have a more active root system which extends faster and penetrates deeper into the soil. In this case, not only more nutrients would be available, but also a stronger root system could produce more cytokinin. Differences in cytokinin content in turn influence kernel size probably by attraction of metabolites and enhancement of the sink capacity (location of product utilization)
and the accumulation processes, and further, perhaps, by retarda-
tion of senescence and by prolongation of the filling period.

Michael and Seiler-Kelbitsch (1972) reported that root activity is
related to the regulation of grain growth and size. Association between
cytokinlin activity and kernel size suggests that cytokinin and surely
other growth substances as well participate in the regulation of grain
size. The cytokinin content seems to depend on an inherent productive
ability of the grain, possibly in relation to growth of embryo (Steward
and Chaplin, 1952) and to the transport of cytokinin from the roots. The
root is the most important center for cytokinin production (Kende, 1964).
Cytokinins have been shown to increase both auxin production (Jordan and
Skoog, 1971), and GA production in the shoot (Sebanek, 1966; Karanov
SUMMARY AND CONCLUSIONS

Field experiments were conducted during the growing seasons of 1978 and 1979. Different plant growth regulating chemicals were either injected into the 14th stem internode, 12th stem internode, mixed in lanolin paste and applied on the surface of the first ear and conjunction point of the ear shank and stem, or applied to the soil.

Results on the effect of compounds on percent of filled kernels and dry weight of the first ear showed no significant differences between treated plants and controls regardless of the method of application and placement of compounds. The effect of compounds at different rates on the dry weight of the first ear showed a trend toward decreased dry weight at higher concentrations of ABA, IAA, and NAA. Low IAA levels tended to stimulate growth, whereas those at high concentrations suppressed growth. The inhibitory effect of IAA at high concentrations may be due to the production of a secondary inhibitory substance (e.g., ABA), and the inhibitory effect of the latter one may have been accomplished through an effect on GA metabolism, and suppression of subsequent physiological processes.

The trend toward increased percent of filled kernels of the first ear with BA and GA compared to IAA and control treatment indicates a complex and delicate interaction between hormones and nutritional factors that causes differential growth responses.

Despite the significant effect of compounds in increasing the grain yield of the second ear, and the consistency in the order of effectiveness of the compounds in increasing grain yield, ear length, and cob length, BA > GA > IAA > NAA and regardless of the method of application, the basipetal
pattern of earshoot development was evident by the decrease in grain yield per ear from the top ear downward. The failure of the plants to produce normal second ears might have been due to the result of incomplete silk emergence during the pollen shedding period, rather than the failure of formation of the floral organs.

The effect of compounds BA, GA and IAA and the effect of the same compounds plus NAA on the development of the third ear showed that, although the hormones increased the development of the third ear, they were not able to transfer the third ear from a nonfunctional form to a functional form. In other words, the increased inhibition of the basipetal pattern of development of earshoots on the corn plant was much stronger than the effects brought about by the application of compounds.

Study of the effect of chemical growth regulators, ACA and ACE, on vegetative growth and yield components of 'Pioneer 3780' corn cultivar in Field A showed a significant increase in leaf width and weight per ear due to ACA compared to ACE. Also, there was a trend toward a greater grain yield with ACA than with ACE. There were no differences between ACA and ACE on height, population, and ears per plant. The results from Field B showed an increase in height of plants and weight per ear and this increase in weight per ear was to the extent that caused significant increase in grain yield with ACA treated plants compared to ACE treated plants. In Field C, where ACA and ACE were applied in anhydrous ammonia, the components of yield were affected similarly by ACA and ACE. However, ACE had a greater effect on height of the plants during the second measurement and on LL than did ACA. The effect of the different rates of chemicals followed the same trend as in Fields A and B. The response of seedlings was limited
to a range of concentrations of chemicals in which adverse effects were caused by chemicals beyond a certain concentration.

The effect of close to the row (10 cm) and far from the row (40 cm) application of chemicals showed increased leaf width, leaf length, and height with close application which eventually resulted in increased weight per ear, grain yield and kernels per unit area \((m^2)\). The reasoning behind the effect of ACA on vegetative growth of the plants and greater weight per ear and grain yield could be due to availability of Zn and/or could be indirectly related to \textit{in vivo} changes of endogenous hormones and their effect on stimulating root and vegetative growth.


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ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my major professor, Dr. Irvin C. Anderson. His sincerity, guidance, and encouragement was certainly an inspiration to me and will always be remembered and appreciated.

My gratitude is also extended to the other members of my graduate committee, Drs. Ervin L. Denisen, Clifford E. Lamotte, Robert B. Pearce, and David K. Whigham, for their helpful guidance. Special thanks are also extended to Dr. David F. Cox for his cooperation in statistical analysis of the data.

I am also indebted to my wife, son, and my family for their moral support and encouragement.

Thanks are also extended to Mrs. Donna Gladon for the help and advice she has given me as well as for typing this manuscript, and to my friends in crop production and physiology group for their valuable help during field work.