

To the Graduate Council:

I am submitting herewith a dissertation written by Amma Pokua Bruce entitled "The Use of Plant Growth Regulators To Enhance Yield and Production Efficiency of Soybean (Glycine max L. Merrill)." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Science.

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THE USE OF PLANT GROWTH REGULATORS
TO ENHANCE YIELD AND PRODUCTION
EFFICIENCY OF SOYBEAN (GLYCINE MAX L. MERRILL)

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ABSTRACT

The plant breeder uses many tools to produce higher quantity and quality crops suitable for various environments. Plant growth regulators are one possible tool. This study was undertaken to evaluate the potential of some promising plant growth regulators in modifying soybean (Glycine max L. Merrill) plant size and shape, selectively promoting flower and pod abortion and enhancing yields.

Two determinate varieties, Forrest and Essex, and one indeterminate line, TN77-31, were planted in early to mid-May and early to mid-June of 1983-1985. The treatments gibberellic acid, 6-benzyladenine, daminozide, chlorflurenol, mepiquat chloride, ancymidol, ethephon, and brassinosteroid 1105 were applied at various growth stages. Measurements taken included yield, frequency of one-, two- and three-seed pods on mainstem and branches, hundred-seed weight, protein, oil, linolenic acid and linoleic acid percentages, plant height, number of nodes on mainstem, internode length, number of branches and nodes on branches.

Results indicated growth regulator treatments did not produce consistently significant results. Response was also dependent on planting date. Gibberellic acid treatments mainly produced positive effects on the number of pods on branches of Forrest and Essex and also increased their height, branch number and nodes per branch; for TN77-31, only increased branch node number occurred. Plant growth regulator treatments following delayed planting produced similar results for

Forrest, but for Essex, results for the morphological characteristics changed--node number decreased, and internode length and nodes per branch increased; TN77-31 plants were shortened, nodes per branch were increased and yields were lowered.

Ethephon decreased yield and hundred-seed weight, mainstem two-seed pods of Essex, three-seed pods of Forrest and hundred-seed weight of TN77-31 and shortened plants of all varieties in the May plantings. Following ethephon treatments in delayed plantings, Essex seed yield and hundred-seed weight decreased, but branch number, nodes per branch and leaf area increased; only TN77-31's hundred-seed weight decreased, but Forrest branch two-seed pods and hundred-seed weight increased, and nodes per branch decreased.

All chlorflurenol-treated plants were dark green and senescence was delayed. In the earlier plantings, chlorflurenol applications significantly shortened Essex and Forrest heights, decreased Forrest yield, and linoleic and linolenic acid percentages, and increased hundred-seed weight, mainstem three-seed pods and oil. For TN77-31, hundred-seed weight was significantly affected, percentage of protein and number of mainstem three-seed pods were increased; whereas oil and linolenic acid percentages were decreased. Delayed planting combined with chlorflurenol applications reduced seed yields and shortened internode lengths for TN77-31 as well as increased hundred-seed weight and linolenic acid percentages but caused a decrease in percentage oil for Forrest.

Although significant responses to the growth regulators occurred erratically and no positive effects on yield occurred, plant size was modified and seed quality changed from treatments imposed in this study.

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PART I: INTRODUCTION AND LITERATURE REVIEW

CHAPTER 1

INTRODUCTION

The population of the world is increasing at an alarming rate. The projected world population for the year 2025 is 8.7 billion (World Almanac, 1987). Increases in food production must keep up with population increase if starvation is to be prevented throughout the world. The good news is that for most crops biological limits have not yet been reached for yield. According to Wittwer (1978) "the biological processes or phenomena that limit the stability and magnitude of crop productivity and the most efficient use of resources (land, water, fertilizer, energy, climate) include photosynthesis, biological nitrogen fixation, photorespiration, transpiration, leaf senescence, dormancy, growth rates, nutrient and water uptake, flower bud differentiation, fruit and seed set, harvest index, and resistance to chemical, biological and environmental stresses. All the above processes are hormonal or special substance mediated." A plant breeder improves both the yield and quality of crops using any available means. The use of plant growth regulators is one possible tool available to plant breeders to overcome the barriers identified by Wittwer. They have been utilized successfully on various crops.

Naturally occurring growth substances in plants play a major role in controlling growth and development by effective processes like root

initiation, onset and termination of dormancy and rest, flowering, fruit set and development, abscission and senescence (Weaver, 1972). It should be possible to alter these processes beneficially by the proper application of plant growth regulators. In theory, a plant growth regulator should, at a certain point, be able to control growth and induce the plant to produce more and larger seeds, instead of unnecessary vegetative growth (Jobman, 1977).

Plant growth regulators are, for practical purposes, defined as "either natural or synthetic compounds that are applied directly to a plant to alter its life processes or structure in some beneficial way so as to enhance yields, improve quality, or facilitate harvesting" (Nickell, 1979). Hardy (1979) visualized plant growth regulators as providing broad spectrum solutions for increasing crop productivity and optimizing the limited resources. To him, plant growth regulators would not only increase yield, but also improve the nutritional quality of crops and make production easier and more convenient. He predicted that by the year 2000, plant growth regulators would be used, first, as yield enhancers and, second, as quality improvers and production process facilitators and would be as important as fertilizers or plant protectant chemicals in the production of the world's crops.

Cooke (1985) has classified the present role of the compounds in agriculture into four categories, namely: yield enhancement, energy and labor conservation, quality control, and control of plant height and shape. Currently plant growth regulators are used extensively for

horticultural crops (Nickell, 1978, 1979; Bruinsma, 1981), but there is limited use in the major agricultural crops.

Jobman (1977) noted that a plant growth regulator must have three important characteristics if it is to succeed: (i) give consistent results, (ii) be easy to apply, (iii) "offer some latitude on application timing if it has wide commercial appeal to farmers".

It is relative to the first characteristic which triidobenzoic acid (TIBA) lacks. This plant growth regulator seemed to offer some promise for soybean (Glycine max L. Merrill) yield improvement, but had to be taken off the market because of inconsistencies in yield results.

New plant growth regulators are continuously becoming available, and their effects should be evaluated. In addition, there are a number of growth regulators used in other crops that have not been fully evaluated for soybean production. Many of these compounds should be evaluated for their potential use in modifying plant size and shape, reducing flower and pod abortion and enhancing yields.

In 1985 about 0.6 million hectares of soybeans were grown in the state of Tennessee (Tennessee Dept. of Agriculture, 1986). If plant growth regulators could be used to cause economic increases in yields, this could result in substantially increased profits for Tennessee soybean producers.

The objectives of this study were to determine if:

1. soybean yields could be increased through the application of different classes of chemical compounds which are known to affect plant growth and development,

2. plant size and shape could be altered in a beneficial way by the different chemical compounds in order to improve production and harvesting efficiency, and

3. specific compounds could be used to "thin" flowers and pods in order to increase seed yield.



CHAPTER 2

LITERATURE REVIEW

Limitations On Soybean Yield

Since soybean seeds contain approximately 40 percent protein and 20 percent oil (Shibles et al., 1975), they can be used to help solve the problem of malnutrition in many areas of the world. However, the concept of a "yield barrier" in soybean production exists since there is only a 1 percent per year increase in commercial soybean yield per hectare; thus, the increase is slow in comparison to advances in other crops (Sinclair and de Wit, 1976).

Clapp (1975) concluded that the potential seed yield of soybeans is not realized because of the abortion of a lot of flowers and young pods. Flower and pod abortion can be as high as 80 percent (van Schaik and Probst, 1958), with the largest number of abscissions occurring after fertilization (Shibles et al., 1975; van Schaik and Probst, 1958). Reducing the abortion rate could lead to increased yields. Seed yield is determined basically by the number of flowers a plant can produce, how many of those develop into mature seed, and the size of the seed (van Schaik and Probst, 1958).

Sinclair and de Wit (1976) hypothesized that it is the "self-destructive" process in soybeans that has placed a potential limit on

total seed production. Their premise is that the self-destructive process occurs because the soybean seed has such a high demand for nitrogen that, in order to sustain growth, nitrogen is translocated from the vegetative parts to the seed during seed development. This process leads to lower physiological activity and finally results in senescence. The leaf senescence process, also called monocarpic senescence, is prevented when soybean plants are depodded (Lindoo and Nooden, 1976). An increase in nitrogen supply, either from the roots or from stored nitrogen in vegetative parts, might lengthen the seed development period and increase seed yields.

Abu-Shakra et al. (1978) suggested that prolonging photosynthesis and nitrogen fixation during the reproductive period should be a way of increasing yields. They were able to obtain, through selection, soybean lines that had delayed leaf senescence. These plants had leaves with high ribulose phosphate carboxylase activity and high activity in the root nodules. They advocated using these lines as germplasm in crosses and incorporating the characteristics into favorable genetic backgrounds, thereby increasing seed yield and symbiotic nitrogen fixation.

The theory that loss of nitrogen from the leaves to support seed growth is the cause of senescence in soybeans is brought into question by the work of Streeter, 1978; Nooden et al., 1979; and Sesay and Shibles, 1980. Foliar application of a mineral nutrient solution to three soybean varieties during the seed-filling period only delayed the

decline of N, P, and K in leaf laminae, but did not delay or prevent senescence. Senescence, therefore, is not caused by loss of leaf nitrogen when nitrogen is not limiting (Sesay and Shibles, 1980). Mild nitrogen withdrawal during the reproductive stage led to decreases in seed size, but did not cause premature leaf senescence (Streeter, 1978). Mondal et al. (1978) reported that leaves of "desinked" 'Hodgson' plants in which chlorophyll contents remained high declined in photosynthetic rate similar to that of leaves of control plants. Phillips et al. (1984), using soybean lines with delayed leaf senescence phenotype (DLS), showed that the DLS lines yielded less than the variety 'Elf'. In addition, they reported that an inverse relationship existed between yield and expression of the delayed leaf senescence phenotype. These results led them to hypothesize "that maximum soybean seed yields can only be achieved with plants whose leaves senesce during seed development."

Role of Plant Growth Regulators (PGR)

Regardless of the causes of the limitations to soybean yield, it is agreed that efforts to overcome them must continue. If plant growth regulators are to be used to improve yields, it is important to know the factors that limit soybean yields (Peat and Jeffcoat, 1982). As stated before and reiterated by Oplinger (1985) for soybeans, agronomic characteristics like "high pod abortion, low pod set, lodging, and

inadequate assimilation of nitrogen" make soybean a good candidate for improvement with PGRs. There have been success stories with PGRs in a lot of crops (Nickell, 1982). Growth regulators have influenced flowering and fruit set in other crops (Morgan, 1979). Daminozide, ethephon, and gibberellins have induced or promoted flowering, fruit retention and size in several vegetable and fruit crops (Cooke, 1985; Nickell, 1982).

Both breeding programs and research in PGRs have the same objective of modifying crop performance for the benefit of all (Nickell, 1982). Conventional plant breeding methods require time, and one can only agree with Wittwer (1978) that "meanwhile plant growth regulators offer an immediate and very practical solution to many production problems." Hardy (1979) concluded that plant growth regulators have "inherent" advantages over genetic solutions for regulating important plant processes. His reasoning was that a broad-spectrum chemical which affects a particular biochemical process could be used for different cultivars as well as different crops, thereby having a quick impact as compared to a slow and tedious genetic manipulation.

Effect of Plant Growth Regulators on Soybeans

Various people have tried to prevent self-destruction, or monocarpic senescence, by applying plant growth regulators with the hope that treated plants would support or sustain fruit and seed development. Applications of a combination of naphthalene acetic acid (NAA) and

benzyladenine (BA) have been shown to prevent senescence, but did not increase yields, pod number nor seed number in the cultivar 'Anoka' (Nooden et al., 1979). Dybing and Lay (1981a, 1981b) identified chlorflurenol (a morphactin) as the chemical that most consistently delayed senescence in soybeans. However chlorflurenol decreased yield, most probably as a result of reduction in seed size. Applications of chlorflurenol at R5 delayed soybean leaf yellowing, but earlier applications resulted in growth abnormalities. These experiments showed the importance of time of application of growth regulators. Testing various auxin-transport inhibitors (e.g., chlorflurenol, methyl chlorflurenol, TIBA) on soybeans grown in greenhouses, Nooden and Nooden (1985) found that, although these chemicals delayed senescence and increased pod number, they did not cause an increase in seed yield. Foliar application of a morphactin (EMO-7301) at flower initiation, did not increase soybean yields in studies conducted by Clapp (1975). Plant height was reduced by all rates of applications, and the highest rate reduced the number of pods per plant and seeds per pod and delayed maturity.

Lodging of soybean plants causes losses of quality and quantity of seed (Weber and Fehr, 1966). If lodging can be prevented, it is possible that there will be an increase in harvestable yields. Therefore, there is heightened interest in plant growth retardants. These are synthetic, organic chemicals that, when applied to responsive plants, reduce the rate of stem elongation, usually without producing

substantial growth malformations (Nickell, 1982). These chemicals affect stem growth mainly by inhibiting cell division and, to a lesser degree, cell elongation of subapical regions of the shoot tip (Nickell, 1982). Growth retardants like mepiquat chloride and mepiquat chloride in combination with ethephon have been used beneficially in cotton and the cereal crops (Ware, 1983; Schott and Rittig, 1982). Schott and Rittig attribute the beneficial effects of mepiquat chloride treatments on cotton yields to increased light penetration due to reduced leaf area without decreased leaf volume.

Akao et al. (1982) treated soybean plants with three growth retardants to determine their effect on soybean development and yield. The most effective growth retardant in the study, N-dimethyl aminosuccinamic acid, increased the number of pods per plant. Suppression of mainstem elongation was a result of a decrease in both number of nodes and internode length.

Application of several anti-auxins on the soybean cultivar 'Fiskeby V' showed that the chemicals increased the number of pods retained on the soybean plant at maturity, but did not always result in increased yield (Boize, 1982). The chemical treatments apparently prevented the shedding of some immature pods.

According to Peat and Jeffcoat (1982), the use of growth retardants on indeterminate soybean varieties was not only to reduce lodging, but also to reduce vegetative growth occurring after flowering with the expectation that this would increase the availability of

assimilates for seed production. Tanner and Ahmed (1974) believe that their work supports this theory and that triidobenzoic (TIBA) acts by slowing down vegetative growth and promoting reproductive growth. Their experiments with TIBA, an anti-auxin, not only increased pod number, but also reduced height, lodging and seed size. They concluded that plant growth regulators are tools that can be used to alter plant growth and enable researchers to study new plant types to determine which changes should be incorporated genetically.

Application of a growth retardant, BTS 44584 at an R1 growth stage increased net photosynthetic rates, leaf thickness, and chlorophyll content and decreased leaf size, leading to a significant increase in yield of soybeans with associated increases in pod number (Hewitt et al., 1982). The researchers proposed that the chemical stimulated yield by affecting net photosynthesis and carbohydrate availability throughout seed set and pod development. Their conclusion was that the chemical may have acted by affecting light penetration (since treated plants had thicker and smaller leaves than control plants) or carbon dioxide uptake or both.

Apart from reduction in stem length, other morphological changes on plants with a morphactin (chlorflurenol-methylester) include the release of lateral buds from apical dominance, which is associated with increased endogenous cytokinins (Dua et al., 1978). The reduction in stem length was a result of reduction in cell length and cell number.

Application of 'Ethrel' (2-chloroethyl phosphonic acid) on 'Amsoy' soybeans at different developmental stages caused not only a reduction in height (anti-lodging effect), but also a reduction in seed weight, three- and four-seeded pods and, most important, a reduction in seed yield (Slife and Earley, 1970). Similar results were obtained by Urwiler and Stutte (1986) when high rates of ethephon were applied to the cultivar 'Davis'. This study indicated ethephon increased ethylene levels in soybean tissue, leading to increased soybean floral abscission plus the other negative results observed by Slife and Earley. Blomquist et al. (1973) treated three soybean cultivars with Ethrel and established that reduction in lodging of the Ethrel treated plants was a result of the enhancement of the activities of enzymes involved in lignin formation (e.g. phenylalanine ammonia lyase).

Realizing that growth is influenced by both the nutrient environment and the amount of hormones present regardless of origin (endogenous or exogenous), Ounsworth and Pillay (1969) undertook a study to determine how the application of growth regulators affected soybean growth as well as uptake of nitrogen, phosphorus and potassium. The growth patterns were different, depending on the growth regulator applied. Gibberellic acid (GA) increased plant height, internode length, and potassium uptake; whereas Alar reduced plant height, but resulted in increased potassium and phosphorus uptake.

Brassinosteroids are synthetic plant growth regulators which resemble the naturally occurring phytohormone brassinolide. They have

been referred to as "hormones of promise." Brassinosteroids are reported to increase yield, growth efficiency, growth rate and leaf area. Brassinosteroids cause soybeans to mature earlier than untreated plants without causing a decrease in yield (Patrico, 1983).

Plant Growth Regulator Affects on Seed Protein and Oil

Soybean is one of the crops of the world that is high in both protein and oil. Cultivars contain approximately 20 percent oil and 40 percent protein (Shibles et al., 1975). Therefore this crop is important worldwide because a large number of people do not consume the minimum recommended calories of fat and protein (Salunkhe and Desai, 1986), and they are also malnourished because of the shortage or nonexistence of animal protein.

Economically, quality factors are potentially as important as yield (Dybing and Lay, 1982). However there are major difficulties in selecting plants for increased protein because of the negative genetic correlations which exist among percent protein and yield and percent oil.

In 1979 Hardy stated that PGRs would be useful to improve the nutritional quality of crops. The same vision is shared by Cooke (1985) who saw the need to increase the world's supply of protein and the possibility of doing so with the appropriate plant growth regulator. He surmised that not only the total protein content, but the essential

amino acids and saturated and unsaturated lipids as well should be responsive to plant growth regulators. Dybing and Lay (1982) found that percent oil in soybeans was increased when chlorflurenol was applied at the R6 growth stage; however protein was reduced ($r = 0.87$). On the other hand, Slife and Earley (1970) reported that treatment of soybeans with Ethrel did not affect protein and oil.

Soybean oil contains 12-15 percent saturated acids and 85-88 percent unsaturated acids (Salunkhe and Desai, 1986). Weiss (1983) reported that the unsaturated acids are made up of 10 percent linolenic, 55 percent oleic and 30 percent linoleic acid. Poor flavor and instability in soybean oil is due to the relatively high linolenic acid content (Weiss, 1983; Hammond, 1984). Refined soybean oil, therefore, needs to be hydrogenated to lower the linolenic acid content to an acceptable level (Burton et al., 1983). Since the hydrogenation process is getting more expensive, Burton et al. thought it important to seek alternative measures to lower the linolenic acid concentration in soybean oil.

Planting Date

Various investigations show that variations in planting date affect not only yield, but various yield components and agronomic characteristics as well (Egli, 1975; Osler and Cartter, 1954; Anderson and Vasilas, 1985). Anderson and Vasilas (1985) determined that delayed

planting decreased yields mainly by decreasing the number of seed. Significant genotype x planting date interactions have been reported for seed yield, lodging, and height at maturity, indicating that genotypes respond differently to early and late planting dates (Carter and Boerma, 1979).

Multiple cropping systems like double cropping and relay intercropping, which utilize late planting dates, are increasing in popularity among farmers (Jeffers and Triplett, 1979; McBroom et al., 1981). Jeffers and Triplett (1979) reported that soybean yields from relay cropping and from double-cropping were approximately 80 percent and 60 percent, respectively, of yields from monocropped soybeans.

Jeffers (1984) discussed the problem of intercropped soybeans' interfering with wheat harvest. He was able to slow soybean growth with a growth retardant so that the soybean plant height did not interfere with wheat harvest. Treated plants continued growth after the wheat was harvested.

Stutte and Davis (1983) state that everyone wants soybeans with higher yields which are rich in protein or oil or both. They comment on the fact that synthetic plant regulation seeks to either alter the levels of the naturally occurring phytohormones or stimulate/inhibit their activities in order to allow the plant to achieve its potential for production. To them, success in the use of PGRs on soybeans will depend on proper evaluation of the different soybean varieties and

growth types grown under different environmental conditions and with different rates and times for applying the chemicals.



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PART II: EFFECT OF PLANT GROWTH REGULATORS
ON SOYBEAN YIELD AND YIELD CHARACTERISTICS



CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

A "yield barrier" exists in soybeans since there is only a 1 percent per year increase in commercial soybean yield per hectare; thus increase is slow in comparison to advances in other crops (Sinclair and de Wit, 1976).

One way of breaking the ceiling on soybean productivity is by reducing the high rate of abortion of flowers and young pods (Clapp, 1975). The abortion rate can be as high as 80+ percent (Richmond, 1980; van Schaik and Probst, 1958), with most floral abscissions occurring after fertilization (Shibles et al., 1975; van Schaik and Probst, 1958).

Another plausible way of increasing yields may be to prolong photosynthesis and nitrogen fixation during the reproductive period (Abu-Shakra et al., 1978). Sinclair and de Wit (1976) hypothesized that the "self destructive" process in soybeans placed a potential limit on total soybean production.

Soybeans are high in both protein and oil, with the seed of most cultivars containing about 40 percent protein and 20 percent oil (Shibles et al., 1975). Unsaturated acids in soybean oil are made up of 10 percent linolenic, 55 percent oleic and 30 percent linoleic acids (Weiss, 1983). Poor flavor and instability in soybean oil is due to the relatively high linolenic acid content (Hammond, 1984; Weiss, 1983).

Since hydrogenation is expensive, alternative measures to lower linolenic acid concentration should be sought (Burton et al., 1983). Plant growth regulators have been used successfully in various crops to solve many problems (Nickell, 1978 and 1982; Morgan, 1979). Soybeans, because of agronomic characteristics like high pod abortion rate, low pod set, lodging and inadequate nitrogen assimilation (Oplinger, 1985), are a good candidate for improvement with PGRs. Plant growth regulators should not only increase yield, but also improve the nutritional quality of crops (Hardy, 1979) by improving total protein content, essential amino acids and saturated and unsaturated lipids (Cooke, 1985).

As yet, no plant growth regulator is registered for use on soybeans. TIBA had to be taken off the market due to inconsistencies in results. A lot of experiments have been conducted with PGRs to increase yield, but applications of most of these compounds have not resulted in yield increases (Dybing and Lay, 1981a,b; Clapp, 1975; Boize, 1982; Nooden and Nooden, 1985; Slife and Earley, 1970). Ethrel treatments have not affected protein and oil (Slife and Earley, 1970), while treatments with chlorflurenol have been reported to increase percent oil and reduce percent protein (Dybing and Lay, 1982).

This study was conducted to evaluate the performance of some new growth regulators, in addition to some of those which have been successful in other crops, with the intention of (a) enhancing the yield of soybeans and (b) thinning the number of flowers and pods at different stages during reproductive growth in order to enhance yield.

CHAPTER 2

MATERIALS AND METHODS

The experiments were performed at the University of Tennessee Plant Science Field Laboratory in Knoxville for three years (1983-1985).

Two determinate cultivars, 'Essex' and 'Forrest', and one indeterminate experimental soybean line, TN77-31 were used in the experiments. The varieties were planted in early to mid-May and again in early to mid-June each year in order to simulate conventional and double-crop planting dates, respectively.

The experiments were conducted in a split-plot arrangement of treatments in a randomized complete block design with three replications. Varieties served as main plots, and growth regulator chemicals served as subplots. Plots consisted of four rows 3.05 m long and 0.91 m between rows with 100 seeds per row. Only the two center rows were treated with the appropriate chemical.

The growth regulators used in the experiments were gibberellic acid (GA), 6-benzyladenine (BA), daminozide (DA), chlorflurenol (CH), mepiquat chloride (MC), ancymidol (AN), ethephon (ET) and brassinosteroid 1105 (BR). A description of each chemical, as well as rates and times of application, is presented in Table A-1 in the Appendix and Tables 1 and 2. Plants in the control treatment did not have any plant growth regulator applied. In 1983, 'X-77' (1 ml l⁻¹) was

Table 1. Abbreviation and descriptions of growth regulator treatments and growth stages at which they were applied to three soybean varieties

Abbreviation	Description
GA(S)	Gibberellic acid, seed treatment
GA(V2) [†]	Gibberellic acid, applied at V2 growth stage
GA(R1)	Gibberellic acid, applied at R1 growth stage
ET(R1)	Ethephon, applied at R1 growth stage
ET(R1+R3)	Ethephon applied at R1 growth stage and again at R3 growth stage
BA(R1)	6-Benzyladenine, applied at R1 growth stage
AN(R1)	Ancymidol applied at R1 growth stage
DA(R1)	Daminozide applied at R1 growth stage
CH(R1)	Chlorflurenol applied at R1 growth stage
MC+ET(R1)	Mepiquat chloride and Ethephon both applied at R1 growth stage
BR	Brassinosteroid 1105 applied at V2 and 2 and 4 days later (1984)
	Brassinosteroid 1105 applied at cotyledonary growth stage and 2, 4 and 6 days later (1985)
BR+NAA	Brassinosteroid 1105 and naphthaleneacetic acid applied at same growth stages as for BR
GA(V2)+CH(R1)	Gibberellic acid applied at V2 and Chlorflurenol applied at R1 growth stage. (This treatment for only Forrest cultivar, June planting)

[†]Growth stages (after Fehr et al., 1971) at which growth regulators were applied foliarly are shown inside parentheses (S = seed treatment)

Table 2. Time and rates of application of plant growth regulators used in experiments during 1983-85

Treatment	Rates		
	1983	1984	1985
	----- ppm -----		
GA(S1) [†]	25,000	22,500	98
GA(S2)	--	11,268	390
GA(S3)	--	5,616	--
GA(V2)	250	250	250
GA(R1)	250	250	250
ET1(R1)	1,000	1,000	1,000
ET2(R1)	500	500	2,000
ET4(R1)	--	--	4,000
ET(R1+R3)	1,000 + 500	1,000 + 500	4,000 + 2,000
BA(R1)	10	10	10
AN(R1)	2	2	2
DA(R1)	1,000	1,000	1,000
CH(R1)	50	50	50
MC(R1)	400	400	400
MC+ET(R1)	400 + 500	400 + 500	400 + 2,000
BR --	1	1	
BR+NAA	--	1 + 1.86	1 + 1.86
GA(V2)+CH(R1)	250 + 50	250 + 50	250 + 50

[†]S= seed; V2 = two nodes on main stem; R1 = first flower; R3 = first pod

See Table 1 for detailed description

CRANES & CREST

used as a surfactant; whereas 0.5 percent 'Tween 20' was used in 1984 and 1985. No surfactant was used for the brassinosteroid treatments. All of these treatments with the exception of the GA seed treatment were applied as a foliar spray at growth stages V2, R1 or R3 or combinations of them by means of a pressurized hand sprayer (207 KPa) with a single flat fan nozzle (No. 8003). The seed treatments consisted of coating the seeds with a suspension of gibberellic acid in vegetable oil prior to planting.

All genotypes received all plant growth regulator treatments for the May planting. However, for the June planting, Essex was not treated with any of the growth retardants in order to prevent further reduction in height in the late planting. Forrest received the growth retardants CH plus a combination of CH and GA. TN77-31, a tall indeterminate line, was treated with the growth retardants CH, MC and DA.

The GA concentration used for seed treatment differed each year. The 1983 seed treatment caused excessive elongation of internodes, leading to lodging and premature death of all plants. The three lower concentrations in 1984 did not result in such an extreme reaction, but plant stand was poor in some cases. A greenhouse experiment in 1985, using various GA concentrations, resulted in selecting two concentrations (98 ppm and 390 ppm) for the field experiments.

In 1984 and 1985, flower buds, open flowers and pods were counted just before the ethephon treatments were applied and again about two days after application of the chemical. Two plants were selected at

maturity from each plot and the frequency of one-, two- and three-seed pods at each node on the mainstem and branches was determined.

The two treated rows of each plot were trimmed to 2.44 m at maturity. The plants were harvested and threshed, and plot yield determined. Seed yield was adjusted to 13 percent moisture. Seed samples were sent to the U.S.D.A Northern Regional Research Center in Peoria, Illinois, for the determination of percent protein and percent oil. In addition, the linolenic and linoleic acid percentages were determined for only the chlorflurenol and control treatments.

CHAPTER 3

RESULTS

Yield and Yield Characteristics: May PlantingSeed Yield

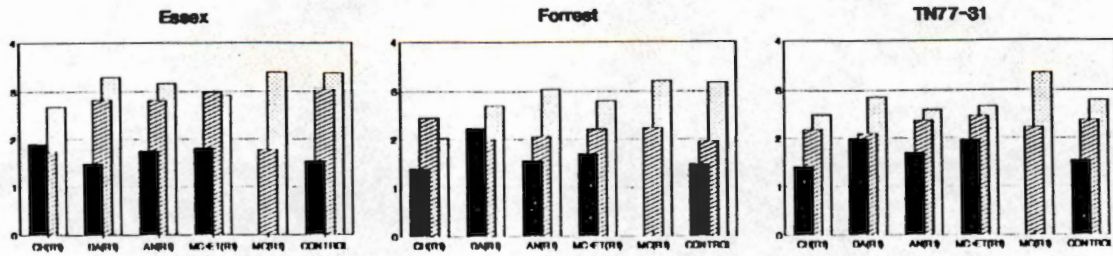
Growth retardants: In 1983 and 1984, no growth retardants significantly affected seed yield of the three varieties. In 1985, although chlorflurenol tended to decrease seed yield in all varieties, this decrease was significantly different from the control only for Forrest (Fig. 1).

Ethephon treatments: Ethephon applied at beginning of flowering and again at early pod fill [ET(R1+R3)] was the only ethephon treatment that significantly affected varietal yield, lowering Essex yield only in 1985 (Fig. 1).

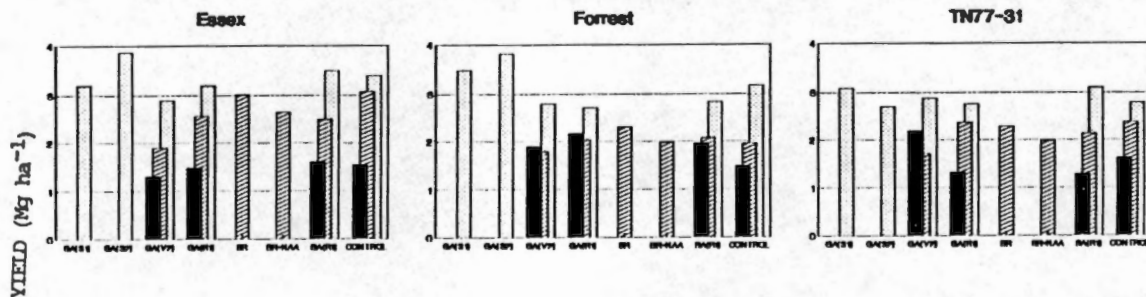
Growth promoters: The seed treatment of gibberellic acid at a concentration of 390 ppm (GAS2) increased seed yield of the determinate varieties (Forrest and Essex) in 1985, but these were not significantly different from the control. No growth promoter significantly affected seed yield of any variety in 1983 and 1984 (Fig. 1).

The relationship among varieties with respect to seed yield remained relatively the same after growth regulator applications as with no treatment (control).

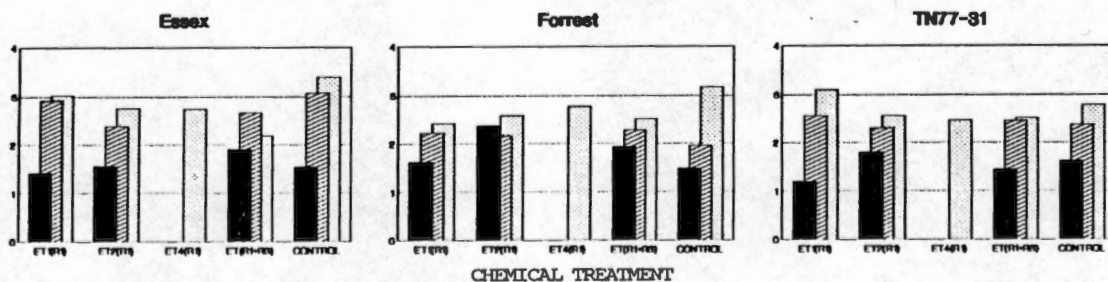
Growth Retardants



Growth Promoters



Ethephon[§]



LSD(0.5) = 0.7 (1983)
= 1.3 (1984)
= 0.5 (1985)

LSD(0.5) = 0.8 (1983)
= 1.0 (1984)
= 0.5 (1985)

LSD(0.5) = 0.9 (1983)
= 0.6 (1984)
= 0.4 (1985)

■ 1983 ▨ 1984 □ 1985

§1985 ET rates different from 1983 and 1984.

Fig. 1. Growth regulator effects on mean yield (Mg ha^{-1}) of three soybean varieties planted in May 1983-1985.

Hundred-Seed Weight

Growth retardants: Chlorflurenol is the only growth retardant that affected varietal hundred-seed weight. This treatment significantly increased hundred-seed weight of Forrest in 1985 (Table 3) and that of TN77-31 in 1984, but significantly decreased it in 1983 for TN77-31.

Ethephon treatments: Of the ethephon treatments, only ET(R1+R3) significantly altered seed weight. The treatment ET(R1+R3) significantly lowered hundred seed weight of Essex in 1985 and that of TN77-31 in 1983 (Table 3).

Growth promoters: Benzyladenine (BAR1) is the only growth promoter that significantly affected hundred-seed weight. This treatment significantly decreased seed weight of only TN77-31 in 1983 (Table 3).

Although the other treatments had no significant effects on hundred-seed weight, some important trends occurred: GA(S1) and GA(S2) increased seed weight of all varieties in 1985, and GA(V2) decreased Essex seed weight all three years of the experiment (Table 3).

Frequency of One-Seed Pods On Mainstem

Growth retardants: No growth retardant significantly altered varietal mainstem one-seed pod number any year. However, ancymidol AN(R1) consistently affected the varieties, increasing the number of one-seed pods of TN77-31 and decreasing that of Forrest from 1983 through 1985 (Fig. 2).

Table 3. Mean hundred seed weight (g) of three soybean varieties as affected by growth regulator treatment and planting date

Chemical Treatments [†]	-----1983-----						-----1984-----						-----1985-----					
	May Planting			June Planting			May Planting			June Planting			May Planting			June Planting		
	ES [‡]	PO [‡]	TN [‡]	ES	PO	TN	ES	PO	TN	ES	PO	TN	ES	PO	TN	ES	PO	TN
Control	10.7 ^{ab}	10.7 ^a	14.0 ^a	11.6 ^a	11.6 ^a	14.1 ^a	13.7 ^a	11.2 ^a	13.2 ^{bc}	11.6 ^a	11.5 ^a	15.4 ^a	14.4 ^{ab}	11.7 ^{bcd}	14.7 ^{ab}	13.2 ^a	11.4 ^b	15.6 ^b
GROWTH RETARDANTS																		
CH(R1)	10.8 ^a	10.1 ^a	11.7 ^{cd}	-	-	12.6 ^a	12.6 ^a	11.2 ^a	15.2 ^{ab}	-	11.5 ^a	13.9 ^a	13.7 ^{abc}	17.8 ^a	16.0 ^a	-	11.4 ^{ab}	17.7 ^a
DA(R1)	10.7 ^a	10.6 ^a	13.6 ^{ab}	-	-	13.6 ^a	13.4 ^a	11.0 ^a	13.1 ^{bc}	-	-	15.2 ^a	13.9 ^{abc}	11.9 ^{bcd}	13.1 ^a	-	-	15.2 ^b
AN(R1)	11.2 ^a	10.9 ^a	13.0 ^{abc}	-	-	-	13.4 ^a	11.6 ^a	14.3 ^{ab}	-	-	-	14.4 ^{ab}	12.3 ^{bcd}	15.1 ^{ab}	-	-	-
MC+ET(R1)	10.7 ^a	10.4 ^a	13.4 ^{ab}	-	-	13.1 ^a	13.4 ^a	10.5 ^a	13.3 ^{bc}	-	-	13.5 ^a	14.7 ^{ab}	11.2 ^d	14.6 ^{ab}	-	-	15.0 ^{bc}
MC(R1)	-	-	-	-	-	-	12.6 ^a	11.5 ^a	13.8 ^{bc}	-	-	13.9 ^a	14.3 ^{ab}	12.0 ^{bcd}	15.7 ^a	-	-	15.8 ^b
ETHEPHON																		
ET [†] (R1)	11.2 ^a	10.9 ^a	12.6 ^{a-d}	11.2 ^a	11.1 ^a	13.3 ^a	13.3 ^a	10.9 ^a	13.6 ^{bc}	10.8 ^{ab}	10.8 ^a	14.0 ^a	14.4 ^{ab}	11.3 ^{cd}	14.6 ^{ab}	11.4 ^a	11.6 ^b	15.0 ^{bc}
ET [†] (R1)	10.5 ^a	10.9 ^a	12.7 ^{a-d}	10.9 ^a	11.2 ^a	13.1 ^a	12.8 ^a	10.8 ^a	13.2 ^{bc}	11.2 ^a	10.5 ^a	13.1 ^a	13.7 ^{abc}	11.7 ^{bcd}	14.8 ^{ab}	12.6 ^a	11.9 ^b	14.8 ^{bc}
ET [†] (R1)	-	-	-	-	-	-	-	-	-	-	-	-	13.5 ^{abc}	12.5 ^b	14.8 ^{ab}	11.8 ^a	13.4 ^a	15.3 ^{bc}
ET(R1+R3)	10.4 ^a	10.7 ^a	11.5 ^d	10.9 ^a	10.7 ^a	12.5 ^a	13.6 ^a	10.9 ^a	13.2 ^{bc}	10.3 ^b	10.7 ^a	13.7 ^a	12.9 ^c	11.8 ^{bcd}	14.1 ^b	11.3 ^a	13.2 ^a	14.2 ^c
GROWTH PROMOTERS																		
GA(S1)	-	-	-	-	-	-	-	-	-	-	-	-	14.4 ^{ab}	12.2 ^{bcd}	15.6 ^a	12.1 ^a	11.5 ^b	15.8 ^b
GA(S2)	-	-	-	-	-	-	-	-	-	-	-	-	14.5 ^{ab}	12.2 ^{bcd}	15.5 ^{ab}	11.4 ^a	11.8 ^b	15.8 ^b
GA(V2)	10.0 ^a	11.0 ^a	12.6 ^{a-d}	11.7 ^a	10.8 ^a	13.0 ^a	12.0 ^a	11.0 ^a	12.4 ^c	11.3 ^a	10.7 ^a	14.1 ^a	13.3 ^{bc}	12.0 ^{bcd}	15.0 ^{ab}	11.4 ^a	10.6 ^b	14.8 ^{bc}
GA(R1)	10.1 ^a	10.5 ^a	12.6 ^{a-d}	-	-	-	-	-	13.2 ^{bc}	-	-	-	13.7 ^{abc}	12.3 ^{bc}	14.9 ^{ab}	-	-	-
GA(V2)+CH(R1)	-	-	-	-	10.8 ^a	-	-	10.8 ^a	12.9 ^{bc}	11.3 ^a	11.0 ^a	14.0 ^a	-	-	-	-	13.4 ^a	-
BR	-	-	-	-	-	-	13.1 ^a	10.8 ^a	12.9 ^{bc}	11.3 ^a	12.0 ^a	14.0 ^a	-	-	-	12.9 ^a	11.8 ^b	15.3 ^{bc}
BR+NAA	-	-	-	-	-	-	13.0 ^a	10.9 ^a	13.4 ^{bc}	11.7 ^a	11.3 ^a	12.8 ^a	-	-	-	12.9 ^a	11.2 ^b	15.9 ^b
BA(R1)	11.0 ^a	10.8 ^a	12.2 ^{bcd}	-	-	-	13.3 ^a	11.7 ^a	13.5 ^{bc}	-	-	-	14.4 ^{ab}	11.8 ^{bcd}	15.7 ^a	-	-	-

[†] See Tables 1 and 2 for description.[‡] ES = Essex, PO = Forest, IN = IN77-31.[§] Means with a common letter within year, planting date, and variety are not significantly different at P<0.05 based on Student-Newman-Keul test.

GROWTH RETARDANTS Essex

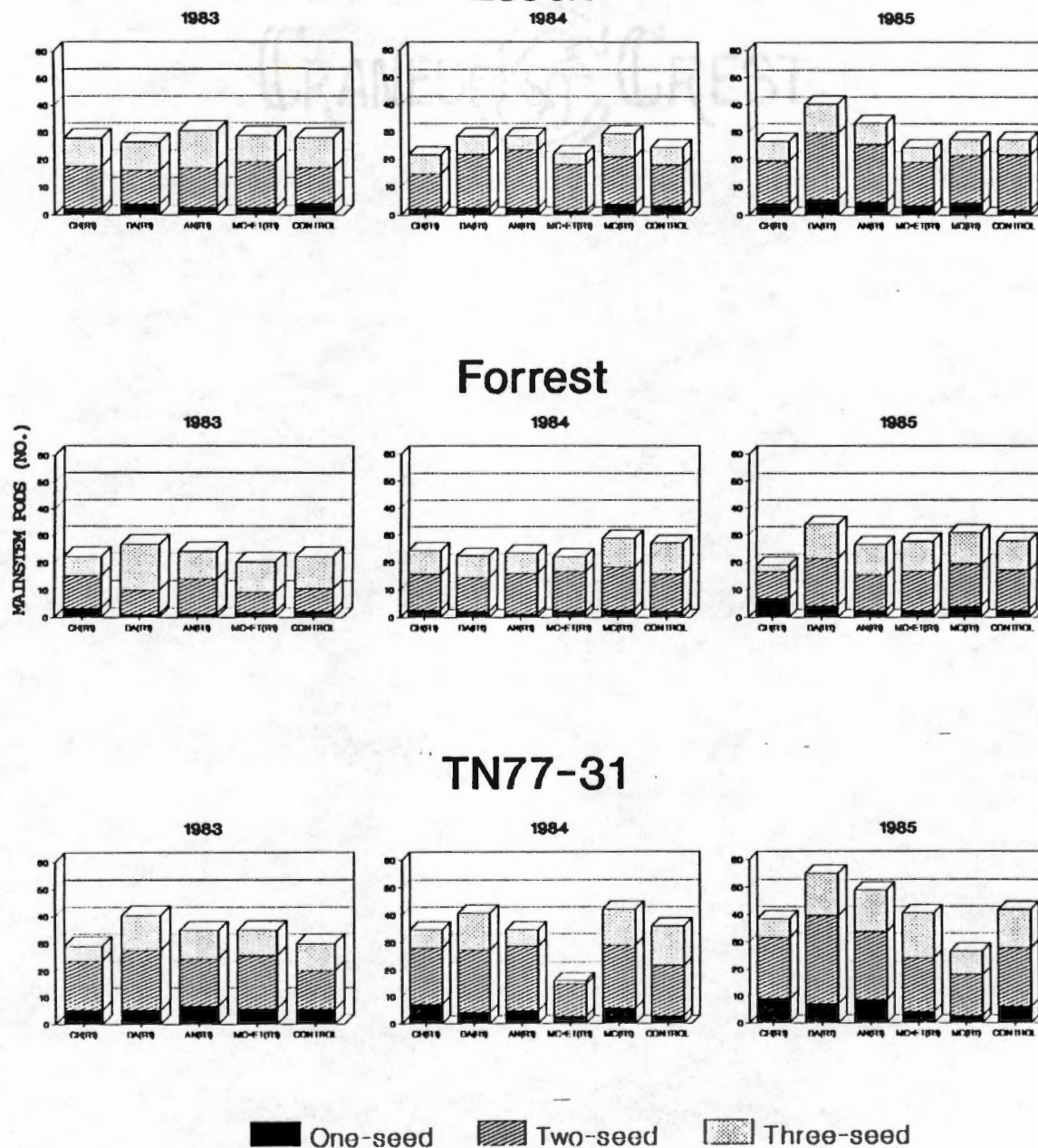


Fig. 2. The effects of growth retardants on mean number of one-, two- and three-seed pods on the mainstem of three soybean varieties planted in May 1983-1985.

Ethephon treatments: The ethephon treatments did not significantly affect the number of mainstem one-seed pods (Fig. 3).

Growth promoters: No growth promoter altered the number of mainstem one-seed pods (Fig. 4).

Frequency of Two-Seed Pods on Mainstem

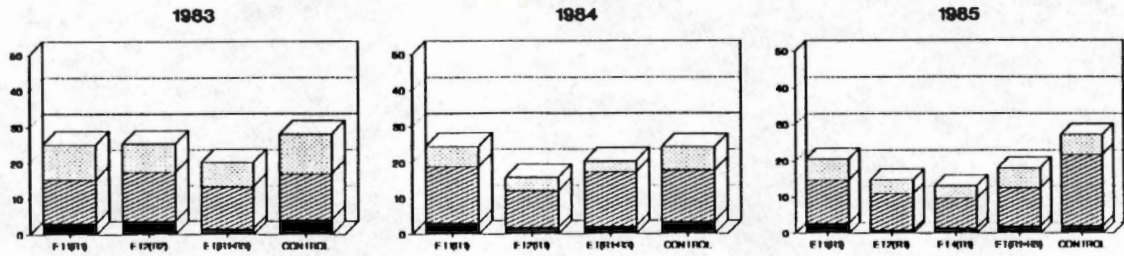
Growth retardants: The growth retardants did not significantly change the frequency of two-seed pods on the mainstem. Chlorflurenol, daminozide and ancymidol increased the frequency of two-seed pods for the TN77-31 variety all three years, even though the increases were not significantly different from the control (Fig. 2).

Ethephon treatments: In 1985 all the ethephon treatments (1000, 2000, 4000, 4000+2000 ppm) tended to reduce the frequency of two-seed pods on the mainstem of all varieties, but a significant reduction ($P < 0.05$) resulted from only the 4000 ppm concentration (ET4R1) on the Essex variety (Fig. 3).

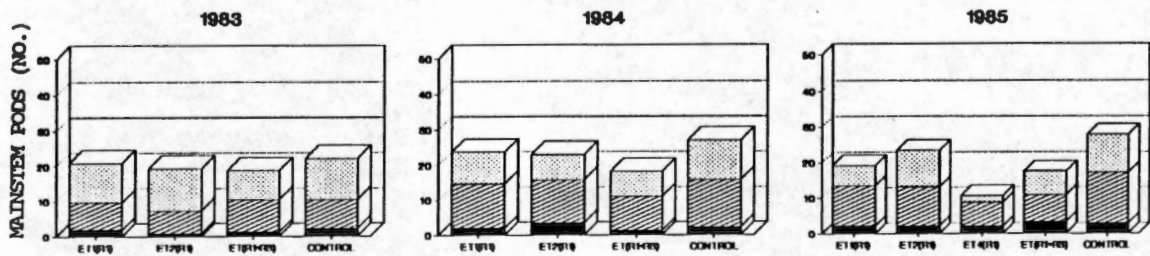
The 500 and 1000 ppm concentrations (ET1R1, ET2R1 respectively) reduced the frequency of two-seed pods per mainstem for the Forrest variety in 1983 and 1984, but these were not significantly different from the control.

Growth promoters: Gibberellic acid applied at V2 (GAV2) significantly reduced the frequency of two-seed pods on the mainstem for the Essex variety in 1984 only (Fig. 4). Applications of the other growth

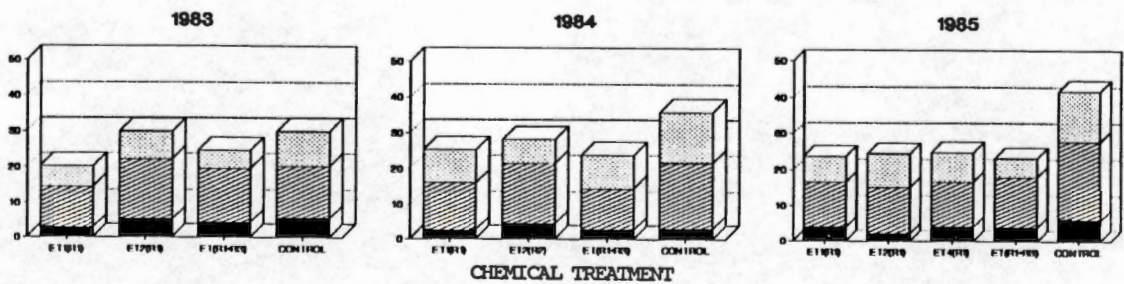
ETHEPHON[§] Essex



Forrest



TN77-31



One-seed
 Two-seed
 Three-seed

§1985 ET rates different from 1983 and 1984.

Fig. 3. The effects of ethephon treatments on mean number of one-, two- and three-seed pods on the mainstem of three soybean varieties planted in May 1983-1985.

GROWTH PROMOTERS Essex

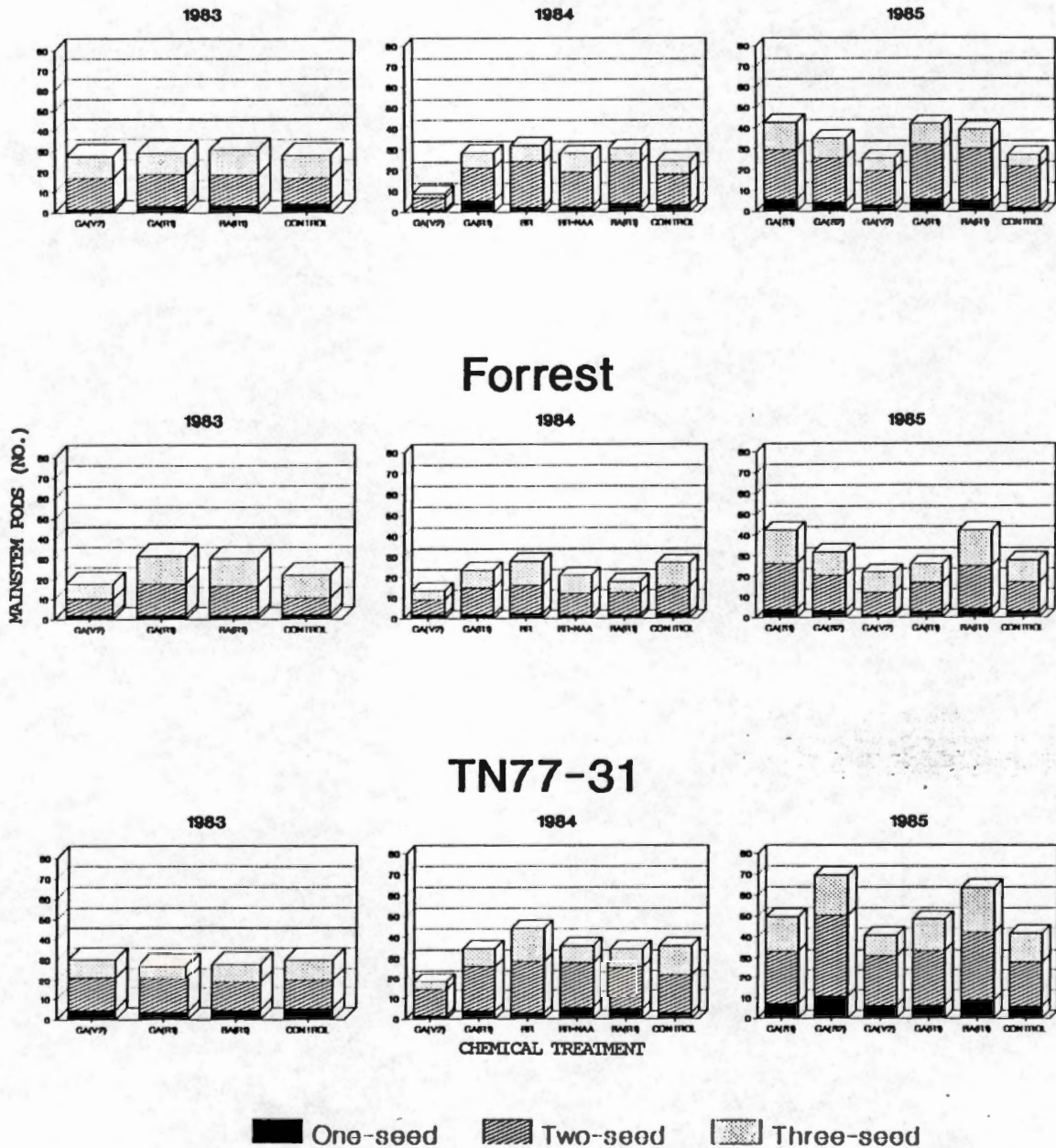


Fig. 4. The effects of growth promoters on mean number of one-, two- and three-seed pods on the mainstem of three soybean varieties planted in May 1983-1985.

promoters did not significantly change the frequency of two-seed pods per mainstem from that of the control.

Frequency of Three-Seed Pods on Mainstem

Growth retardants: Chlorflurenol and MC+ET(R1) significantly decreased the frequency of three-seed pods per mainstem for Forrest (in 1985) and TN77-31 (in 1984) (Fig. 2). Apart from these two chemicals, no other growth retardant significantly affected any variety's frequency of three-seed pods per mainstem. Chlorflurenol produced non-significant ($P>0.05$) decreases in pod number per mainstem for Forrest in 1984 and for TN77-31 in 1983-1985.

Ethephon treatments: Although all the different concentrations caused reductions in the frequency of three-seed pods per mainstem for all varieties for all three years of the experiment, only the highest concentration of ethephon [4000 ppm, i.e. ET4(R1)], applied in 1985 to Forrest, produced a decrease large enough to be significantly different from the control (Fig. 3).

Growth promoters: Both the gibberellic acid seed treatments (GAS1 and GAS2) increased the frequency of three-seed pods per mainstem of all varieties when applied in 1985, but it was only for the Essex variety that a significant increase was produced by GA(S1) (Fig. 4). None of the other growth promoters had any significant effects on the varietal frequency of three-seed pods per mainstem, although GA(V2) had the tendency to reduce the pod number per mainstem.

Frequency of One-Seed Pods on Branches

Growth retardants: The growth retardants increased the frequency of one-seed pods on branches in all varieties almost every year they were applied. However, it was only chlorflurenol (CHR1) applied on Essex in 1984 that had any significant effect. It significantly increased the frequency of one-seed pods on Essex branches over that of the control plants (Fig. 5).

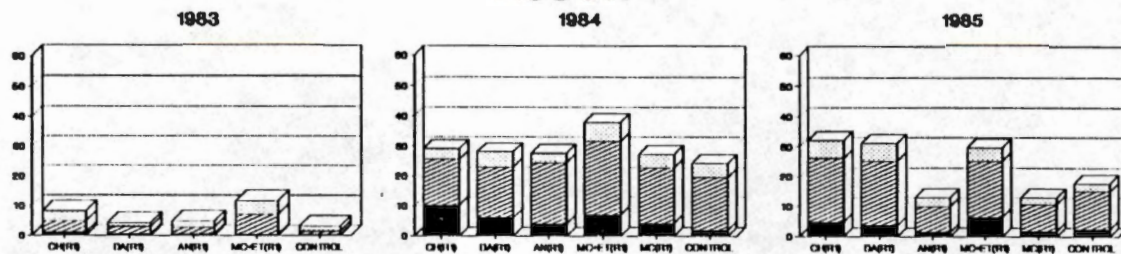
Ethephon treatments: Ethephon at rate 1000ppm (ET2R1) increased the frequency of pods per branch of Essex significantly in 1984 only (Fig. 6). The general trend was towards increased pods from ethephon application for all varieties.

Growth promoters: GA(V2) significantly increased the frequency of one-seed pods on Essex branches in 1984 and on branches of Forrest in 1985 (Fig. 7). There was a pattern of increased pods per branch with growth promoter applications for all years except for Forrest in 1984, when applications decreased pod numbers per branch.

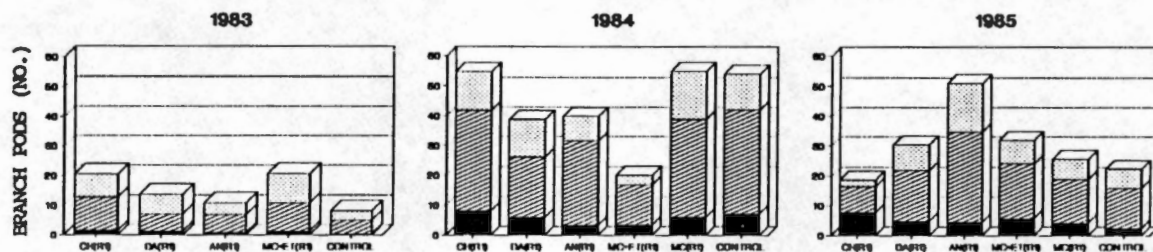
Frequency of Two-Seed Pods on Branches

Growth retardants: Of the growth retardant treatments applied on the varieties during the experimental years, only the treatment AN(R1) applied on the variety Forrest in 1985 significantly increased the frequency of two-seed pods on branches (Fig. 5). The effect of AN(R1) on Forrest pod number per branch was significantly different from that of CH(R1) and of MC(R1).

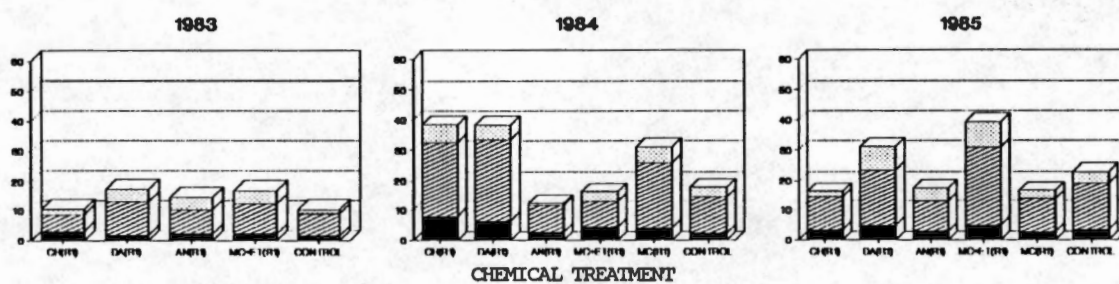
GROWTH RETARDANTS Essex



Forrest



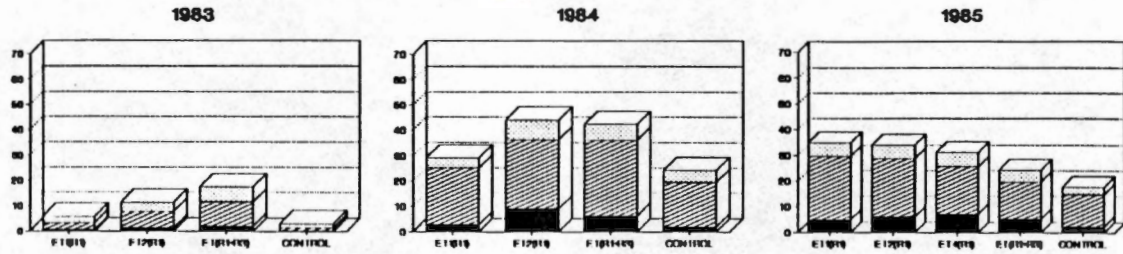
TN77-31



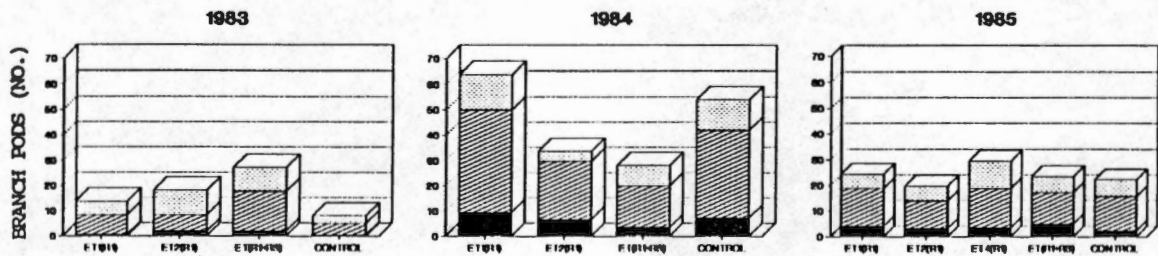
One-seed
 Two-seed
 Three-seed

Fig. 5. The effects of growth retardants on mean number of one-, two- and three-seed pods on branches of three soybean varieties planted in May 1983-1985.

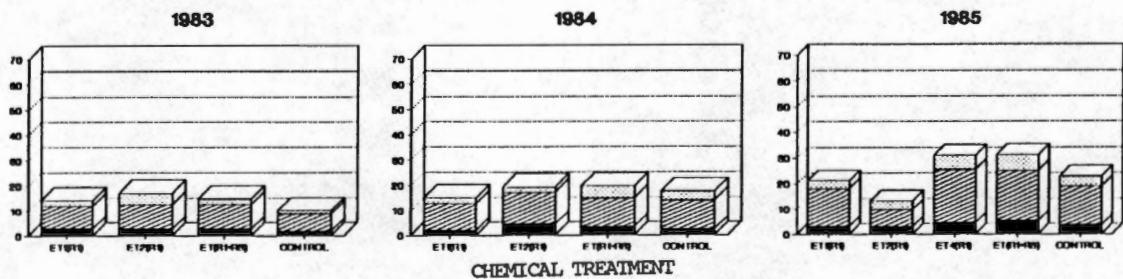
ETHEPHON^s Essex



Forrest



TN77-31



■ One-seed ▨ Two-seed ▩ Three-seed

^s1985 ET rates different from 1983 and 1984.

Fig. 6. The effects of ethephon treatments on mean number of one-, two- and three-seed pods on branches of three soybean varieties planted in May 1983-1985.

GROWTH PROMOTERS Essex

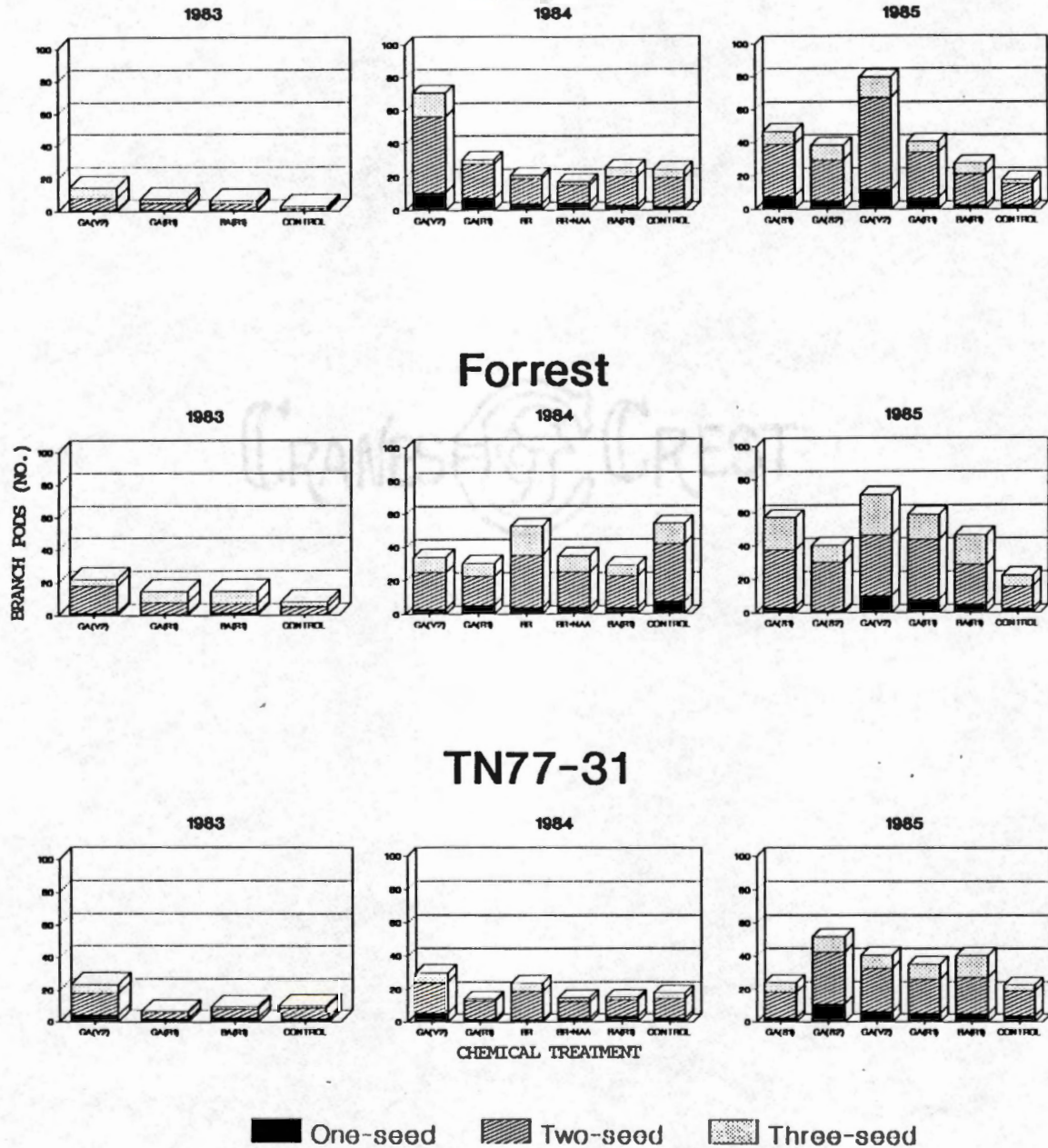


Fig. 7. The effects of growth promoters on mean number of one-, two- and three-seed pods on branches of three soybean varieties planted in May 1983-1985.

Ethephon treatments: No ethephon treatment significantly affected the frequency of two-seed pods per branch for the three varieties. Ethephon application tended to increase the two-seed pod number per branch (Fig. 6).

Growth promoters: Gibberellic acid applied at V2 (GAV2) significantly increased the frequency of two-seed pods on Essex branches in 1984 and 1985 (Fig. 7). When gibberellic acid was applied as seed treatments (GAS1, GAS2) as well as foliarly at the trifoliolate stage (GAV2) and at early pod production (GAR1), the frequency of two-seed pods was significantly ($P \leq 0.05$) increased on Forrest branches in 1985. These GA treatments were not significantly different from each other.

Frequency of Three-Seed Pods on Branches

Growth retardants: Growth retardant treatments did not affect the frequency of varietal three-seed pods per branch significantly (Fig. 5).

Ethephon treatments: No significant effects occurred from application of the ethephon treatments on the three varieties. However, these applications, except for Forrest and TN77-31 in 1984, caused some increases in the frequency of three-seed pods per branches (Fig. 6).

Growth promoters: GAS1 and GAV2 were the only two growth promoter treatments that significantly increased the frequency of pods per branch. These treatments increased the frequency of the three-seed pods per branches of Forrest only in 1985. This same year, all the growth

promoter treatments tended to increase the three-seed pods per branch of all varieties (Fig. 7).

Total Number of Pods Per Plant

Growth retardants: The growth retardants did not significantly affect total pod number of any variety, although most treatments had the tendency to increase the pod number of the varieties (Table 4).

Ethephon treatments: Total pod number was not significantly affected by any ethephon treatment. However, there was the tendency for these treatments to increase the total pod number of Essex (Table 4).

Growth promoters: Gibberellic acid applied at V2 (GAV2) and applied as seed treatment at 98 ppm (GAS1) and benzyl adenine (BAR1) are the only growth promoters that produced significant effects. These treatments significantly increased total pod number of only the variety Forrest in 1985 (Table 4). There was the tendency for the growth promoters to increase Essex pod number; whereas, no such trends occurred for TN77-31.

Yield and Yield Characteristics: June Planting

Seed Yield

Growth retardants: Chlorflurenol when applied alone (CHR1) and in combination with gibberellic acid (GAV2+CHR1) tended generally to decrease yields of the varieties in the June plantings. In 1985 the

Table 4. Total number of pods per plant of three soybean varieties as affected by growth regulator treatment and planting date

Chemical Treatments [†]	-----1983-----						-----1984-----						-----1985-----					
	May Planting			June Planting			May Planting			June Planting			May Planting			June Planting		
	ES [‡]	FO [‡]	TN [‡]	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN
Control	31.2 ^{ab}	30.3 ^a	40.3 ^a	23.2 ^a	35.5 ^a	35.2 ^a	48.7 ^a	81.0 ^a	53.8 ^a	32.2 ^a	54.8 ^a	33.3 ^a	44.8 ^{ab}	50.2 ^{d-e}	64.7 ^{ab}	60.7 ^{bc}	31.8 ^c	58.5 ^a
<u>GROWTH RETARDANTS</u>																		
CH(R1)	36.2 ^a	43.0 ^a	39.7 ^a	-	-	41.7 ^a	50.8 ^a	79.0 ^a	72.8 ^a	-	36.2 ^a	32.5 ^a	58.8 ^{ab}	37.5 ^g	54.7 ^{ab}	-	75.3 ^{abc}	74.7 ^a
DA(R1)	30.7 ^a	40.7 ^a	58.0 ^a	-	-	45.0 ^a	56.5 ^a	61.0 ^a	79.0 ^a	-	-	41.8 ^a	71.7 ^{ab}	64.5 ^{b-g}	86.3 ^{ab}	-	-	87.3 ^a
AN(R1)	35.7 ^a	35.0 ^a	49.5 ^a	-	-	-	56.3 ^a	63.7 ^a	46.8 ^a	-	-	-	46.0 ^{ab}	77.5 ^{b-e}	66.3 ^{ab}	-	-	-
MC+ET(R1)	40.5 ^a	41.2 ^a	52.0 ^a	-	-	42.7 ^a	60.0 ^a	42.2 ^a	32.0 ^a	-	-	22.2 ^a	53.8 ^{ab}	59.7 ^{c-g}	79.8 ^{ab}	-	64.0 ^a	-
MC(R1)	-	-	-	-	-	-	56.7 ^a	83.8 ^a	73.0 ^a	-	-	33.2 ^a	40.3 ^b	56.5 ^{c-g}	43.5 ^b	-	-	69.0 ^a
<u>ETHEPHON</u>																		
ET ₁ (R1)	31.0 ^a	34.8 ^a	34.5 ^a	31.7 ^a	42.7 ^a	39.3 ^a	54.0 ^a	87.3 ^a	40.7 ^a	33.8 ^a	56.2 ^a	28.0 ^a	55.5 ^{ab}	43.5 ^{efg}	44.8 ^b	47.0 ^b	45.0 ^{abc}	85.7 ^a
ET ₂ (R1)	36.8 ^a	37.5 ^a	47.0 ^a	24.8 ^a	32.8 ^a	38.0 ^a	60.0 ^a	56.7 ^a	47.5 ^a	43.3 ^a	40.5 ^a	25.8 ^a	48.8 ^{ab}	43.5 ^{efg}	37.8 ^b	69.0 ^b	70.5 ^{abc}	57.8 ^a
ET ₃ (R1)	-	-	-	-	-	-	-	-	-	-	-	-	44.3 ^{ab}	40.2 ^{fg}	55.8 ^{ab}	40.3 ^{bc}	59.2 ^{abc}	62.7 ^a
ET(R1+R3)	37.7 ^a	45.8 ^a	39.8 ^a	28.8 ^a	45.7 ^a	42.7 ^a	62.7 ^a	46.2 ^b	43.5 ^b	34.3 ^a	62.3 ^a	33.6 ^a	42.3 ^{ab}	40.8 ^{fg}	54.7 ^{ab}	35.7 ^c	58.8 ^{abc}	52.7 ^a
<u>GROWTH PROMOTERS</u>																		
GA(S1)	-	-	-	-	-	-	-	-	-	-	-	-	89.5 ^{ab}	99.7 ^{ab}	74.3 ^{ab}	59.7 ^{bc}	93.7 ^{ab}	83.2 ^a
GA(S2)	-	-	-	-	-	-	-	-	-	-	-	-	73.7 ^{ab}	72.2 ^{b-f}	121.5 ^a	69.5 ^b	107.7 ^a	77.8 ^b
GA(V2)	42.2 ^a	40.0 ^a	53.8 ^a	36.3 ^a	41.0 ^a	39.8 ^a	79.8 ^a	47.8 ^a	48.3 ^a	48.8 ^a	45.2 ^a	40.2 ^a	105.0 ^a	93.0 ^{abc}	81.7 ^{ab}	97.5 ^a	74.0 ^{abc}	90.5 ^a
GA(R1)	36.8 ^a	46.5 ^a	33.8 ^a	-	-	-	58.8 ^a	54.0 ^a	46.8 ^a	-	-	-	83.2 ^{ab}	84.8 ^{a-d}	84.0 ^{ab}	-	-	-
GA(V2)+CH(R1)	-	-	-	-	47.0 ^a	-	52.5 ^a	80.3 ^a	68.3 ^a	41.5 ^a	52.0 ^a	39.0 ^a	-	-	-	-	43.3 ^{bc}	-
BR	-	-	-	-	-	-	-	-	50.7 ^a	38.5 ^a	48.8 ^a	36.5 ^a	-	-	-	51.2 ^{bc}	63.0 ^{abc}	97.5 ^a
BR+NAA	-	-	-	-	-	-	45.3 ^a	55.7 ^a	50.7 ^a	38.5 ^a	40.5 ^a	36.5 ^a	-	-	-	66.0 ^b	70.7 ^{abc}	74.5 ^a
BA(R1)	36.2 ^a	45.2 ^a	37.5 ^a	-	-	-	56.2 ^a	47.0 ^a	49.5 ^a	-	-	-	66.8 ^{ab}	89.0 ^{abc}	104.2 ^{ab}	-	-	-

[†]See Tables 1 and 2 for description.

[‡]ES = Essex, FO = Forest, TN = TN77-31.

[§]Means with the same letter within years, planting date and variety are not significantly different at 5% level of probability.

GAV2+CHR1 treatment significantly reduced the seed yield of only Forrest (Fig. 8).

For the variety TN77-31, all the growth retardants applied in 1984 and 1985 suppressed yield in the June plantings, but significant decreases were produced by only chlorflurenol (CHR1) in 1984 and by both CHR1 and MC+ET(R1) in 1985 (Fig. 8).

Ethephon treatments: The ethephon treatment, ET(R1+R3), in 1985 was the only treatment that significantly affected Essex, and it decreased seed yield (Fig. 8). No ethephon treatment significantly affected the seed yield of Forrest and TN77-31.

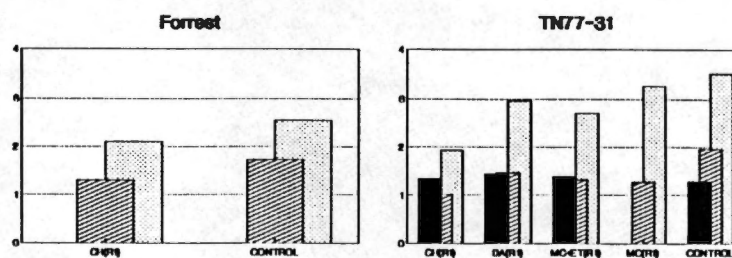
Growth promoters: Gibberellic acid applied at V2 (GAV2) significantly decreased seed yield of TN77-31 in 1985 only (Fig. 8), though this treatment tended to decrease (not significantly) seed yield of Forrest and TN77-31 all three years.

Brassinosteroid alone (BR) and in combination with naphthalene acetic acid (BR and BR+NAA) did not produce any significant effects on varietal yield.

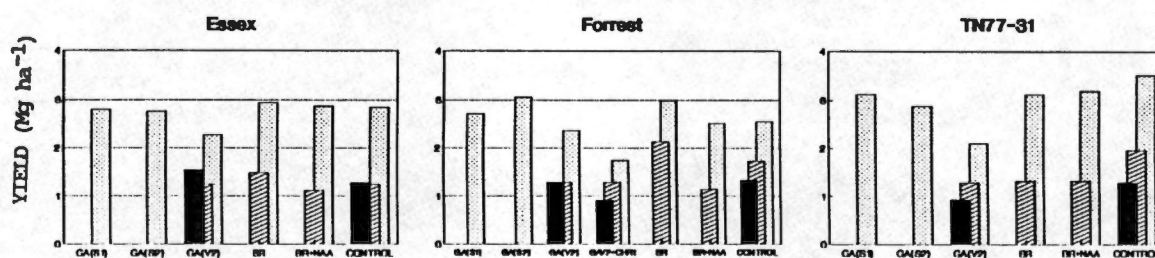
Hundred-Seed Weight

Growth retardants: Application of chlorflurenol alone did not significantly affect hundred-seed weight of Forrest in the June plantings, but in combination with gibberellic acid (GAV2+CHR1), it significantly increased hundred-seed weight in 1985 (Table 3).

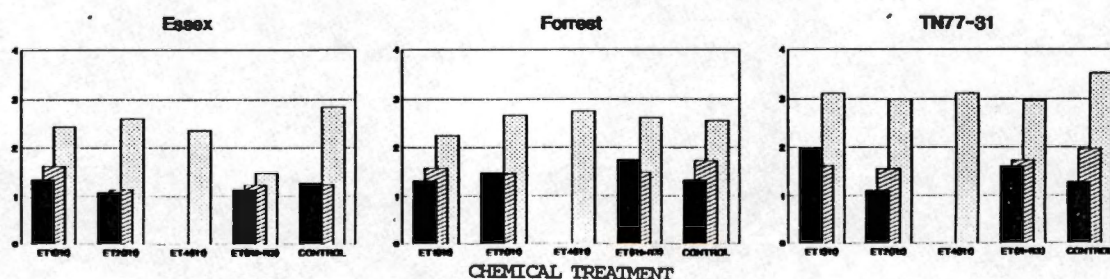
Growth Retardants



Growth Promoters



Ethephon[§]



LSD(0.5) = 0.9 (1983)
 = 0.7 (1984)
 = 0.3 (1985)

LSD(0.5) = 0.6 (1983)
 = 0.5 (1984)
 = 0.5 (1985)

LSD(0.5) = 1.2 (1983)
 = 0.5 (1984)
 = 0.5 (1985)

■ 1983 ▨ 1984 ▩ 1985

[§]1985 ET rates different from 1983 and 1984.

Fig. 8. Growth regulator effects on mean yield (Mg ha^{-1}) of three soybean varieties planted in June 1983-1985.

For the variety TN77-31, chlorflurenol applications significantly increased hundred-seed weight in 1985 only. The other growth retardants had no significant effects on seed weight.

Ethephon treatments: The ethephon treatments generally tended to decrease the hundred-seed weight of Essex and TN77-31, but only ET(R1+R3) applied to Essex in 1984 (1000 ppm + 500 ppm) and to TN77-31 in 1985 (4000 ppm + 2000 ppm) significantly lowered hundred-seed weight (Table 3). Two treatments, ET(R1+R3) and ET4(R1), increased the seed weight of Forrest significantly in 1985.

Growth promoters: No growth promoter significantly affected the hundred-seed weight of any variety, although GA(V2) resulted in a trend toward a lower seed weight for Forrest and TN77-31 all three years (Table 3).

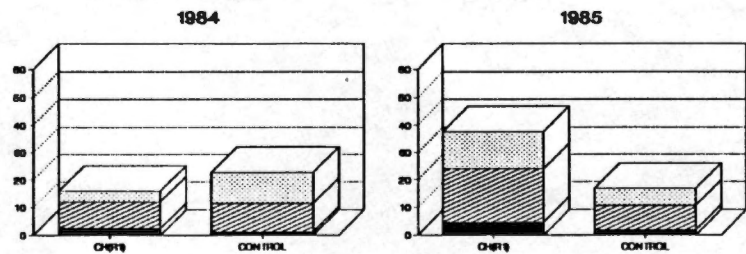
Frequency of One-Seed Pods on Mainstem

No growth regulators significantly affected the frequency of varietal one-seed pods on mainstem (Figs. 9-11).

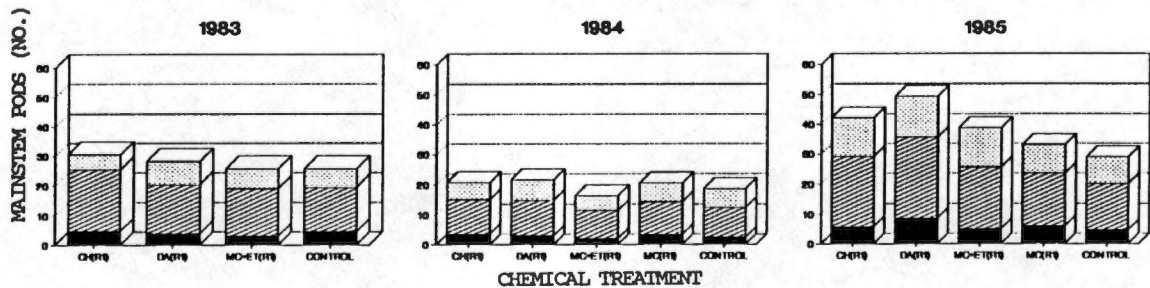
Frequency of Two-Seed Pods on Mainstem

Growth retardants: The growth retardants had no significant effects on the frequency of two-seed pods per mainstem for Forrest and TN77-31, although there was a trend for pod increase for the variety TN77-31 (Fig. 9).

GROWTH RETARDANTS Forrest



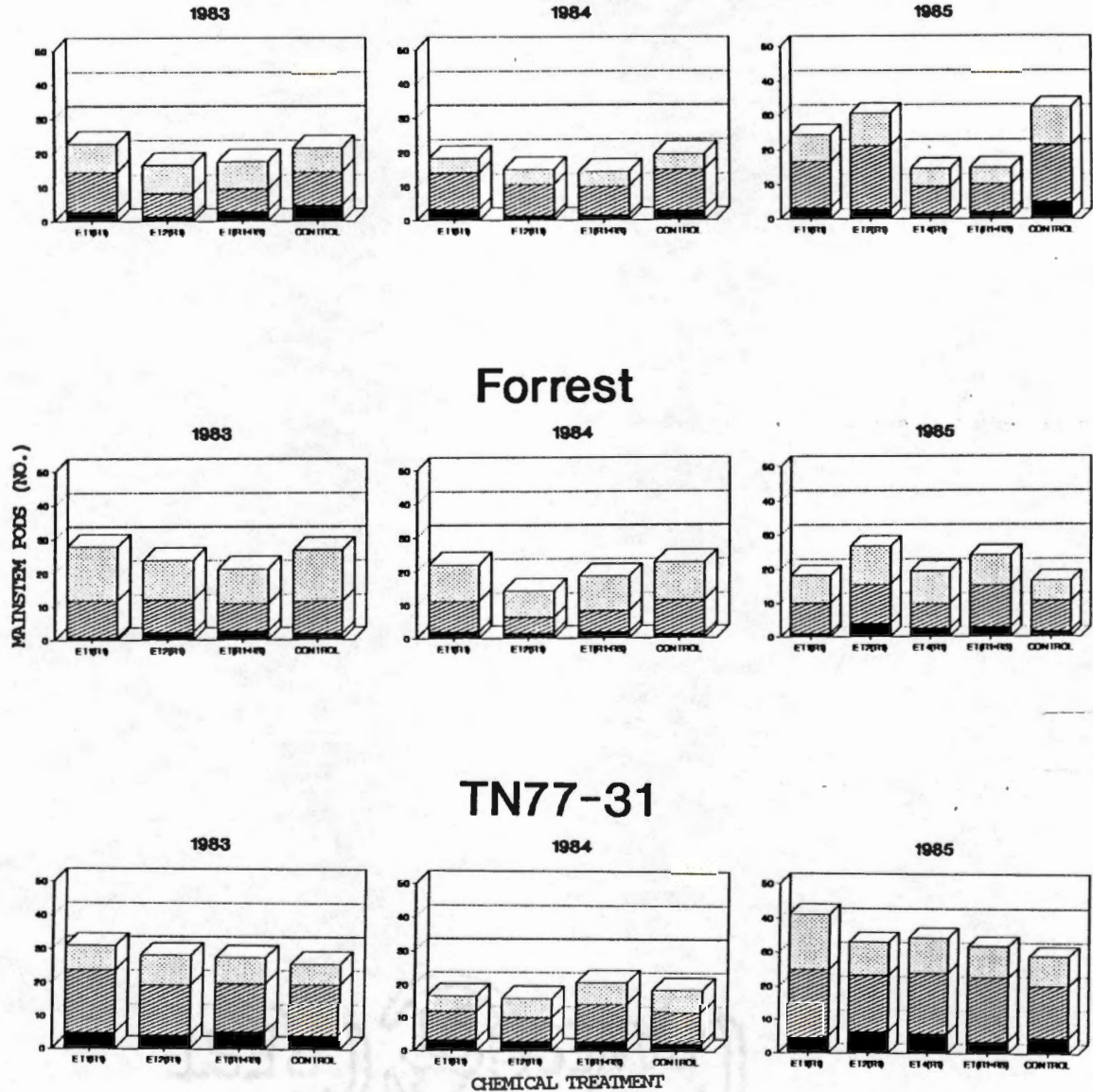
TN77-31



One-seed
 Two-seed
 Three-seed

Fig. 9. The effects of growth retardants on mean number of one-, two- and three-seed pods on the mainstem of three soybean varieties planted in June 1983-1985.

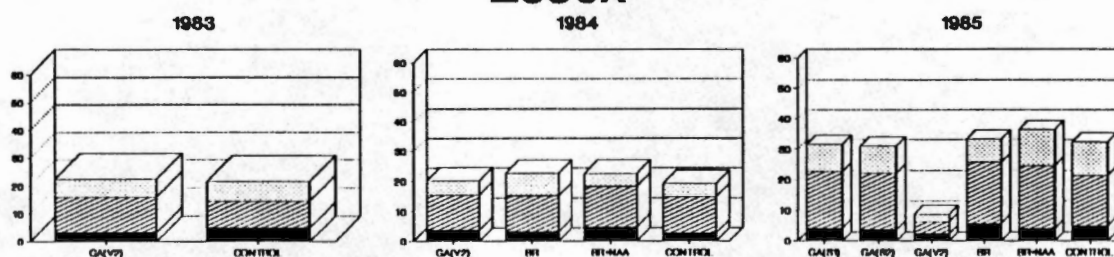
ETHEPHON[§] Essex



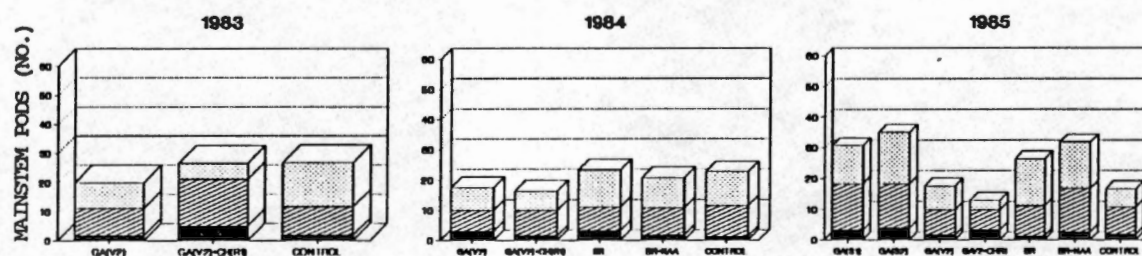
§1985 ET rates different from 1983 and 1984.

Fig. 10. The effects of ethephon treatments on mean number of one-, two- and three-seed pods on the mainstem of three soybean varieties planted in June 1983-1985.

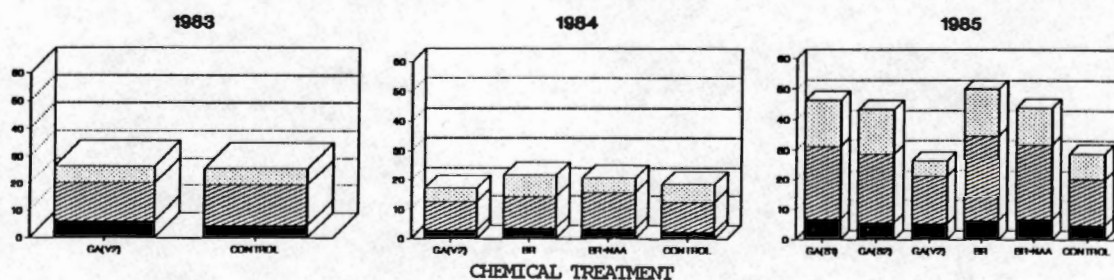
GROWTH PROMOTERS Essex



Forrest



TN77-31



One-seed
 Two-seed
 Three-seed

Fig. 11. The effects of growth promoters on mean number of one-, two- and three-seed pods on the mainstem of three soybean varieties planted in June 1983-1985.

Ethephon treatments: No ethephon treatment significantly affected the number of pods per mainstem (Fig. 10).

Growth promoters: Gibberellic acid applied at V2 had the tendency to lower the frequency of two-seed pods per mainstem for all varieties but it was only in 1985 that GA(V2) significantly decreased the number of pods per mainstem for the Essex variety (Fig. 11). None of the other growth promoters had any significant effects on two-seed pod number, though the gibberellic acid seed treatments increased pod number per mainstem of all varieties when applied in 1985 and BR and BR+NAA increased two-seed pod number per mainstem for TN77-31 in 1984 and 1985.

Frequency of Three-Seed Pods on Mainstem

Growth retardants: Chlorflurenol in combination with gibberellic acid [GAV2 +CHR1] tended to decrease the frequency of three-seed pods per mainstem for Forrest all three years, but a significant decrease occurred only in 1983 (Fig. 9). Applied alone, chlorflurenol [CHR1] did not produce consistent results. None of the growth retardants significantly affected the frequency of three-seed pods per mainstem of TN77-31.

Ethephon treatments: The ethephon treatments had no significant effects on varietal frequency of three-seeds per mainstem (Fig. 10).

Growth promoters: Gibberellic acid applied at V2 (GAV2) had no consistent effects on Forrest, but consistently lowered the frequency of three-seed pods per mainstem for Essex, for which the decreases were

significant in 1985 (Fig. 11). For both Essex and TN77-31 (1985), the effect of GA(V2) was significantly different from that of gibberellic acid applied as seed treatments.

Frequency of One-Seed Pods on Branches

Growth retardants: The growth retardants did not significantly increase the frequency of one-seed pods per branches for Forrest and TN77-31 during any of the three years (Fig. 12). There was a tendency for one-seed pods on branches of TN77-31 to increase with use of the growth retardants in 1983 and 1984.

Ethephon treatments: Of all the ethephon treatments applied on the three varieties from 1983-1985, only ET2(R1) significantly affected pod number per branch by increasing the frequency of one-seed pods on Forrest branches in 1985 (Fig. 13). The trend for all varieties, as can be seen from the graphs, was towards an increase in the frequency of one-seed pods per branches with ethephon use in 1983 and 1984.

Growth promoters: The gibberellic acid treatments applied at V2 and as a seed treatment at the rate of 390ppm (GAS2) significantly increased the frequency of one-seed pods on branches of Forrest in 1985 (Fig. 14). No other growth promoter had any significant effect on any variety in any year.

GROWTH RETARDANTS Forrest

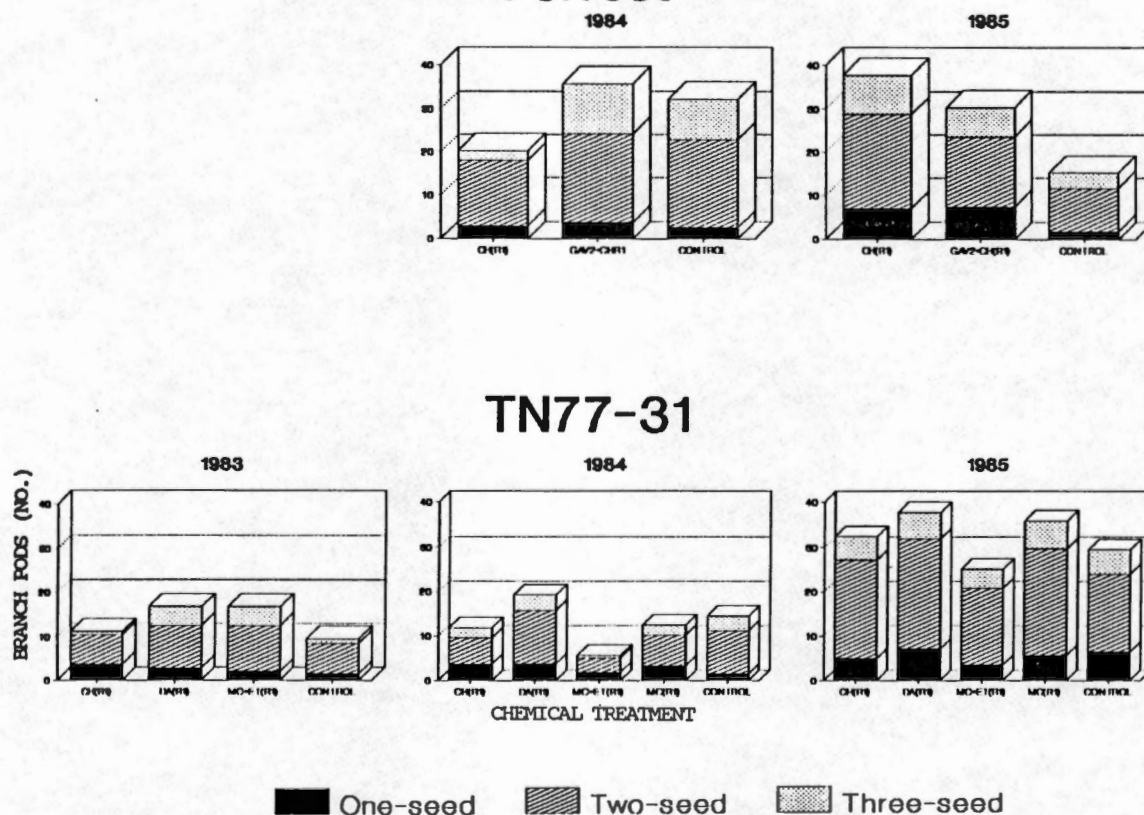
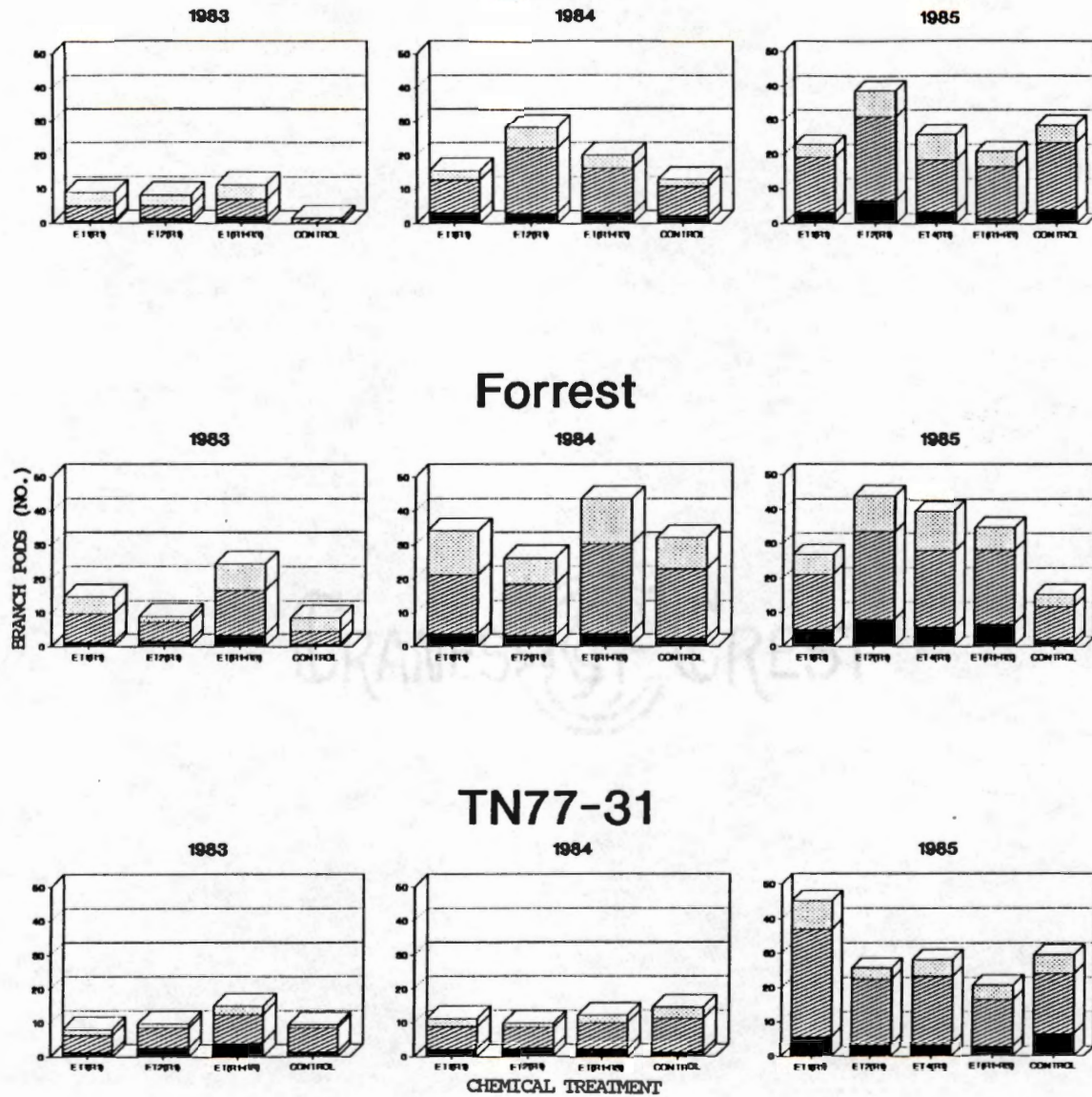


Fig. 12. The effects of growth retardants on mean number of one-, two- and three-seed pods on branches of three soybean varieties planted in June 1983-1985.

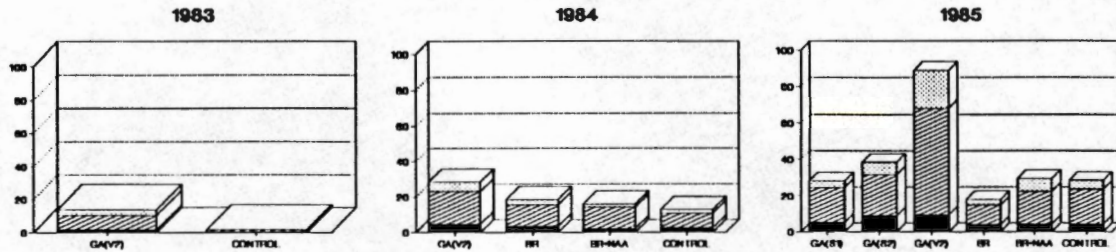
ETHEPHON[§] Essex



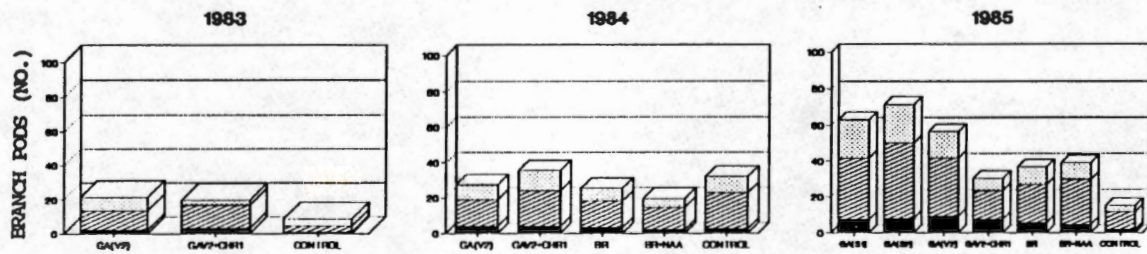
§1985 ET rates different from 1983 and 1984.

Fig. 13. The effects of ethephon treatments on mean number of one-, two- and three-seed pods on branches of three soybean varieties planted in June 1983-1985.

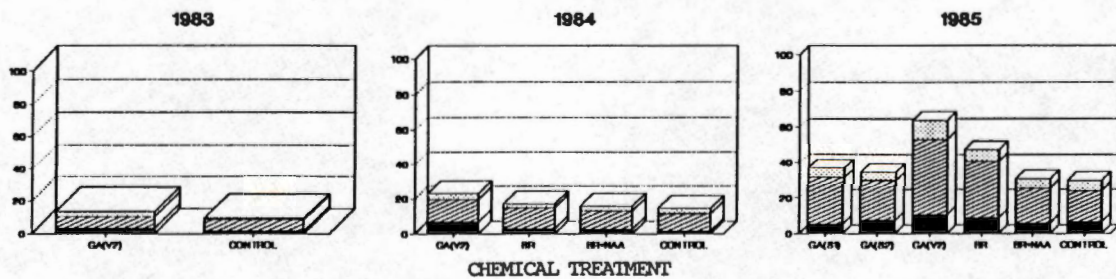
GROWTH PROMOTERS Essex



Forrest



TN77-31



One-seed
 Two-seed
 Three-seed

Fig. 14. The effects of growth promoters on mean number of one-, two- and three-seed pods on branches of three soybean varieties planted in June 1983-1985.

Frequency of Two-Seed Pods on Branches

Growth retardants: The growth retardants used on TN77-31 did not significantly affect its frequency of two-seed pods per branch in any of the three years of application (Fig. 12.)

Ethephon treatment: It was only in 1983 that an ethephon treatment significantly affected the frequency of varietal branches having two-seed pods; ET1R1 (500ppm) and ETR1+R3 significantly increased the frequency of two-seed pods per branch, but only for the Forrest variety (Fig. 13,). The other treatments produced no significant effects.

Growth promoters: GA(V2) significantly increased the frequency of two-seed pods per Essex branch in 1985 only, although in the other years, all the growth promoters increased pod number per branch over that of the control treatment (Fig. 14). For the variety Forrest, GA applied alone (GAV2) and in combination with CH (GAV2+CHR1) in 1983 and GA applied as a seed treatment (GAS2) in 1985 all significantly increased the frequency of two-seed pods per branch. No growth promoter applications had any significant effects on the variety TN77-31 from 1983-1985.

Frequency of Three-Seed Pods on Branches

Growth retardants: The treatments produced no significant effects on the frequency of three-seed pods on branches of any of the varieties (Fig. 12).

Ethephon treatments: The ethephon treatments did not significantly affect the frequency of varietal three-seed pods per branch, although there was the tendency for three-seed pods per branch to occur more frequently with ethephon application.

Growth promoters: Of the growth promoters applied on the three soybean varieties from 1983-1985, only the gibberellic acid treatments had significant effects. Gibberellic acid applied at V2 significantly increased Essex branch three-seed pod frequency in 1985 only; both GA seed treatments (GAS1, GAS2) caused increases in Forrest three-seed pod frequency that year.

Total Number of Pods Per Plant

Growth retardants: No growth retardant significantly changed the total number of pods per plant (Table 4).

Ethephon treatments: These treatments did not significantly affect varietal total number of pods.

Growth promoters: The treatment GA(V2) had the tendency to increase total pod number of the Essex variety and caused a significant increase in Essex total pod number in 1985 (Table 4). The other growth promoters generally increased pod number but did not produce any significant effects.

The two gibberellic acid seed treatments (GAS1 and GAS2) are the only growth promoters that significantly increased the total pod number

of Forrest in 1985. The other treatments increased pod number that year, but not significantly.

Although no growth promoter significantly affected the total pod number of TN77-31, they all had a tendency to increase pod number (Table 4).

Quality Factors: May Planting

Crude Protein and Oil

Growth retardants: The growth retardants did not significantly affect either the protein or oil contents of Essex (Tables 5 and 6). Some growth retardants produced significant effects on both the protein and oil percentages of the Forrest variety. In 1985, chlorflurenol significantly decreased the oil percent of Forrest seed, and produced a corresponding significant increase in protein percent.

Chlorflurenol, the only growth retardant that had any significant effects on TN77-31, significantly increased percent protein in 1984 and 1985, but significantly decreased percent oil in 1984 only.

Ethephon treatments: None of the ethephon treatments, from 500 ppm to the highest concentration of 4000 ppm, had any significant effects on varietal protein or oil percentages (Tables 5 and 6).

Growth promoters: The growth promoters had no significant effects on varietal protein and oil percentages (Tables 5 and 6).

Table 5. Effects of growth regulator treatments on three soybean varieties' protein content (%) during three years of testing, 1983-1985

Chemical Treatments [†]	-----1983-----						-----1984-----						-----1985-----					
	May Planting			June Planting			May Planting			June Planting			May Planting			June Planting		
	ES [‡]	FO [‡]	TN [‡]	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN
Control	42.9 ^{ab}	39.2 ^a	39.3 ^a	42.6 ^a	37.0 ^a	37.2 ^a	43.6 ^a	41.2 ^a	39.1 ^b	43.0 ^a	40.0 ^a	38.1 ^a	44.8 ^a	41.7 ^{bcd}	39.3 ^b	42.9 ^a	38.9 ^a	38.5 ^a
GROWTH RETARDANTS																		
CH(R1)	43.3 ^a	39.8 ^a	39.8 ^a	-	-	37.5 ^a	43.3 ^a	41.6 ^a	42.1 ^a	-	41.1 ^a	40.6 ^a	43.6 ^a	43.3 ^a	40.9 ^a	-	39.8 ^a	39.8 ^a
DA(R1)	42.8 ^a	37.5 ^a	38.3 ^a	-	-	36.8 ^a	44.0 ^a	40.3 ^a	39.8 ^b	-	-	39.6 ^a	45.2 ^a	42.9 ^{ab}	39.2 ^b	-	-	38.4 ^a
AN(R1)	42.9 ^a	39.4 ^a	37.3 ^a	-	-	-	43.9 ^a	40.9 ^a	40.0 ^b	-	-	-	44.2 ^a	41.6 ^{bcd}	39.2 ^b	-	-	-
MC+ET(R1)	42.6 ^a	39.8 ^a	38.1 ^a	-	-	36.4 ^a	43.9 ^a	40.6 ^a	39.6 ^b	-	-	38.9 ^a	44.5 ^a	42.6 ^{abc}	38.8 ^b	-	-	38.1 ^a
MC(R1)	-	-	-	-	-	-	43.2 ^a	42.1 ^a	40.2 ^b	-	-	39.1 ^a	44.6 ^a	41.8 ^{bcd}	39.3 ^b	-	-	38.5 ^a
ETHEPHON																		
ET(R1)	42.4 ^a	40.1 ^a	36.3 ^a	41.1 ^a	38.2 ^a	37.1 ^a	44.3 ^a	40.8 ^a	40.0 ^b	42.4 ^a	38.5 ^a	38.5 ^a	-	-	-	-	-	-
ET1(R1)	42.7 ^a	39.0 ^a	37.7 ^a	40.2 ^a	37.6 ^a	36.5 ^a	43.8 ^a	40.3 ^a	40.6 ^b	44.0 ^a	39.6 ^a	37.7 ^a	44.3 ^a	42.7 ^{abc}	39.2 ^b	42.3 ^a	39.6 ^a	37.6 ^a
ET2(R1)	-	-	-	-	-	-	-	-	-	-	-	-	43.8 ^a	41.5 ^{bcd}	39.0 ^b	42.5 ^a	39.0 ^a	38.3 ^a
ET4(R1)	-	-	-	-	-	-	-	-	-	-	-	-	44.0 ^a	42.4 ^{abcd}	39.1 ^b	42.8 ^a	39.2 ^a	37.7 ^a
ET(R1+R3)	42.9 ^a	38.4 ^a	36.0 ^a	40.9 ^a	37.7 ^a	36.5 ^a	44.2 ^a	40.7 ^a	39.4 ^b	43.7 ^a	38.8 ^a	37.8 ^a	43.7 ^a	41.6 ^{bcd}	38.4 ^b	42.1 ^a	40.1 ^a	37.6 ^a
ET(R1+R3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GROWTH PROMOTERS																		
GA(S1)	-	-	-	40.1 ^a	39.2 ^a	39.3 ^a	-	-	-	-	-	-	44.4 ^a	41.5 ^{bcd}	38.8 ^b	42.8 ^a	39.1 ^a	38.8 ^a
GA(S2)	-	-	-	41.3 ^a	37.5 ^a	38.7 ^a	43.3 ^a	42.1 ^a	48.5 ^b	-	-	-	44.3 ^a	41.0 ^d	38.9 ^b	42.5 ^a	38.9 ^a	38.9 ^a
GA(V2)	43.2 ^a	39.8 ^a	37.5 ^a	41.3 ^a	37.5 ^a	38.7 ^a	43.3 ^a	42.1 ^a	48.5 ^b	43.0 ^a	39.6 ^a	39.1 ^a	44.7 ^a	41.2 ^{cd}	40.1 ^{ab}	43.1 ^a	39.9 ^a	39.1 ^a
GA(R1)	41.3 ^a	40.0 ^a	37.2 ^a	-	-	-	43.3 ^a	39.6 ^a	39.6 ^b	-	-	-	44.6 ^a	41.4 ^{bcd}	38.7 ^b	-	-	-
GA(V2)+CH(R1)	-	-	-	-	38.2 ^a	-	-	41.5 ^a	40.4 ^b	43.6 ^a	39.4 ^a	37.9 ^a	-	-	-	40.9 ^a	40.9 ^a	38.1 ^a
BR	-	-	-	-	-	-	44.1 ^a	39.3 ^a	39.6 ^b	43.4 ^a	39.4 ^a	39.0 ^a	-	-	-	43.2 ^a	39.0 ^a	38.1 ^a
BR+NAA	-	-	-	-	-	-	42.1 ^a	39.3 ^a	39.6 ^b	43.4 ^a	39.9 ^a	39.0 ^a	-	-	-	42.8 ^a	39.5 ^a	38.2 ^a
Ba(R1)	43.6 ^a	40.8 ^a	37.2 ^a	-	-	-	43.7 ^a	42.4 ^a	40.3 ^b	-	-	-	44.5 ^a	41.8 ^{bcd}	38.9 ^b	-	-	-

[†] See Tables 1 and 2 for description.[‡] ES = Essex, FO = Forest, TN = TN77-31.[§] Means followed by a common letter within year, planting date and variety are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test.

Table 6. Effects of growth regulator treatments on three soybean varieties' oil content (%) during three years of testing, 1983-1985

Chemical Treatments [†]	-----1983-----						-----1984-----						-----1985-----					
	May Planting			June Planting			May Planting			June Planting			May Planting			June Planting		
	ES [‡]	FO [‡]	TN [‡]	ES	TN	ES	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN
Control	20.8 ^{ab}	21.3 ^a	19.9 ^a	19.9 ^a	20.2 ^a	21.1 ^a	20.2 ^a	20.2 ^a	19.8 ^{ab}	20.3 ^a	19.5 ^a	20.0 ^a	20.1 ^a	20.0 ^a	20.6 ^{ab}	20.5 ^a	20.2 ^{ab}	20.4 ^a
GROWTH RETARDANTS																		
CH(R1)	20.3 ^a	20.2 ^a	19.8 ^a	-	19.8 ^a	-	20.4 ^a	20.4 ^a	19.2 ^{ab}	18.5 ^b	-	19.1 ^b	20.3 ^a	20.3 ^a	18.0 ^c	19.3 ^b	-	19.4 ^{ab}
DA(R1)	20.3 ^a	21.2 ^a	20.7 ^a	-	19.9 ^a	-	20.1 ^a	20.0 ^{ab}	19.9 ^a	-	-	20.3 ^a	20.0 ^a	19.5 ^{ab}	20.5 ^{ab}	-	-	20.3 ^a
AN(R1)	20.1 ^a	20.9 ^a	21.2 ^a	-	-	-	20.0 ^a	20.0 ^{ab}	20.0 ^a	-	-	-	20.0 ^a	20.2 ^a	20.8 ^a	-	-	-
MC+ET(R1)	20.8 ^a	21.1 ^a	20.1 ^a	-	20.4 ^a	-	20.0 ^a	19.7 ^{ab}	20.2 ^a	-	-	20.6 ^a	20.2 ^a	18.8 ^b	20.4 ^{ab}	-	-	20.6 ^a
MC(R1)	-	-	-	-	-	-	20.3 ^a	18.9 ^b	19.8 ^a	-	-	20.7 ^a	20.3 ^a	20.2 ^a	20.8 ^a	-	-	20.5 ^a
ETHEPHON																		
ET ₁ (R1)	20.8 ^a	20.5 ^a	21.8 ^a	20.4 ^a	20.2 ^a	21.0 ^a	19.5 ^a	19.9 ^{ab}	20.0 ^a	19.7 ^a	20.9 ^a	20.7 ^a	-	19.7 ^a	20.3 ^{ab}	20.6 ^a	19.8 ^{ab}	20.8 ^a
ET ₂ (R1)	20.6 ^a	21.2 ^a	20.9 ^a	21.2 ^a	20.6 ^a	20.6 ^a	20.0 ^a	19.9 ^{ab}	19.6 ^a	19.1 ^a	20.2 ^a	20.7 ^a	20.3 ^a	20.2 ^a	20.2 ^{ab}	20.2 ^a	19.6 ^{ab}	20.1 ^a
ET ₃ (R1)	-	-	-	-	-	-	-	-	-	-	-	-	20.4 ^a	19.3 ^{ab}	20.4 ^{ab}	19.7 ^a	19.6 ^{ab}	20.8 ^a
ET ₄ (R1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ET(R1+R3)	20.3 ^a	21.5 ^a	21.2 ^a	20.2 ^a	20.8 ^a	20.1 ^a	20.1 ^a	19.7 ^{ab}	20.3 ^a	19.1 ^a	20.4 ^a	20.6 ^a	20.1 ^a	19.8 ^a	20.8 ^a	19.9 ^a	19.6 ^{ab}	21.0 ^a
ET(R1+R3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GROWTH PROMOTERS																		
GA(S1)	-	-	-	20.8 ^a	20.5 ^a	19.8 ^a	-	-	-	-	-	-	20.5 ^a	20.0 ^a	20.6 ^{ab}	20.6 ^a	20.5 ^{ab}	20.2 ^a
GA(S2)	-	-	-	-	-	-	-	-	-	-	-	-	20.3 ^a	20.4 ^a	20.5 ^{ab}	20.6 ^a	20.7 ^a	19.7 ^a
GA(V2)	20.0 ^a	21.0 ^a	20.9 ^a	20.3 ^a	20.2 ^a	19.8 ^a	20.2 ^a	19.5 ^{ab}	19.9 ^a	19.9 ^a	20.1 ^a	20.7 ^a	20.0 ^a	20.0 ^a	20.2 ^{ab}	20.4 ^a	19.9 ^{ab}	20.3 ^a
GA(R1)	21.5 ^a	20.5 ^a	20.7 ^a	-	-	-	20.0 ^a	20.0 ^{ab}	20.4 ^a	-	20.4 ^a	-	20.2 ^a	20.3 ^a	20.7 ^a	-	-	-
GA(V2)+CH(R1)	-	-	-	-	20.6 ^a	-	-	-	-	-	-	-	-	-	-	-	19.1 ^b	-
BR	-	-	-	-	-	-	19.9 ^a	19.8 ^{ab}	20.4 ^a	19.2 ^a	20.0 ^a	20.8 ^a	-	-	-	20.5 ^a	20.2 ^{ab}	20.2 ^a
BR+NAA	-	-	-	-	-	-	20.9 ^a	20.7 ^a	20.3 ^a	19.4 ^a	20.3 ^a	20.8 ^a	-	-	-	20.5 ^a	20.2 ^{ab}	20.2 ^a
BA(R1)	20.6 ^a	20.4 ^a	21.1 ^a	-	-	-	20.2 ^a	19.2 ^{ab}	20.0 ^a	-	-	-	20.0 ^a	19.5 ^{ab}	20.9 ^a	-	-	-

[†] See Tables 1 and 2 for description[‡] ES = Essex, FO = Forest, TN = TN77-31[§] Means with a common letter within year, planting date and variety are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test

Ester (Fatty Acid) Analysis

Chlorflurenol (CHR1) significantly affected Forrest's linoleic and linolenic acid percentages in only 1985 and linolenic acid percentage of TN77-31 in 1984 and 1985 (Table 7). These ester percentages were not affected significantly by the applications of chlorflurenol on Essex.

In 1985 the chlorflurenol application decreased both linoleic and linolenic acid percentages of Forrest. For TN77-31 the treatment produced a decrease in linolenic acid percentages in both 1984 and 1985 but did not affect linoleic acid percentages. These results suggest that chlorflurenol might have potential in reducing poor flavor and instability in soybean oil of some varieties. High linolenic acid content is the cause of poor flavor and instability of soybean oil (Weiss, 1983; Hammond, 1984).

Quality Factors: June Planting

Protein and Oil Percentages

Of all the growth regulator treatments used (growth retardants, ethephon treatments, growth promoters) only the growth retardant chlorflurenol had any significant effects when compared to the control. This treatment significantly decreased percent oil of Forrest only in 1984 (Table 6) and though it tended to increase percentage protein this year; the increase was not significantly different from the control (Table 5).

Table 7. Percent values for esters (fatty acids) of three varieties as affected by chemical treatments and planting date

VARIETY	YEAR	May Planting				June Planting					
		(18:2) [†]		(18:3) [†]		(18:2) [†]			(18:3) [†]		
		CONT [‡]	CH [‡]	CONT	CH	CONT	CH	GA+CH	CONT	CH	GA+CH
ESSEX	1983	58.4a [§]	58.5a	6.9a	7.8a	-	-	-	-	-	-
	1984	57.8a	57.2a	7.6a	7.5a	-	-	-	-	-	-
	1985	58.7a	58.4a	8.3a	8.6a	-	-	-	-	-	-
FORREST	1983	57.0a	57.0a	6.7a	7.1a	-	-	-	-	-	-
	1984	58.0a	58.7a	7.2a	7.5a	59.0a	58.1a	58.3a	8.2a	8.0a	8.3a
	1985	57.6a	54.4b	7.6a	7.1b	57.3a	57.4a	55.0a	8.1a	8.1a	7.5a
TN77-31	1983	58.7a	57.6a	8.0a	7.7a	58.4a	57.7a	-	8.3b	8.7a	-
	1984	57.8a	57.0a	8.3a	7.9b	57.6a	55.8a	-	9.0a	7.9b	-
	1985	57.7a	58.5a	8.2a	7.4b	56.3a	56.2a	-	8.5a	8.7a	-

[†] 18:2 = Linoleic acid; 18:3 = Linolenic acid

[‡] CONT = no chemical treatment; CH = chlorflurenol applied at R1 growth stage; GA+CH = gibberellic acid applied at V2 growth stage and chlorflurenol applied at R1 growth stage.

[§] Means followed by a common letter within variety, year, and ester group are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test.

Ester Analysis

The chemical treatments applied to Forrest had no significant effects on either linoleic or linolenic acid percentages. However, application of chlorflurenol to TN77-31 increased linolenic acid percentage significantly in 1983, but decreased it significantly in 1984 (Table 7).

Abortion of Buds, Flowers and Pods: May Planting

In 1985 flower and bud counts were taken at the beginning of flowering (R1), and growth regulator treatments were applied immediately afterwards. Two or three days after spraying, another count was taken. For the ET(R1+R3) treatment, a third count was taken at pod initiation (R3); then the treatment was applied, and a last count taken two or three days later. A negative ABORT1, ABORT2 indicates an increase in the number of buds/flowers/pods after spraying. A positive ABORT1, ABORT2 indicates a reduction in the number of buds/flowers/pods after spraying and, thus, abortion occurred.

Results indicate that the number of buds and flowers of the control plants of all varieties increased as flowering progressed (CTSAFT1; Table 8). Essex did not respond to the ethephon treatments; application of the various treatments to Essex plants caused increases in flower number that were not significantly different from the increase for the control plants (See ABORT1, Table 8).

Table 8. Counts of flowers, buds and pods, and abortion rates of three soybean varieties planted in May 1985, as affected by ethephon treatments

Variety	Tx†	CTSBEF1‡	CTSAPT1	CTSBEF2	CTSAPT2	ABORT1	ABORT2
Essex	ET1(R1)	130.0	149.8	-	-	-19.8a§	-
Essex	ET2(R1)	144.8	168.5	-	-	-23.7a	-
Essex	ET(R1+R3)	113.8	116.8	-	-	-3.0a	9.5a
Essex	Control	132.5	153.2	128.5	119.0	-20.7a	2.8a
Essex	MC+ET(R1)	132.8	158.7	152.0	149.2	-25.8a	-
Essex	ET4(R1)	123.5	125.8	-	-	-2.3a	-
Essex	MC(R1)	111.7	120.7	-	-	-9.0a	-
Forrest	ET1(R1)	153.5	212.2	-	-	-58.7c	-
Forrest	ET2(R1)	178.2	105.3	-	-	72.8ab	-
Forrest	ET(R1+R3)	175.0	64.0	71.5	83.5	111.0a	-12.0b
Forrest	Control	197.5	235.0	244.0	225.3	-37.5c	18.7a
Forrest	MC+ET(R1)	180.8	204.2	-	-	-23.3c	-
Forrest	ET4(R1)	161.5	112.8	-	-	48.7b	-
Forrest	MC(R1)	174.3	219.2	-	-	-44.8c	-
TN77-31	ET1(R1)	168.5	194.0	-	-	-25.5a	-
TN77-31	ET2(R1)	139.5	171.2	-	-	-31.7a	-
TN77-31	ET(R1+R3)	147.2	169.5	134.5	121.2	-22.3a	13.3b
TN77-31	Control	179.8	221.7	271.0	177.7	-41.8a	-6.7a
TN77-31	MC+ET(R1)	134.5	147.7	-	-	-13.2a	-
TN77-31	ET4(R1)	172.3	177.0	-	-	-4.7a	-
TN77-31	MC(R1)	142.8	160.7	-	-	-17.8a	-

†Chemical treatment at particular growth stages.

‡CTSBEF1 = Count of flowers/buds before spraying at R1; CTSAPT1 = Count of flowers/buds after spraying at R1; CTSBEF2 = Count of flowers/buds/pods before spraying at R3; CTSAPT2 = Count of flowers/buds/pods after spraying at R3; ABORT1 = CTSBEF1 - CTSAPT1; ABORT2 = CTSBEF2 - CTSAPT2

§Means followed by a common letter within abortion group and variety are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test.

Spraying of the higher concentrations of ethephon [ET2(R1), ET4(R1) and ET(R1+R3)] on the variety Forrest caused significant abortion of flowers and buds, with the treatment ET(R1+R3) producing the highest number of abortions (Table 8). The treatments applied to TN77-31 led to increases in flower and bud numbers.

The figures for ABORT2 for the control plants of Essex and Forrest (the determinate varieties) show that abortion of flowers and pods occurred just after pod initiation (R3), and an increase in number occurred at this stage for TN77-31 (the indeterminate line). The second application of ethephon at R3 for the treatment ET(R1+R3) caused: (i) the abortion of Essex flowers/pods, but this abortion was not significantly different from that of the control, (ii) significant abortion of TN77-31 flowers and pods, and (iii) increases in the flower/pod number of Forrest.

Abortion of Buds, Flowers and Pods: June Planting

In the control plants, the number of buds and flowers of all varieties increased as flowering progressed (CTSAFT1 and CTSBEF2 Table 9).

The higher concentrations of ethephon [ET2(R1), ET4(R1) and ET(R1+R3)] all caused abortion of buds/flowers in all varieties when treatments were applied at beginning flowering. The combination treatment [MC+ET(R1)] also caused abortion of TN77-31's flowers/buds.

Table 9. Counts of flowers, buds, and pods and abortion rates of three soybean varieties planted in June 1985, as affected by ethephon treatments

Variety	T _{ET} [†]	CTSBEF1 [‡]	CTSAPT1	CTSBEF2	CTSAPT2	ABORT1	ABORT2
Essex	ET1(R1)	131.8	138.8	-	-	-7.0b [§]	-
Essex	ET2(R1)	185.8	173.8	-	-	12.0ab	-
Essex	ET(R1+R3)	103.2	74.5	74.5	67.8	28.7a	6.7a
Essex	Control	158.0	163.2	163.7	160.7	-5.2b	2.5a
Essex	MC+ET(R1)	136.2	109.0	-	-	27.2a	-
Forrest	ET1(R1)	174.0	192.5	-	-	-18.5c	-
Forrest	ET2(R1)	244.2	220.0	-	-	24.2b	-
Forrest	ET(R1+R3)	190.1	118.7	79.7	97.3	71.5a	-17.6b
Forrest	Control	154.0	163.5	166.2	159.8	-9.5a	6.3a
Forrest	ET4(R1)	192.0	98.7	-	-	93.3a	-
TN77-31	ET1(R1)	183.3	197.3	-	-	-14.0bc	-
TN77-31	ET2(R1)	125.3	125.2	-	-	0.2a	-
TN77-31	ET(R1+R3)	148.2	143.4	143.4	138.6	4.8a	4.8a
TN77-31	Control	148.2	143.4	156.2	172.2	-17.2c	-16.0b
TN77-31	MC+ET(R1)	141.0	137.3	-	-	3.7a	-
TN77-31	ET4(R1)	149.2	143.3	-	-	5.8a	-
TN77-31	MC(R1)	137.3	150.2	-	-	-12.8bc	-

[†]Chemical treatment at particular growth stages.

[‡]CTSBEF1 = Count of flowers/buds before spraying at R1; CTSAPT1 = Count of flowers/buds after spraying at R1; CTSBEF2 = Count of flowers/buds/pods before spraying at R3; CTSAPT2 = Count of flowers/buds/pods after spraying at R3; ABORT1 = CTSBEF1 - CTSAPT1; ABORT2 = CTSBEF2 - CTSAPT2

[§]Means followed by a common letter within abortion group and variety are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test.

The figures obtained for ABORT2 indicate that abortion of flowers and pods occurred even for untreated plants just after pod initiation (R3) for the varieties Forrest and Essex; whereas for TN77-31 an increase in flowers and pods occurred at this same period. Application of ethephon [ET(R1+R3)] at R3 growth stage (pod initiation), led to abortion of Essex and TN77-31 flowers and pods, but increased flower/pod number of TN77-31 (Table 9). As in the May planting, the abortion of flowers and pods of the Essex variety was not significantly different from that which occurred in the control, but for TN77-31 it was significant ($P \leq 0.05$).

Stepwise Multiple Regression Analysis:

May Planting

Chemical Treatment Effect

One-variable model: Multivariate analyses of all measured characteristics were used to identify the most important characteristics that affect yield.

The R^2 values were determined for the best one-, two-, and three-variable models for each chemical treatment when all varieties were combined (Tables 10, 11, 12) and for each variety separately (Tables 13 and 14). Yield was the dependent variable, and the independent variables entered were hundred-seed weight, total number of pods, plant

Table 10. The multiple regression (R^2) values within each growth regulator treatment for the best one-, two-, and three-variable model to explain variation in yield when summarized across the three soybean varieties, 1983

	May Planting			June Planting		
	One-variable	Two-variables	Three-variables	One-variable	Two-variables	Three-variables
Control	INTL (0.51)*	NBR, INTL (0.65)*	TPD, NBR, INTL (0.85)*	SDMT (0.29)	SDMT, NODE (0.75)*	SDMT, HT, NPB (0.96)**
<u>GROWTH RETARDANTS</u>						
CH(R1)	INTL (0.12)	TPD, NBR (0.27)	TPD, NBR, INTL (0.63)	-	-	-
DA(R1)	INTL (0.59)*	SDMT, TPD (0.81)**	TPD, NBR, INTL (0.95)**	-	-	-
AN(R1)	NPB (0.31)	SDMT, NODE (0.85)**	SDMT, NODE, NBR (0.87)**	-	-	-
MC + ET(R1)	TPD (0.64)**	TPD, INTL (0.67)*	TPD, NBR, INTL (0.76)*	-	-	-
MC(R1)	-	-	-	-	-	-
GA(V2) + CH(R1)	-	-	-	-	-	-
<u>ETHEPHON</u>						
ET ₁ (R1)	TPD (0.62)**	NODE, TPD (0.79)	HT, TPD, INTL (0.84)*	HT (0.65)**	HT, NBR (0.78)	HT, TPD, NBR (0.83)*
ET ₁ (R1(500))	INTL (0.56)	NPB, INTL (0.69)	HT, NPB, INTL (0.88)	TPD (0.42)	TPD, INTL (0.67)*	HT, TPD, INTL (0.70)
ET ₂ (R1)	-	-	-	-	-	-
ET ₂ (R1)	-	-	-	-	-	-
ET ₁ (R1+R3)	INTL (0.54)	TPD, INTL (0.69)	HT, TPD, INTL (0.79)	TPD (0.72)**	TPD, INTL (0.78)**	TPD, NPB, INTL (0.80)*
ET(R1(4000)+R3(2000))	-	-	-	-	-	-
<u>GROWTH PROMOTERS</u>						
GA(S1)	-	-	-	-	-	-
GA(S2)	-	-	-	-	-	-
GA(V2)	HT (0.92)**	HT, TPD (0.96)**	SDMT, TPD, INTL (0.98)	NODE (0.22)	NBR, NPB (0.55)	HT, NBR, NPB (0.59)
GA(R1)	TPD (0.62)**	SDMT, NPB (0.80)**	SDMT, TPD, INTL (0.87)**	-	-	-
BR	-	-	-	-	-	-
BR + NAA	-	-	-	-	-	-
BA	INTL (0.87)	HT, INTL (0.94)**	HT, NPB, INTL (0.95)**	-	-	-

* SDMT = Hundred seedweight, TPD = Total number of pods, HT = Plant height, NBR = Number of branches per plant, NPB = Average number of nodes per branch, INTL = Average internode length, NODE = Total number of nodes on mainstem.

*, **Significantly different from zero at $P \leq 0.05$ and 0.01 , respectively

Table 11. The multiple regression (R^2) values within each growth regulator treatment for the best one-, two-, and three-variable model to explain variation in yield when summarized across the three soybean varieties, 1984

	May Planting			June Planting		
	One-variable	Two-variables	Three-variables	One-variable	Two-variables	Three-variables
Control	SDMT [†] (0.49)*	SDMT,TPD(0.67)*	SDMT,HT,TPD(0.71)	HT(0.58)*	SDMT,NBR(0.73)*	SDMT,HT,NBR(0.75)
GROWTH RETARDANTS						
CH(R1)	INTL(0.82)**	SDMT,INTL(0.89)**	SDMT,TPD,INTL(0.93)**	TPD(0.78)*	NODE,TPD(0.86)*	SDMT,NODE,NBR(0.96)
DA(R1)	SDMT(0.35)	SDMT,INTL(0.84)**	SDMT,NODE,INTL(0.94)**	-	-	-
AN(R1)	SDMT(0.24)	SDMT,NODE(0.57)	SDMT,HT,INTL(0.88)**	-	-	-
MC + ET(R1)	SDMT(0.60)*	SDMT,TPD(0.80)*	NODE,TPD,INTL(0.93)**	-	-	-
MC(R1)	INTL(0.43)*	TPD,INTL(0.61)	TPD,NBR,INTL(0.68)	-	-	-
GA(V2) + CH(R1)	-	-	-	-	-	-
ETHEPHON						
ET ₁ (R1)(500)	SDMT(0.43)*	SDMT,NODE(0.59)	SDMT,NODE,NBR(0.65)	INTL(0.15)	NPB,INTL(0.28)	NBR,NPB,INTL(0.43)
ET ₁ [†] (R1(1000))	NBR(0.21)	NBR,INTL(0.35)	HT,NBR,NPB(0.56)	INTL(0.56)*	TPD,INTL(0.85)**	TPD,NPB,INTL(0.89)**
ET ₂ (R1)	-	-	-	-	-	-
ET ₂ (R1)	-	-	-	-	-	-
ET(R1(1000) + R3(500))	SDMT(0.41)	SDMT,TPD(0.49)	SDMT,TPD,NBR(0.59)	SDMT(0.54)*	SDMT,NODE(0.66)*	SDMT,NODE,NPB(0.86)*
ET(R1(4000) + R3(2000))	-	-	-	-	-	-
GROWTH PROMOTERS						
GA(S1)	-	-	-	-	-	-
GA(S2)	-	-	-	-	-	-
GA(V2)	NBR(0.62)**	SDMT,NPB(0.72)*	SDMT,NBR,NPB(0.83)*	TPD(0.10)	TPD,NPB(0.26)	SDMT,TPD,NPB(0.42)
GA(R1)	TPD(0.51)*	SDMT,TPD(0.76)**	SDMT,TPD,INTL(0.84)**	-	-	-
BR	SDMT(0.27)	SDMT,NBR(0.91)**	SDMT,NODE,NBR(0.98)**	INTL(0.32)	NODE,INTL(0.45)	NODE,TPD,INTL(0.68)
BR + NAA	NPB(0.39)	HT,NPB(0.72)*	SDMT,HT,NODE(0.77)*	HT(0.57)*	SDMT,HT(0.64)	SDMT,HT,TPD(0.68)
BA	NPB(0.37)	TPD,NPB(0.56)	SDMT,NBR,NPB(0.74)	-	-	-

[†]SDMT = Hundred seedweight, TPD = Total number of pods, HT = Plant height, NBR = Number of branches per plant, NPB = Average number of nodes per branch, INTL = Average internode length, NODE = Total number of nodes on mainstem

*,**Significantly different from zero at P<0.05 and 0.01, respectively

Table 12. The multiple regression (R^2) values within each growth regulator treatment for the best one-, two-, and three-variable model to explain variation in yield when summarized across the three soybean varieties, 1985

	May Planting			June Planting		
	One-variable	Two-variables	Three-variables	One-variable	Two-variables	Three-variables
Control	INTL [†] (0.67)**	SDWT, INTL (0.84)**	SDWT, NBR, INTL (0.88)**	MODE (0.66)**	MODE, NPB (0.85)**	TPD, NBR, INTL (0.93)**
<u>GROWTH RETARDANTS</u>						
CH(R1)	NBR (0.29)	HT, INTL (0.50)	HT, MODE, INTL (0.94)**	HT (0.60)	HT, TPD (0.99)**	SDWT, HT, TPD (0.99)**
DA(R1)	INTL (0.11)	SDWT, MODE (0.25)	SDWT, MODE, NBR (0.42)	-	-	-
AN(R1)	MODE (0.35)	HT, INTL (0.52)	SDWT, HT, INTL (0.69)	-	-	-
MC + ET(R1)	INTL (0.30)	NBR, NPB (0.50)	SDWT, HT, NBR (0.81)*	-	-	-
MC(R1)	TPD (0.12)	TPD, NBR (0.46)	TPD, NBR, NPB (0.64)	-	-	-
GA(V2) + CH(R1)	-	-	-	-	-	-
<u>ETHEPHON</u>						
ET ₁ (R1)	-	-	-	-	-	-
ET ₁ (R1 (1000))	SDWT (0.58)*	SDWT, TPD (0.67)*	SDWT, TPD, NBR (0.75)	HT (0.50)*	MODES, TPD (0.68)*	HT, TPD, INTL (0.85)*
ET ₂ (R1)	NBR (0.35)	NBR, INTL (0.47)	HT, MODE, NBR (0.64)	INTL (0.40)	SDWT, INTL (0.50)	SDWT, HT, INTL (0.69)
ET ₂ (R1)	NPB (0.20)	SDWT, MODE (0.39)	SDWT, HT, TPD (0.46)	SDWT (0.75)**	TPD, INTL (0.82)**	TPD, NBR, INTL (0.90)**
ET(R1 + R3)	-	-	-	-	-	-
ET(R1 + R3 (2000))	NBR (0.32)	NBR, INTL (0.71)*	SDWT, NBR, INTL (0.89)**	MODE (0.59)*	MODE, TPD (0.73)*	MODE, TPD, NPB (0.77)*
<u>GROWTH PROMOTERS</u>						
GA(S1)	SDWT (0.54)*	SDWT, TPD (0.64)*	SDWT, MODE, INTL (0.82)*	MODE (0.39)	MODE, TPD (0.51)	MODE, NPB, INTL (0.74)
GA(S2)	MODE (0.54)*	MODE, NPB (0.61)	HT, NBR, NPB (0.67)	NBR (0.58)*	SDWT, MODE (0.77)*	SDWT, MODE, NBR (0.80)*
GA(V2)	SDWT (0.13)	SDWT, MODE (0.32)	SDWT, HT, MODE (0.40)	NBR (0.60)*	NBR, INTL (0.69)*	SDWT, MODE, NBR (0.84)*
GA(R1)	NBR (0.32)	TPD, NBR (0.41)	TPD, NBR, NPB (0.46)	-	-	-
BR	-	-	-	SDWT (0.17)	SDWT, TPD (0.20)	SDWT, MODE, NBR (0.57)
BR + NAA	-	-	-	SDWT (0.64)**	SDWT, TPD (0.68)*	SDWT, MODE, TPD (0.73)
BA	INTL (0.41)	SDWT, INTL (0.49)	SDWT, NPB, INTL (0.52)	-	-	-

[†] SDWT = Hundred seedweight, TPD = Total number of pods, HT = Plant height, NBR = Number of branches per plant, NPB = Average number of nodes per branch, INTL = Average internode length, MODE = Total number of nodes on mainstem.

*, **Significantly different from zero at $P \leq 0.05$ and 0.01, respectively

Table 13. The multiple regression (R^2) values for each variety for the best one-, two-, and three-variable model to explain variation in yield of each soybean variety each year, 1983-1985 when 7 independent variables were used

YEAR	VARIETY	May Planting			June Planting		
		One-variable	Two-variables	Three-variables	One-variable	Two-variables	Three-variables
1983	ESSEX	TPD(0.43)**	SDMT, TPD(0.55)**	SDMT, TPD, INTL(0.58)**	HT(0.64)**	SDMT, HT(0.72)**	SDMT, HT, INTL(0.74)**
	FORREST	INTL(0.45)**	TPD, INTL(0.62)**	SDMT, TPD, INTL(0.63)**	HT(0.65)**	HT, TPD(0.71)**	HT, TPD, NPB(0.73)**
	TN77-31	TPD(0.57)**	TPD, INTL(0.70)**	TPD, NPB, INTL(0.74)**	HT(0.49)**	HT, TPD(0.66)**	HT, TPD, NPB(0.74)**
1984	ESSEX	SDMT(0.73)**	SDMT, HT(0.80)**	SDMT, HT, INTL(0.80)**	INTL(0.27)*	NODE, INTL(0.30)*	HT, NPB, INTL(0.33)
	FORREST	INTL(0.52)**	TPD, INTL(0.60)**	SDMT, TPD, INTL(0.60)**	HT(0.28)**	TPD, NPB(0.56)**	SDMT, TPD, NPB(0.67)**
	TN77-31	HT(0.14)*	HT, NPB(0.25)**	HT, NPB, INTL(0.27)**	INTL(0.45)**	NPB, INTL(0.59)**	SDMT, NPB, INTL(0.67)**
1985	ESSEX	SDMT(0.37)**	SDMT, TPD(0.41)**	SDMT, TPD, NPB(0.47)**	HT(0.24)**	SDMT, HT(0.27)*	SDMT, HT, TPD(0.30)*
	FORREST	TPD(0.19)**	TPD, NPB(0.26)**	SDMT, TPD, NPB(0.30)**	HT(0.36)**	HT, NPB(0.43)**	HT, NODE, NPB(0.48)**
	TN77-31	SDMT(0.32)**	SDMT, HT(0.46)**	SDMT, HT, NPB(0.48)**	HT(0.38)**	SDMT, HT(0.43)**	SDMT, HT, NODE(0.45)**

† SDMT = Hundred seedweight, TPD = Total number of pods, HT = Plant height, NPB = Number of branches per plant, NPB = Average number of nodes per branch, INTL = Average internode length, NODE = Total number of nodes on mainstem

*, **Significantly different from zero at $P \leq 0.05$ and 0.01 , respectively

Table 14. The multiple regression (R^2) values for the best one-, two-, and three-variable model to explain variation in yield of each soybean variety each year when 15 independent variables were used

YEAR	VARIETY	May Planting			June Planting		
		One-variable	Two-variables	Three-variables	One-variable	Two-variables	Three-variables
1983	ESSEX	TWO(0.37)**	ONE, TWO(0.47)**	SDMT, TWO, POD3A(0.58)**	HT(0.64)**	SDMT, HT(0.72)**	SDMT, NBR, POD2B(0.89)**
	FORREST	INTL(0.45)**	THREE, INTL(0.66)**	THREE, POD3, INTL(0.74)**	HT(0.65)**	HT, POD2A(0.70)**	HT, ONE, THREE(0.77)**
	TW77-31	HT(0.43)**	THREE, INTL(0.60)**	TWO, POD3A, INTL(0.70)**	HT(0.49)**	HT, TWO(0.75)**	TWO, THREE, INTL(0.81)**
1984	ESSEX	SDMT(0.73)**	SDMT, HT(0.80)**	SDMT, HT, POD2B(0.82)**	INTL(0.27)*	ONE, INTL(0.32)*	ONE, NPB, INTL(0.37)
	FORREST	INTL(0.52)**	ONE, INTL(0.67)**	ONE, THREE, INTL(0.71)**	THREE(0.36)**	SDMT, THREE(0.48)**	SDMT, THREE, NPB(0.53)**
	TW77-31	HT(0.14)*	HT, NBR(0.25)**	HT, NBR, POD1A(0.29)**	INTL(0.45)**	NBR, INTL(0.59)**	SDMT, NBR, INTL(0.67)**
1985	ESSEX	SDMT(0.37)**	SDMT, TWO(0.50)**	SDMT, TWO, NPB(0.52)**	HT(0.24)**	THREE, POD1A(0.40)**	SDMT, THREE, POD1A(0.43)**
	FORREST	TWO(0.26)**	POD1A, POD2A(0.37)**	TWO, POD1A, POD2A(0.45)**	HT(0.36)**	HT, POD1B(0.47)**	HT, POD3A, POD1B(0.50)**
	TW77-31	SDMT(0.32)**	SDMT, HT(0.46)**	SDMT, HT, NPB(0.48)**	HT(0.38)**	HT, TWO(0.46)**	HT, TWO, THREE(0.51)**

†SDMT = Hundred seedweight, ONE, TWO, THREE = Number of one-, two-, three-seed pods on mainstem; POD1A, POD2A, POD3A = Number of one-, two-, three-pods on a branch A, POD1B, POD2B, POD3B = Number of one-, two-, three-seed pods on branch B; TPD = Total number of pods, HT = Plant height, NBR = Number of branches per plant, NPB = Average number of nodes per branch, INTL = Average internode length, NODE = Total number of nodes on mainstem

*, **Significantly different from zero at $P \leq 0.05$ and 0.01 , respectively

height, number of branches per plant, number of nodes per branch, internode length and number of nodes on the mainstem.

No single variable emerged as the main predictor variable for yield. Almost every year, a different variable became the single most important one for the particular chemical treatment. From 1983 to 1985, morphological characteristics like internode length, number of nodes per branch and number of nodes on mainstem, as single variables accounted for 12-82 percent of the variation in yield associated with the growth retardants. Components of yield like hundred-seed weight and total pod number accounted for 12-64 percent of the variation.

For the ethephon treatments, internode length accounted for 54-56 percent of the variation and total number of pods, 62 percent in 1983; seedweight for 41-58 percent, number of branches for 21-35 percent and number of nodes per branch for 20 percent, all in 1984-85.

From 1983 to 1985, seedweight accounted for 13-27 percent, total number of pods for 51-62 percent, internode length for 41-87 percent, height for 92 percent, number of branches for 32-62 percent and nodes per branch 37-39 percent of the variation in yield for plants treated with the various growth promoters.

Two-variable model: The best two-variable model to explain yield variation differed every year. Two variables together did explain a lot more of the variation in yields (as high as 89 percent for growth retardants in 1984, up to 96 percent for growth promoters in 1983 and up to 79 percent for the ethephon treatments in 1983 (Tables 10 and 11)).

In 1984, the same two variables, seed weight and internode length, made up the best two-variable model for both chlorflurenol and daminozide treatments (Table 11).

Three-variable model: As more variables are added to the model, a greater percentage of the variation is accounted for. As much as 95 percent for growth retardants, 89 percent for the ethephon treatments and 98 percent of the yield variation was explained by the three-variable models (Tables 10-12). The variables differed from year to year, but seedweight and/or total pod number were almost always part of the trio.

Variety Effect

One-variable model: All treatments were combined in this analysis, and the independent variables used were hundred-seed weight, total number of pods per plant, plant height, number of branches per plant, average number of nodes per branch, average internode length and total number of nodes on mainstem. From 1983 through 1985, components of yield were the most important variable in explaining variation in Essex yield. Total number of pods accounted for 43 percent of the variation in 1983; whereas in 1984 and 1985, seed weight accounted for 73 percent and 37 percent respectively (Table 13).

Internode length explained 45 percent and 52 percent of the variation in yield of Forrest in 1983 and in 1984 respectively and total pod number explained 19 percent of yield variation in 1985. The best

single model to explain variation in yield for TN77-31 varied from year to year. In 1983 the total number of pods accounted for 57 percent; in 1984 height explained 14 percent, and in 1985 seed weight explained 32 percent of the variation.

Two- and Three-variable Models: Increase in variable number in the model led to the explanation of a greater percentage of the variation in yield. For the variety Essex, seedweight and total pod number were important variables for both the two- and three-variable models for two years; for Forrest, total pod number and internode length were important, and for TN77-31, no clear trend was apparent for more than one year (Table 13).

Stepwise Multiple Regression Analysis:

June Planting

Chemical Treatment Effect

One-variable model: The best single variable models to explain variation in yield for the treatments in the June planting differ from those for the May planting. For the growth retardants, height accounted for 60 percent of the variation in yield and total number of pods for 78 percent (Tables 11 and 12).

The single variables that best explained yield variations for the ethephon treatments were height, 65 percent; internode length, 15-56 percent; seed weight, 54 percent; and total number of pods, 42-

72 percent (Tables 10-12). Growth promoters, on the other hand, had number of nodes on mainstem explaining 22-39 percent, number of branches, 58-60 percent; internode length, 32 percent; height, 57 percent; and hundred-seed weight, 17-64 percent of the variation of yield.

Two-variable model: The two variables that best explain yield variation differ for planting dates and from year to year. Exceptions were total pod number and internode length explaining 78 percent of the variation in the delayed planting and 69 percent in the early planting (Table 10, ET(R1+R3) treatment); these two variables also explained 67 percent of yield variation for ET1(R1(1000)) treatment in 1983 and 85 percent of variation in 1984 (Tables 10 and 11, respectively).

Three-variable model: Over the years no three-variable model consistently proved to be valid for explaining variations in yield for the different treatments for the June plantings.

Variety Effect

One-variable model: There was more consistency over the years with respect to the best one-variable model. Height explained 64 percent and 24 percent of the variation in Essex yield in 1983 and 1985, respectively, and internode length explained 27 percent in 1984 (Table 13).

Height accounted for 28-65 percent of the variation in Forrest yield all three years; whereas, for TN77-31 height accounted for

38 percent and 49 percent in 1985 and 1983, respectively, and internode length explained 45 percent of the variation in 1984. It must be noted that in 1983 and 1985, height is the single best variable that explained variation for all varieties.

A second analysis was performed with 15 independent variables (Table 14). Total number of pods was broken down into its components-- frequency of one-, two-, or three-seed pods per mainstem and branch. With a few exceptions, the best single-variable models to explain variation in yield when fifteen independent variables were used were similar to the ones for the seven independent variables. In the May planting, the frequency of two-seed pods on a mainstem replaced total pod number for Essex (37 percent) and Forrest (26 percent) in 1983 and 1985, respectively. Height replaced total pod number for TN77-31 in 1983.

For the June planting, the only one-variable model that changed was for Forrest in 1984, when the frequency of three-seed pods per mainstem (36 percent of variation) replaced height. The best one-variable model remained the same for both June and May plantings during the other years.

Two- and three-variable Models: The two variables that explained variation in yield best for the three varieties in 1984 and 1985 also appeared in the three-variable models. In 1984 seed weight and plant height were the variables for Essex, one-seed pods on a mainstem and internode length for Forrest, and plant height and number of branches

per plant for TN77-31. In 1985, hundred-seed weight and the frequency of two-seed pods per branch for Essex, frequency of one-, and two-seed pods per branch for Forrest, and hundred-seed weight and plant height for TN77-31 were the best predictor variables (Table 14).

This same pattern occurred in the delayed planting but the variables involved were different. As occurred in the best single-variable models, wherever total number of pods had been the best predictor, (Table 13) this was replaced by one of its component parts. This was true for both the early and delayed plantings (Table 14).

CHAPTER 4

DISCUSSION

The varieties responded differently to the various growth regulator treatments. There were no consistent responses across the three years even with respect to one growth regulator acting on one variety. Only significant treatment effects will be discussed in this section.

Some of the growth regulator treatments affected pod and seed development. Gibberellic acid applications resulted in mainly positive effects on pods on the branches of the determinate varieties. In 1984 the increase in frequency of one-seed pods and two-seed pods on branches of the variety Essex in association with GA(V2) did not overcome the decrease in the frequency of two-seed pods per mainstem which resulted in no increase in Essex yield. Similar results occurred in the delayed planting, but in a different year (1985). GA(V2) decreased the frequency of two- and three-seed pods per mainstem, but increased one- and three-seed pods on side branches and total pod number. The positive effects did not translate into increase in seed yield.

Significant effects on the variety Forrest occurred only in 1985 for the May planting. Gibberellic acid when applied at V2 increased the frequency of one-, two- and three-seed pods on Forrest branches, which resulted in an increase in total pod number. When applied at beginning

flowering (R1), only the frequency of two-seed pods on branches was increased; and when applied as a seed treatment, the lower rate (GAS1) increased the frequency of two-seed pods and three-seed pods per branch as well as the total pod number; whereas the higher rate (GAS2) increased only the frequency of two-seed pods per branch.

In delayed plantings the GA(V2) treatment decreased the frequency of three-seed pods per mainstem on Forrest. The gibberellic acid seed treatments together with GA(V2) produced similar positive results on the frequency of one-seed pods, two-seed pods and three-seed pods per branch, as occurred with the earlier planting date, but with one exception: GA(V2) decreased the frequency of two-seed pods per branch in 1984. Although the gibberellic acid treatments had no effect on any components of seed yield of the indeterminate variety TN77-31, GA(V2) resulted in decrease in seed yield when the variety was planted in June.

van Schaik and Probst (1958) demonstrated that soybean seed yield is dependent upon the number of pods produced, seeds per pod, and seed size. The treatment, GAV2+CHR1, increased Forrest seed weight, produced no significant effects on seeds per pod and total pod number, but still resulted in a decrease in Forrest seed yield in 1985.

Benzyladenine, a cytokinin, increased total pod number in the 1985 May planting; whereas, brassinosteroid 1105 (BR), a growth stimulant, decreased the frequency of two-seed pods per branch for Forrest in the delayed planting. Combining BR and NAA led to increased activity. The treatment, BR+NAA, increased the frequency of three-seed pods per

mainstem and branches, total pod number (May planting) and the frequency of two-seed pods per branch for Forrest in both May and June plantings. These effects occurred in different years. BA had no effect on Essex and, although it decreased seed weight of TN77-31 in 1983, did not affect its yield.

Ethephon is a source of ethylene which stimulates further ethylene production in the plant (Urwiler and Stutte, 1986; Ware, 1983). Slife and Earley's work (1970) supported by Urwiler and Stutte's showed that ethylene produced a reduction in weight per 100 seeds, the frequency of three-seed pods and four-seed pods and seed yield. Urwiler and Stutte also showed ethylene increased soybean flower shedding. Results in this study agree with the earlier ones stated above with variations occurring according to variety and year. Although the ethephon treatments applied in 1985 increased the shedding (abortion) of only Forrest flowers in the May planting, the ethephon rates ≥ 2000 ppm increased flower abortion of all varieties in the delayed planting, but only the abortion of Essex flowers (28 percent) by ET(R1+R3) translated into decreased seed yield. Although the same treatment aborted 38 percent of Forrest flowers, it was not associated with a decrease in yield, but was associated with a reduction in seed weight; TN77-31 had 3 percent flower abortion, no yield decreases, but an increase in seed weight.

These results indicate that varietal response to ethephon (in terms of flower abortion) varied with planting time. Ethephon increased flower shedding of Essex and TN77-31 only when they were planted late

and for the variety Essex resulted in seed yield reduction. Increase in Forrest flower abortion occurred no matter when planting occurred, but greater flower abortion, as high as 63 percent for the ET(R1+R3) treatment, occurred in the May planting.

Dybing and Lay (1982) determined that the morphactin, chlorflurenol, increased percent oil of 'Swift' soybeans, but reduced its percent protein. Results from this study indicate that, although chlorflurenol was the main plant growth regulator treatment that affected oil and protein content, response varied with soybean variety and planting date. For soybeans planted in May, the response of Forrest and TN77-31 varieties were the converse of Dybing and Lay's variety; chlorflurenol increased percent protein and decreased percent oil (daminozide also decreased percent oil). It must be noted that chlorflurenol did not alter the negative genetic correlation that existed between protein and yield (Dybing and Lay, 1982); chlorflurenol reduced Forrest seed yield with an increase in percent protein (1985). Not only were seed yield and percent oil of Forrest reduced by chlorflurenol application in the May planting, but there was also a reduction in the fatty acid percentages of linolenic and linoleic acids and an increase in the frequency of three-seed pods per mainstem and in seed weight.

Chlorflurenol did not affect the quality factors of Essex seed, but increased the frequency of one-seed pods per branch. For the variety TN77-31, even though percent protein increased in the May

planting, seed yield was not affected but linolenic acid content was reduced; seed weight was increased.

Chlorflurenol decreased oil percent of Forrest seeds in the June planting, but had no effect on percent protein. Although seed oil and protein content of TN77-31 were not affected by chlorflurenol application, seed yield was reduced, and the effect on linolenic acid percent depended on the year the chemical was applied. The yield, protein, oil, and fatty acid percents of the variety Essex were not affected by the chemical when planting was delayed, but the treatment increased the frequency of one-seed pods per branch in 1984.

Seed composition affects the shelf life of soybean oil. Poor flavor and instability in soybean oil are attributed to high linolenic acid content (Shibles et al., 1975, Weiss, 1983). The reduction in linolenic acid percentages of Forrest and TN77-31 by application of chlorflurenol is, therefore, encouraging, especially so for the variety TN77-31 where this reduction occurred consistently for two years in the May plantings with no concurrent significant reduction in seed yield.

CHAPTER 5

SUMMARY

A consistent and significant yield response on soybean is most important if a growth regulator is to be used commercially. Such a response has not been the case with the growth regulator treatments used in this study. Varieties usually responded differently, and most responses were erratic. Most of the plant growth regulators had no positive effects on yield and, in some cases, adverse or negative effects were produced on seed yield. Different treatments affected pod and seed development at one time or another, but did not lead to increased yields.

One plant growth regulator, chlorflurenol consistently shortened the plants of the variety TN77-31, the indeterminate line. Plant size and shape were therefore modified. Chlorflurenol also affected some quality aspects of soybean seed. It reduced the linolenic acid content of TN77-31. This effect is important in improving soybean oil flavor and stability. Chlorflurenol consistently increased percent protein of seed of TN77-31 over two years when TN77-31 was planted in May. No significant seed yield decreases occurred. This treatment could become a profitable practice since yield and protein are normally negatively correlated. This possibility should be investigated further.

The genetic composition of the variety, the environmental conditions under which it was grown, and the rates and times of chemical application were all important in determining the response to a particular plant growth regulator.





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PART III. EFFECTS OF PLANT GROWTH REGULATORS
ON SOYBEAN MORPHOLOGICAL CHARACTERISTICS



CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Yield is affected by many factors that are involved in plant growth (Cooke, 1985), and in soybeans it is "an end product of a complex ecological and biological system in which each plant operates" (Stutte and Davis, 1983). Therefore, a number of different approaches should be investigated in order to improve yield in soybeans.

A less dense and more "erectophile" soybean canopy could be beneficial to photosynthetic productivity (Shibles et al., 1975). Shibles et al. also mention as components of yield variation the number of fruiting nodes and seed set per node. Lodging in soybeans causes losses of both quality and quantity of seed (Weber and Fehr, 1966). Reduced lodging could consequently increase yield; therefore, morphological characteristics are important.

One of the established uses of plant growth regulators (PGRs) is the control of plant height and shape, which indirectly can affect the yield and economy of harvesting (Cooke, 1985; Ounsworth and Pillay, 1969; Blomquist et al., 1973; Slife and Earley, 1970; Dua et al., 1978; Hewitt et al., 1982). It appears that retardation of vegetative growth helps to redirect the plant's energy to reproductive sinks (Schott and Rittig, 1982; Stutte and Davis, 1983; Tanner and Ahmed, 1974). Bruinsma (1982) presumes a combination of "plant architecture" and a change in

growth and developmental rates could be the main reasons for the increase in yield caused by PGR application in some crops.

Applications of various PGRs on soybeans have reduced plant height and increased lodging, usually as a result of decreases in both node number and internode length (Akao et al., 1982; Clapp, 1975; Slife and Earley, 1970; Tanner and Ahmed, 1974), increased plant height and internode length (Ounsworth & Pillay, 1969), increased pod number (Akao et al., 1982; Nooden & Nooden, 1985), delayed maturity (Dybing and Lay, 1981a,b) and released lateral buds from apical dominance (Dua et al., 1978). Usually, these changes occurred with no increases in yield. It is important to note that, since plant type is dependent on physiological activity, the same plant growth regulator may not produce identical results on different plant types (Stutte and Davis, 1983). New plant growth regulators that are continuously becoming available, in addition to those that have successfully been used on other crops, should be evaluated on soybeans. One of the objectives of this study was to attempt to increase the production efficiency of soybean varieties by altering plant size and shape with plant growth regulators.

CHAPTER 2

MATERIALS AND METHODS

The experiments were conducted at the University of Tennessee Plant Science Field Laboratory in Knoxville for four years (1983-1985).

Two determinate cultivars, 'Essex' and 'Forrest', and one indeterminate experimental soybean line, TN77-31, were used in the experiments. The varieties were planted in early to mid-May and again in early to mid-June each year in order to simulate single- and double-crop planting dates, respectively.

The experiments were conducted in a split-plot arrangement of treatments in a randomized complete block design with three replications. Varieties served as mainplots, and growth regulator chemicals served as subplots. Plots consisted of four rows 3.05 m long with 0.91 m between rows and 100 seeds per row. Only the two center rows were treated with the appropriate chemical.

The growth regulators used in the experiments were gibberellic acid (GA), 6-benzyladenine (BA), daminozide (DA), chlorflurenol (CH), mepiquat chloride (MC), ancymidol (AN), ethephon (ET) and brassinosteroid 1105 (BR). A description of each chemical, as well as rates and times of application, is presented in Table A-1 in the Appendix and Tables 1 and 2. The control treatment did not have any plant growth regulator applied. In 1983, 'X-77' (1 ml l⁻¹) was used as

surfactant; whereas 0.5 percent 'Tween 20' was used in 1984 and 1985. No surfactant was used for the brassinosteroid treatments. All these treatments, with the exception of the GA seed treatment, were applied by means of a pressurized hand sprayer with a single flat fan nozzle (No. 8003) at 207 KPa as a foliar spray at growth stages V2, R1 or R3 (Fehr et., 1971) or combinations of them . The seed treatment consisted of coating the seeds with a dilute suspension of gibberellic acid in vegetable oil prior to planting.

All genotypes received all plant growth regulator treatments for the May planting. However, for the June planting, Essex was not treated with any of the growth retardants in order to prevent further reduction in its height in the late planting. Forrest received the growth retardant CH and a combination of CH and GA. TN77-31, a tall indeterminate line, was treated with the growth retardants CH, MC and DA.

The concentrations used for GA seed treatment differed each year. The 1983 seed treatment caused excessive elongation of internodes leading to lodging and premature death of all plants. The three lower concentrations in 1984 did not result in such an extreme reaction, but plant stand was poor in some cases. A greenhouse experiment in 1985, using various GA concentrations, resulted in selecting two lower concentrations (98 ppm and 390 ppm) for the field experiments.

The number of flower buds, open flowers and pods were counted before and after ethephon treatments were sprayed. Twenty trifoliolates

were harvested from the seventh plant node of ethephon-treated plots. Leaflets were separated into side leaflets and terminal leaflet, and leaf area measurements were taken with a 'Li-Cor Area Meter'.

At maturity, two plants were selected from the treated center rows of each plot, and the following measurements taken:

- plant height--height of plant from soil level to the tip of the plant
- number of nodes on mainstem--the first node (assumed to be the cotyledonary node) was the one nearest soil level
- length of internodes on mainstem
- number of branches at each node
- number of nodes on branches

CHAPTER 3

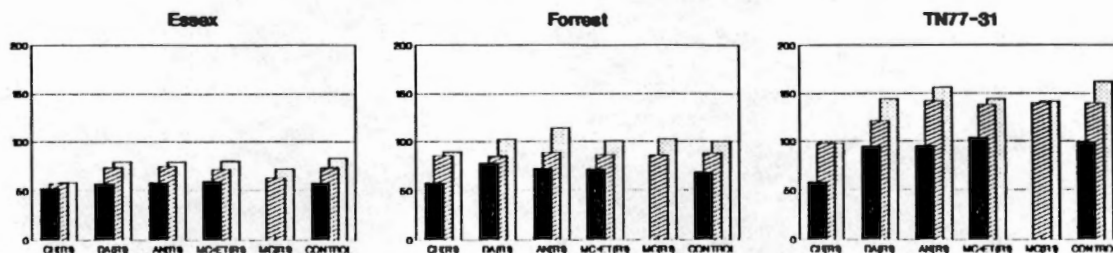
RESULTS

Morphological Characteristics: May PlantingPlant Height

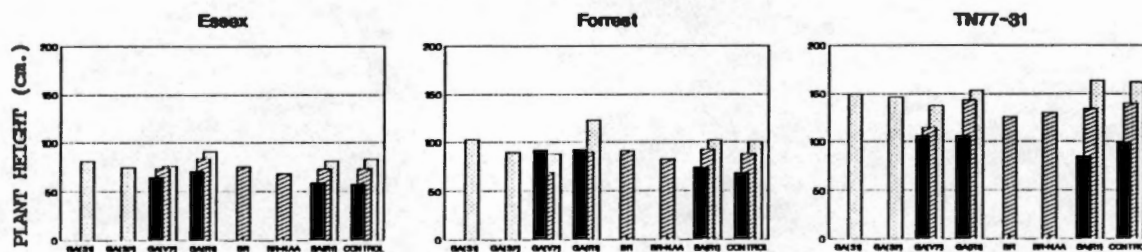
Growth retardants: In general, chlorflurenol tended to reduce the plant height of Essex, Forrest, and TN77-31 in each of the three years (Fig. 15). This reduction in height was significant in all three years for TN77-31, but only significant for the variety Essex in 1985.

The untreated control plants of the three varieties differed significantly in plant height all three years. TN77-31 was the tallest, and Essex was the shortest. There was no significant difference between the heights of Forrest and Essex. Of the growth retardants applied, only chlorflurenol and daminozide altered the relationships of heights among the varieties, causing insignificant differences among them in 1983 only. In 1983, chlorflurenol drastically reduced the height of the indeterminate line, TN77-31, resulting in 41 percent reductions in height, as opposed to 30 percent in 1984 and 40 percent in 1985 (Fig. 15). The reductions in height of Essex by chlorflurenol were 8 percent, 22 percent, 29 percent respectively, during the same years. Daminozide did not significantly affect height of any variety, and

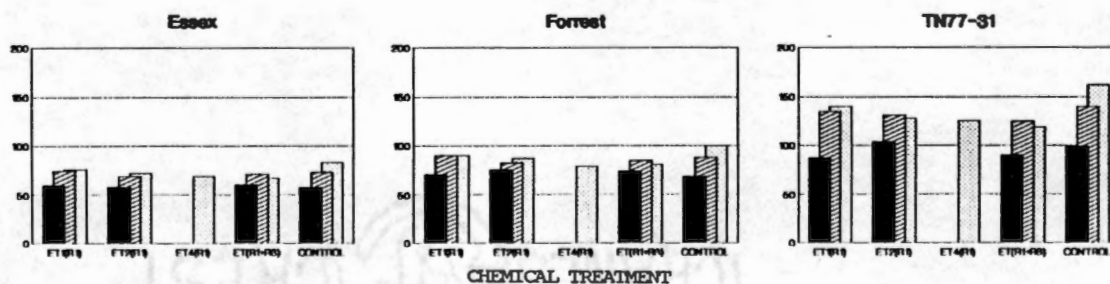
Growth Retardants



Growth Promoters



Ethephon^s



LSD(0.5) = 7.7 (1983)
= 10.4 (1984)
= 7.8 (1985)

LSD(0.5) = 15.2 (1983)
= 18.2 (1984)
= 10.1 (1985)

LSD(0.5) = 21.8 (1983)
= 17.0 (1984)
= 16.7 (1985)

■ 1983 ▨ 1984 ▩ 1985

^s1985 ET rates different from 1983 and 1984.

Fig. 15. Growth regulator effects on mean plant height (cm) of three soybean varieties planted in May 1983-1985.

slight differences among them after daminozide application were probably due to random causes.

The other growth retardants--ancymidol, mepiquat chloride, and the combination treatment of mepiquat chloride and ethephon [MC+ET(R1)] did not significantly alter plant height of any variety (Fig. 15).

Ethephon treatments: The ethephon treatments affected plant height (reduction) of all varieties in 1985 only. Ethephon at rates of 2000 ppm [ET2(R1)] and 4000 ppm [ET4(R1)] and the combination treatment [ET(R1+R3)] significantly reduced the plant height of the indeterminate line TN77-31 (Fig. 15); whereas only the latter two treatments [ET4(R1)] and [ET(R1+R3)] caused significant reduction in height in the determinate cultivars (Forrest and Essex).

Growth promoters: There was a tendency for one or more of the gibberellic acid treatments to increase plant height. Gibberellic acid applied at R1 increased plant height of Essex and Forrest in 1983-1985 and of TN77-31 in 1983 and 1984 (Fig. 15). Gibberellic acid applied at V2 increased plant height of all genotypes in 1983; however, these increases in plant height caused by GA(R1) were significant for both Essex and Forrest in 1985 and for Essex only in 1983. These significant increases in plant height probably explain why the relationships among plant heights of the three varieties were altered in 1983 and 1985.

Neither Brassinosteroid 1105 alone (BR) nor in combination with NAA (BR+NAA) significantly affected plant height, although for the

determinate cultivars, BR had the tendency to increase plant height; whereas in combination with NAA (BR+NAA), plant heights were reduced.

Benzyladenine, a cytokinin, did not significantly affect plant height of any variety, although there was a tendency to increase plant height of Forrest all three years and decrease the height of Essex in 1984 and 1985 in TN77-31 in 1983 and 1984.

Frequency of Nodes on Mainstem

Growth retardants: Chlorflurenol reduced the number of nodes on the mainstem of TN77-31 all three years, but the reduction was significant ($P < 0.05$) in 1983 and 1985 but not in 1984 (Fig. 16). The significant reduction for TN77-31 could be the cause of non significant differences between Forrest and TN77-31 node numbers during these two years. For the determinate varieties, this growth retardant had the general tendency to increase node number.

The untreated (control) plants had significant differences in number of nodes between Forrest and TN77-31, but not between Forrest and Essex. The other growth retardants (daminozide, ancymidol, and mepiquat chloride) did not significantly affect plant height of any variety (Fig. 16).

Ethephon treatments: None of the ethephon treatments affected the number of nodes on the mainstem significantly in any variety (Fig. 16). However, for TN77-31, there was a tendency for ethephon applied at R1 and again at R3 [ET(R1+R3)] to reduce node number in all three years.

Growth promoters: Frequency of nodes on the mainstem of all varieties was not affected significantly by any growth promoter (Fig. 16); however there were some trends. Gibberellic acid applied at V2 increased this trait in Essex in 1983 and 1984 and decreased it in Forrest and TN77-31 in 1984 and 1985. When applied at R1, gibberellic acid increased Essex node number in 1984 and 1985, but reduced TN77-31 node number these two years. Benzyladenine decreased Forrest node number in 1984 and 1985, but increased TN77-31 node number in 1983 and 1985.

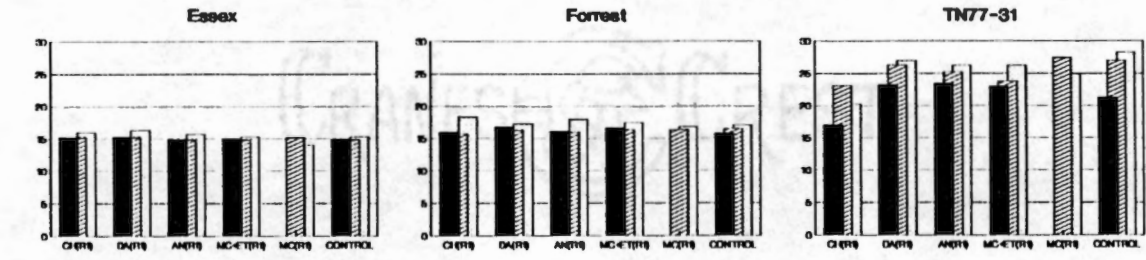
Internode Length of Mainstem

Growth retardants: Except for Forrest in 1984, chlorflurenol reduced mainstem internode length of all varieties all the years (Table 15). This reduction was significant for TN77-31 in 1983 and 1985 and for Essex in 1985. No other growth retardant significantly affected mainstem internode length of any variety although the tendency was to reduce internode length.

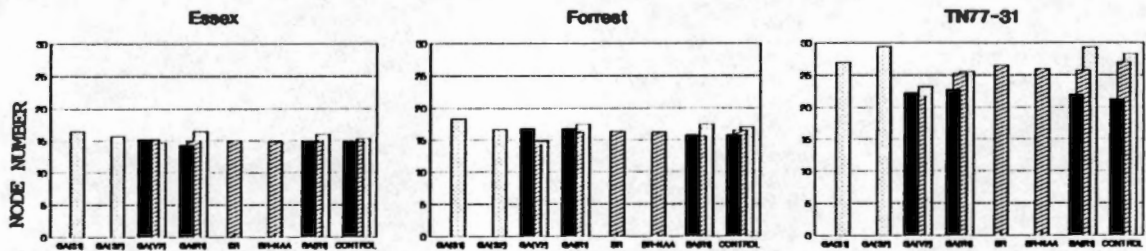
Ethephon treatments: The ethephon treatments did not affect mainstem internode length significantly ($P>0.05$, Table 15).

Growth promoters: Gibberellic acid applied at V2 tended to result in increases in internode length of all varieties for all years except in 1985 and 1984, when internode length of Essex and Forrest, respectively, were reduced by the treatment (Table 15). It must be noted that these increases/decreases were not significantly ($P>0.05$)

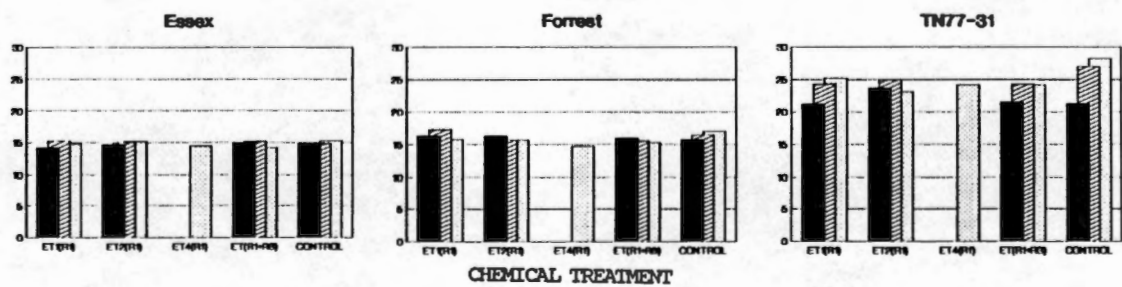
Growth Retardants



Growth Promoters



Ethephon[§]



■ 1983 ▨ 1984 ▤ 1985

§1985 ET rates different from 1983 and 1984.

Fig. 16. Growth regulator effects on mean node number on mainstem of three soybean varieties planted in May 1983-1985.

Table 15. Mean internode length of mainstem (mm) of three soybean varieties as affected by growth regulator treatment and planting date

Chemical Treatments [†]	-----1983-----						-----1984-----						-----1985-----					
	May Planting			June Planting			May Planting			June Planting			May Planting			June Planting		
	ES [‡]	FO [§]	TN [¶]	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN
Control	39.5 ^{ab}	43.9 ^{ab}	47.1 ^a	41.0 ^a	47.0 ^a	46.7 ^a	47.0 ^{abc}	52.3 ^a	52.0 ^a	38.2 ^a	46.3 ^{abc}	51.8 ^a	52.7 ^{ab}	58.9 ^{bc}	58.2 ^{ab}	46.3 ^b	60.0 ^a	66.0 ^a
GROWTH RETARDANTS																		
CH(R1)	35.8 ^a	37.1 ^{ab}	35.8 ^b	-	-	36.6 ^a	37.1 ^c	52.7 ^a	42.1 ^a	-	36.0 ^d	36.9 ^b	37.7 ^c	49.4 ^c	47.4 ^c	-	51.1 ^a	50.0 ^b
DA(R1)	37.2 ^a	43.6 ^{ab}	41.8 ^{ab}	-	-	44.3 ^a	46.2 ^{abc}	51.4 ^a	45.5 ^a	-	-	45.1 ^a	47.7 ^b	58.7 ^{bc}	53.5 ^{abc}	-	-	57.7 ^{ab}
AN(R1)	40.9 ^a	46.2 ^{ab}	42.5 ^{ab}	-	-	-	47.9 ^{abc}	54.2 ^a	56.2 ^a	-	-	-	50.6 ^{ab}	62.7 ^b	60.2 ^a	-	-	-
MC+ET(R1)	39.4 ^a	43.6 ^{ab}	45.5 ^{ab}	-	-	43.6 ^a	45.7 ^{abc}	52.2 ^a	57.4 ^a	-	-	50.2 ^a	50.7 ^{ab}	56.1 ^{bc}	54.6 ^{abc}	-	-	55.7 ^{ab}
MC(R1)	-	-	-	-	-	-	40.4 ^{bc}	51.4 ^a	50.5 ^a	-	-	50.2 ^a	49.7 ^{ab}	60.3 ^b	60.2 ^a	-	-	64.0 ^{ab}
ETHOPHOS																		
ET ₁ (R1)	42.1 ^a	46.2 ^{ab}	42.4 ^{ab}	44.8 ^a	46.6 ^a	47.4 ^a	46.7 ^{abc}	52.1 ^a	55.4 ^a	40.5 ^a	43.5 ^{bcd}	50.5 ^a	49.8 ^{ab}	56.5 ^{bc}	55.5 ^{abc}	47.8 ^b	63.1 ^a	58.6 ^{ab}
ET ₂ (R1)	40.3 ^a	46.9 ^a	44.6 ^{ab}	41.0 ^a	48.5 ^a	39.1 ^a	44.3 ^{abc}	51.4 ^a	51.9 ^a	35.7 ^a	40.1 ^{cd}	51.0 ^a	47.3 ^b	54.7 ^{bc}	54.6 ^{abc}	44.7 ^b	55.8 ^a	60.2 ^{ab}
ET ₃ (R1)	-	-	-	-	-	-	-	-	-	-	-	-	46.8 ^b	53.5 ^{bc}	52.7 ^{abc}	48.2 ^b	57.6 ^a	57.0 ^{ab}
ET(R1+R3)	42.1 ^a	46.9 ^{ab}	41.7 ^{ab}	40.4 ^a	48.9 ^a	46.2 ^a	46.6 ^{abc}	54.1 ^a	51.9 ^a	36.1 ^a	41.7 ^{bcd}	50.8 ^a	46.9 ^b	52.9 ^{bc}	49.1 ^{bc}	47.4 ^b	58.2 ^a	58.7 ^{ab}
GROWTH PROMOTERS																		
GA(S1)	-	-	-	-	-	-	-	-	-	-	-	-	47.3 ^b	54.9 ^{bc}	55.5 ^{abc}	45.5 ^b	56.4 ^a	56.9 ^{ab}
GA(S2)	-	-	-	-	-	-	-	-	-	-	-	-	46.6 ^b	53.8 ^{bc}	50.2 ^{abc}	46.1 ^b	53.0 ^a	54.2 ^{ab}
GA(V2)	43.9 ^a	56.8 ^a	48.0 ^a	43.8 ^a	48.0 ^a	41.9 ^a	50.6 ^{ab}	49.2 ^a	52.1 ^a	35.6 ^a	41.6 ^{bcd}	45.5 ^a	51.4 ^{ab}	59.3 ^{bc}	59.4 ^{ab}	59.5 ^a	56.4 ^a	64.0 ^{ab}
GA(R1)	41.6 ^a	55.4 ^a	47.7 ^a	-	-	-	53.8 ^a	54.6 ^a	56.4 ^a	-	-	-	54.8 ^a	69.9 ^a	60.8 ^a	-	-	-
GA(V2)+CH(R1)	-	-	-	-	36.5 ^b	-	-	-	-	-	42.5 ^{bcd}	-	-	-	-	-	53.0	-
BR	-	-	-	-	-	-	46.9 ^{abc}	55.1 ^a	46.7 ^a	39.3 ^a	52.3 ^a	48.3 ^a	-	-	-	51.1 ^b	62.1 ^a	53.7 ^{ab}
BR+NAA	-	-	-	-	-	-	44.2 ^{abc}	50.1 ^a	49.4 ^a	41.7 ^a	49.5 ^{ab}	46.5 ^a	-	-	-	48.8 ^b	60.4 ^a	58.9 ^a
BA(R1)	39.7 ^a	48.8 ^{ab}	39.6 ^{ab}	-	-	-	46.0 ^{abc}	58.7 ^a	52.5 ^a	-	-	-	49.9 ^{ab}	57.3 ^{bc}	56.4 ^{abc}	-	-	-

[†] See Tables 1 and 2 for description.[‡] ES = Essex, FO = Forest, TN = TN77-31[§] Means followed by a common letter within year, planting, date, and variety are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test

different from the control. Although this treatment did not significantly increase internode length of any variety in 1983-1985, it altered the relationships among the varieties in 1983 (Table 15). With no treatment, there were no significant differences among varietal internode length any year. However, with the application of gibberellic acid at V2 in 1983, internode lengths of all varieties were significantly different from each other.

Gibberellic acid applied at early flowering (R1) increased internode length of all varieties all three years (Table 15). The increase in length was significantly different from the control in 1985 for Forrest only. This 19 percent increase in Forrest internode length may be the reason why internode length for Forrest was significantly different from those of Essex (4 percent increase) and TN77-31 (4 percent increase).

Brassinosteroid (BR) and brassinosteroid in combination with naphthalene acetic acid (BR+NAA) shortened internode length of Essex and TN77-31, although these decreases were not significantly ($P>0.05$) different from the control.

The Benzyladenine treatment, [BA(R1)], did not significantly affect internode length of any of the three varieties.

Number of Branches:

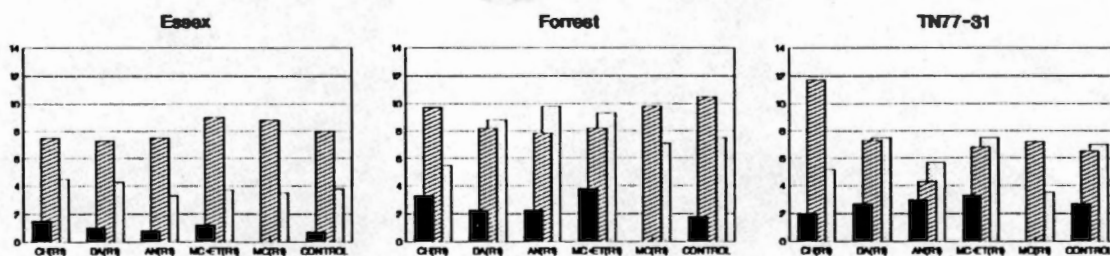
Growth retardants: The growth retardants increased the number of branches of the determinate varieties in 1983 but none of these

increases were significantly different from the control (Fig. 17). This same year, chlorflurenol decreased TN77-31 branch number; whereas the other growth retardants increased this trait but once again, these differences were not significantly different from the control. In 1984 no growth regulator treatment significantly altered the number of branches of any variety. However, most of the growth retardants had a tendency to decrease branch number in the determinate varieties and increase this trait in the indeterminate line (Fig. 17). In 1985 this trend was reversed, with most of the growth retardants increasing branch number in the determinates and decreasing it in TN77-31. The differences were not significantly different from the control.

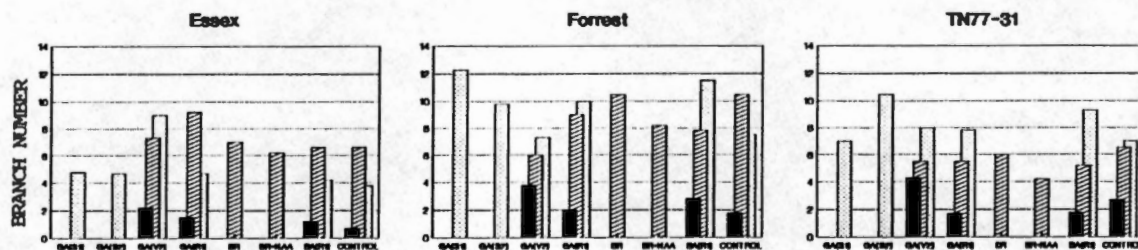
Ethephon treatments: In 1983 all the ethephon treatments increased branch number of all varieties, but it was only in the Essex variety that one treatment, ET(R1+R3), significantly increased branch number above that of the control (Fig. 17). In 1984 and 1985, no ethephon treatment altered branch number significantly ($P>0.05$).

Growth promoters: No growth promoter affected branch number of any variety significantly in 1983 and 1984 (Fig. 17). In 1985 some growth promoters significantly increased branch number of Forrest and Essex plants, but not those of TN77-31. Whereas only gibberellic acid applied at V2 [GA(V2)] significantly increased branch number of Essex over that of the control for Forrest, gibberellic acid applied as a seed treatment (GAS1) and benzyladenine [BA(R1)] both significantly increased branch number (Fig. 17).

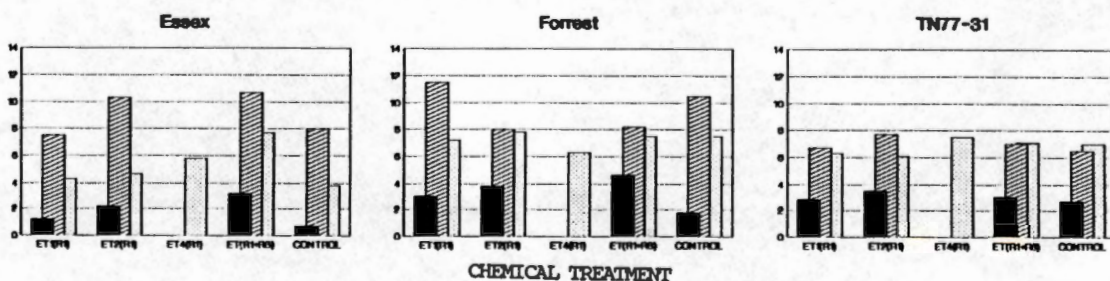
Growth Retardants



Growth Promoters



Ethephon^s



1983 1984 1985

^s1985 ET rates different from 1983 and 1984.

Fig. 17. Growth regulator effects on mean number of branches of three soybean varieties planted in May 1983-1985.

The increases in branch number of Forrest plants after GA(S1) and BA(R1) applications led to a change in the relationships among varieties. With no chemical treatment (control), there were no significant differences among branch numbers of the three varieties, but upon application, there were differences between branch number of Essex and that of Forrest (Fig. 17).

Number of Branch Nodes

Growth retardants: Although no growth retardants significantly altered number of branch nodes of any variety throughout the three years, one treatment, daminozide (DARI), increased TN77-31's branch nodes, and two treatments, chlorflurenol (CH) and MCET(R1), increased the number of branch nodes on Essex these three years (Table 16). This effect on Essex branch number, though not significant, was effective enough to cause a significant difference between Essex branch node number and those of Forrest and TN77-31 although initially (controls) no differences existed.

Ethephon treatments: The ethephon treatments did not significantly affect branch node number of any variety in any year, although for Forrest and Essex in 1983 and 1984, increased ethephon concentrations had a tendency to increase branch node number (Table 16).

Growth promoters: Gibberellic acid applied at V2 was the only growth promoter that affected branch node number significantly. This treatment increased branch node number of all varieties significantly in

Table 16. Mean number of nodes per branch of three soybean varieties as affected by growth regulator treatment and planting date

Chemical Treatments [†]	-----1983-----					-----1984-----					-----1985-----									
	May Planting					June Planting					May Planting					June Planting				
	ES [‡]	FO [‡]	TN [‡]	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN	ES	FO	TN		
Control	1.4 ^{ab}	2.9 ^a	2.9 ^a	0.4 ^b	3.6 ^a	2.1 ^a	2.2 ^b	2.8 ^b	3.5 ^b	2.5 ^a	2.4 ^a	2.4 ^{ab}	3.6 ^{ab}	2.3 ^b	2.9 ^a	2.7 ^b	2.6 ^{bc}	2.6 ^b		
GROWTH RETARDANTS																				
CH(R1)	3.6 ^a	4.0 ^a	3.8 ^a	-	-	2.0 ^a	2.6 ^b	2.7 ^b	3.3 ^b	-	2.7 ^a	2.5 ^{ab}	4.4 ^{ab}	3.4 ^b	2.9 ^a	-	2.2 ^c	2.4 ^b		
DA(R1)	2.3 ^a	4.0 ^a	4.1 ^a	-	-	2.2 ^a	2.1 ^b	2.6 ^b	4.3 ^{ab}	-	-	3.1 ^a	4.0 ^{ab}	2.7 ^b	3.8 ^a	-	-	2.9 ^b		
AN(R1)	1.4 ^a	3.7 ^a	3.3 ^a	-	-	-	2.1 ^b	2.2 ^b	2.9 ^b	-	-	-	3.2 ^{ab}	2.8 ^b	2.7 ^a	-	-	-		
MC+ET(R1)	3.0 ^a	4.3 ^a	3.8 ^a	-	-	3.2 ^a	2.7 ^b	2.6 ^b	2.5 ^b	-	-	1.6 ^b	4.9 ^a	3.1 ^b	3.5 ^a	-	-	2.7 ^b		
MC(R1)	-	-	-	-	-	-	2.1 ^b	2.8 ^b	3.6 ^b	-	-	2.4 ^{ab}	2.5 ^{ab}	2.4 ^b	3.7 ^a	-	-	3.2 ^b		
ETHEPHON																				
ET(R1)	2.5 ^a	3.6 ^a	3.0 ^a	3.0 ^a	4.0 ^a	1.6 ^a	2.6 ^b	3.3 ^{ab}	3.0 ^b	2.1 ^a	3.5 ^a	1.7 ^b	4.1 ^{ab}	3.4 ^b	3.8 ^a	2.9 ^b	3.9 ^a	3.6 ^b		
ET ₂ (R1)	3.0 ^a	3.7 ^a	3.8 ^a	2.5 ^a	2.4 ^b	3.0 ^a	2.7 ^b	2.8 ^b	3.4 ^b	2.4 ^a	3.5 ^a	2.3 ^{ab}	4.7 ^{ab}	2.3 ^b	3.2 ^a	3.4 ^b	2.9 ^{bc}	2.9 ^b		
ET ₃ (R1)	-	-	-	-	-	-	-	-	-	-	-	-	4.0 ^{ab}	3.3 ^b	3.8 ^a	2.9 ^b	2.5 ^{bc}	3.1 ^b		
ET(R1+R3)	3.2 ^a	4.3 ^a	3.7 ^a	2.9 ^a	4.4 ^a	3.1 ^a	2.4 ^b	2.9 ^b	3.4 ^b	2.3 ^a	3.5 ^a	2.2 ^{ab}	3.0 ^{ab}	2.8 ^b	3.5 ^a	2.3 ^b	2.8 ^{bc}	2.7 ^b		
GROWTH PROMOTERS																				
GA(S1)	-	-	-	-	-	-	-	-	-	-	-	-	5.2 ^a	2.9 ^b	3.1 ^a	3.0 ^a	3.0 ^b	2.6 ^b		
GA(S2)	-	-	-	-	-	-	-	-	-	-	-	-	4.0 ^{ab}	2.5 ^b	13.3 ^a	2.9 ^b	3.1 ^b	3.0 ^b		
GA(V2)	3.8 ^a	4.4 ^a	3.7 ^a	3.3 ^a	4.4 ^a	2.6 ^a	4.7 ^a	4.2 ^a	5.6 ^a	3.7 ^a	4.0 ^a	3.1 ^a	4.1 ^{ab}	4.7 ^a	3.9 ^a	4.9 ^a	4.3 ^a	5.7 ^a		
GA(R1)	2.4 ^a	3.5 ^a	2.6 ^a	-	-	-	1.9 ^b	2.5 ^b	3.0 ^b	-	-	-	4.4 ^{ab}	2.6 ^{ab}	3.2 ^a	-	-	-		
GA(V2)+CH(R1)	-	-	-	-	4.8 ^a	-	-	-	-	-	3.6 ^a	-	-	-	-	-	4.4 ^a	-		
BR	-	-	-	-	-	-	1.8 ^b	2.8 ^b	3.6 ^b	2.4 ^a	2.8 ^a	3.0 ^a	-	-	-	3.1 ^b	3.1 ^b	3.2 ^b		
BR+NAA	-	-	-	-	-	-	1.8 ^b	2.6 ^b	3.3 ^b	2.8 ^a	2.7 ^a	3.2 ^a	-	-	-	2.5 ^a	2.5 ^{bc}	-		
BA(R1)	2.2 ^a	4.0 ^a	3.5 ^a	-	-	-	1.9 ^b	2.8 ^b	3.0 ^b	-	-	-	4.2 ^{ab}	2.7 ^b	3.4 ^a	-	-	-		

[†]See Tables 1 and 2 for description.[‡]ES = Essex, FO = Forest, TN = TN77-31[§]Means followed by a common letter within year, planting date and variety are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test

1984 and that of Forrest in 1985 as well (Table 16). All other years, GA(V2) produced insignificant ($P>0.05$) increases in number of branch nodes of all varieties.

Morphological Characteristics: June Planting

Plant Height

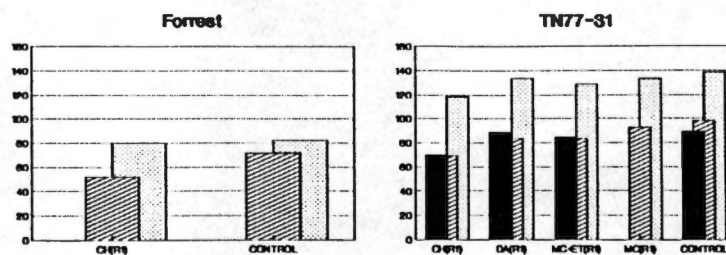
Growth retardants: No growth retardants were used on the Essex variety in the June plantings in 1983-1985. Since late planting results in reduced growth, it was unnecessary to further reduce the height of the shortest variety, Essex.

Applications of GAV2 + CHR1 significantly reduced the plant height of Forrest in 1983 and 1985 (Fig. 18). Chlorflurenol reduced Forrest plant height significantly only in 1984. It was not applied to Forrest in 1983. There was a significant difference between the effect of chlorflurenol alone (CHR1) and in combination with gibberellic acid (GAV2 + CHR1) in 1985 with the latter treatment causing the greater reduction in Forrest plant height.

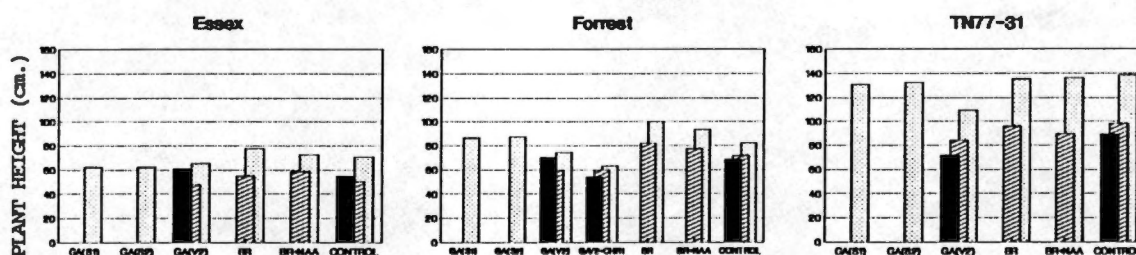
For the variety TN77-31, the growth retardants chlorflurenol, daminozide, mepiquat chloride, and mepiquat chloride in combination with ethephon generally shortened plants, but did not produce significant reductions in height (Fig. 18).

Ethephon treatments: Plant heights of all varieties were not affected significantly by the ethephon treatments. The altered

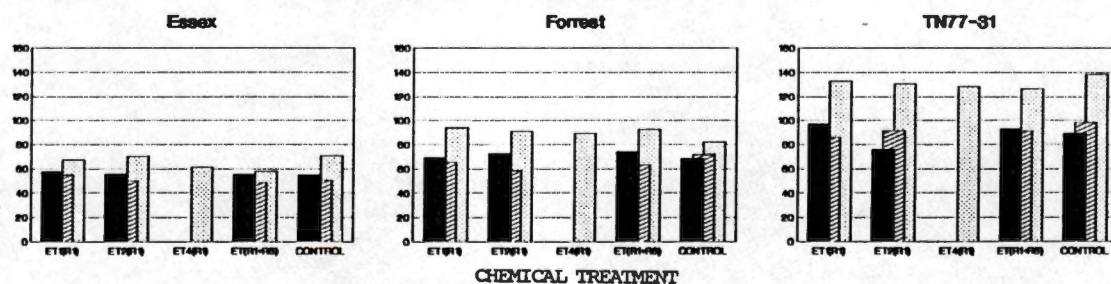
Growth Retardants



Growth Promoters



Ethephon[§]



LSD(0.5) = 6.2 (1983)
= 7.7 (1984)
= 11.8 (1985)

LSD(0.5) = 6.8 (1983)
= 11.5 (1984)
= 8.3 (1985)

LSD(0.5) = 26.6 (1983)
= 16.9 (1984)
= 13.3 (1985)

■ 1983 ▨ 1984 ▩ 1985

§1985 ET rates different from 1983 and 1984.

Fig. 18. Growth regulator effects on mean plant height (cm) of three soybean varieties planted in June 1983-1985.

relationships among varieties (as compared to control) following application of some of the ethephon treatments are difficult to explain (Fig. 18). Overall, the general pattern seemed to be that ethephon caused slight reductions in plant height, but the differences were generally not significantly ($P>0.05$) different from the control.

Growth promoters: Both the brassinosteroid treatment alone (BR) and in combination with naphthalene acetic acid (BR + NAA) increased plant height of the determinate varieties in the years applied (1984, 1985, Fig. 18). However, only the increase in height caused by BR on Forrest in 1985 was significantly ($P\leq 0.05$) different from the control. This could have been the reason for the altered relationships among varieties with respect to plant height. With no chemical treatment (control), plant height of the two determinate varieties (1985) were not significantly different from each other, but were significantly different from the indeterminate variety. With the application of BR, significant differences occurred among the three varieties.

The treatment BR and BR+NAA tended to decrease plant height of TN77-31, although the decreases were not significantly different from the control. In 1985 gibberellic acid applied at V2 (GAV2) significantly decreased plant height of only TN77-31 (Fig. 18).

Number of Nodes on Mainstem

Growth retardants: None of the growth retardants applied on Forrest in 1984 and 1985 and on TN77-31 in 1983-1985 had any significant effects on number of nodes on mainstem (Fig. 19).

Ethephon treatments: The ethephon treatments did not significantly affect number of nodes on mainstem of any variety in any year (Fig. 19).

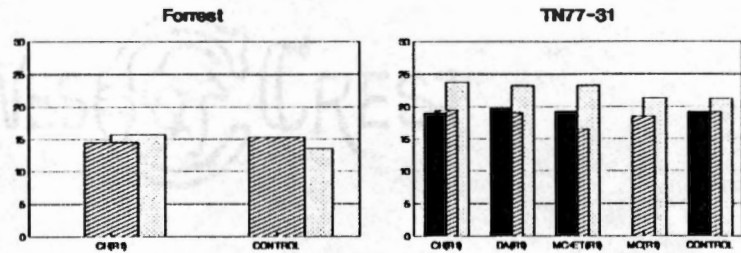
Growth promoters: Except for gibberellic acid applied at V2, no growth promoter significantly altered mainstem node number of any variety. GA(V2) significantly decreased Essex node number in 1985 only (Fig. 19). This treatment resulted in a slight reduction in the number of nodes of Forrest and TN77-31 in 1983-1985.

Slight increases in number of mainstem nodes occurred when both gibberellic acid seed treatments (GAS1 and GAS2) were applied on Forrest and TN77-31 in 1985 and when BR and BR+NAA were applied on TN77-31 in 1984-1985, on Forrest in 1985 and on Essex in 1984 (Fig. 19).

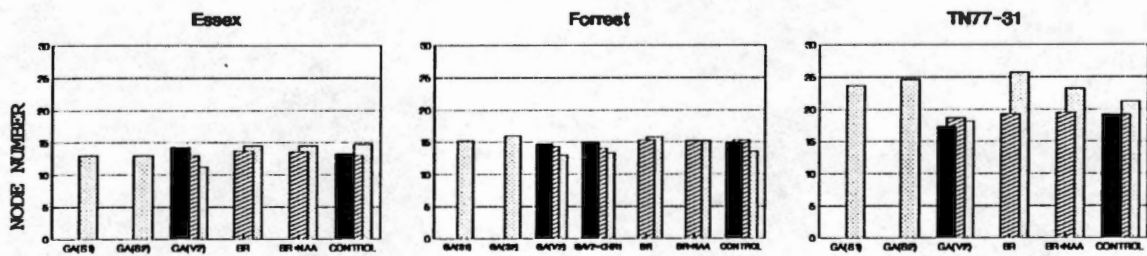
Internode Length of Mainstem

Growth retardants: Chlorflurenol shortened internode length of both Forrest and TN77-31 varieties for the years the chemicals were applied. The decrease in length was significantly different from the control in only 1984 for Forrest and in 1984 and 1985 for TN77-31 (Table 15). The other growth retardants applied on TN77-31 decreased internode length, but not significantly ($P>0.05$). The treatment

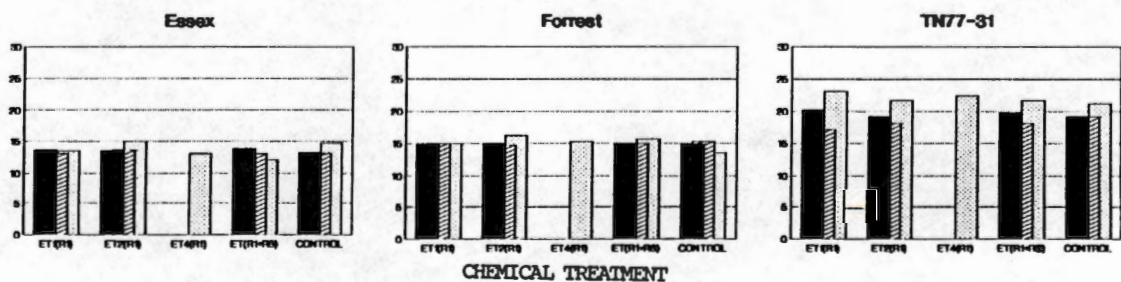
Growth Retardants



Growth Promoters



Ethephon[§]



■ 1983 ▨ 1984 ▤ 1985

[§]1985 ET rates different from 1983 and 1984.

Fig. 19. Growth regulator effects on mean node number on mainstem of three soybean varieties planted in June 1983-1985.

GAV2 + CHR1 shortened the internode length of Forrest all three years, although it was only in 1983 that this treatment produced effects significantly ($P \leq 0.05$) different from the control (Table 15).

Ethephon treatments: Although no ethephon treatment affected varietal internode length significantly, these treatments tended to shorten internode length of TN77-31 (1984, 1985) and of Forrest in 1984 (Table 15). The lowest ethephon concentration (500 ppm) increased internode length of TN77-31 in 1983 and of Essex in 1983 and 1984, but shortened Forrest internode length in 1983 and 1984.

Growth promoters: Gibberellic acid applied at V2, the only growth promoter that significantly affected varietal internode length, significantly ($P \leq 0.05$) increased internode length of Essex only in 1985 (Table 15). With no growth regulators applied (control) internode lengths of Forrest and TN77-31 were not significantly different from each other, but were significantly longer than internode lengths of Essex. The significant increase in Essex internode length in 1985 was enough to alter the relationships among varieties, making all three varieties equal in internode lengths (Table 15).

The treatments BR and BR+NAA resulted in slight increases (not significant) in the internode length of the determinate varieties, Forrest and Essex (Table 15). However these two treatments and the other growth promoters applied on the indeterminate line, TN77-31, tended to cause a slight shortening (not significant) of internode length (Table 15).

Number of Branches

Growth retardants: No growth retardant significantly affected varietal number of branches any year (Fig. 20).

Ethephon treatments: Ethephon applied at R1 at a rate of 1000 ppm (ET2R1) is the only ethephon treatment that significantly affected number of branches of a variety, increasing that of Essex in 1984 (Fig. 20).

Growth promoters: Only one growth promoter, gibberellic acid, applied as a seed treatment at 390 ppm (GAS2), significantly affected varietal branch number--GA(S2) increased the number of branches of Forrest in 1985 (Fig. 20).

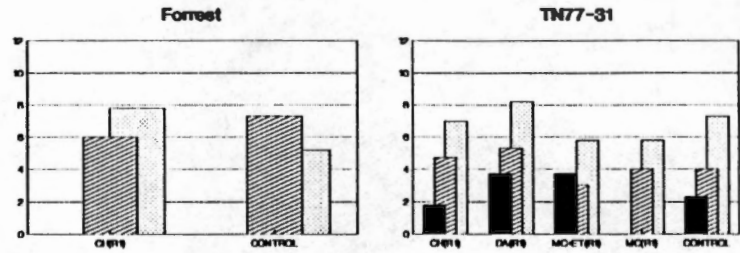
Some consistent trends were apparent. For example, GA(V2) increased the number of branches of Essex all three years; whereas for Forrest this occurred in 1983 and 1985 and for TN77-31 in 1984 only (Fig. 20).

In 1985 the growth promoters GA(S1), GA(V2), BR and BR+NAA increased number of branches for Forrest, but GA(S2), GA(S1), BR and BR+NAA produced a decrease for Essex, and except for GA(S1), these chemicals caused a decrease for TN77-31 (Fig. 20).

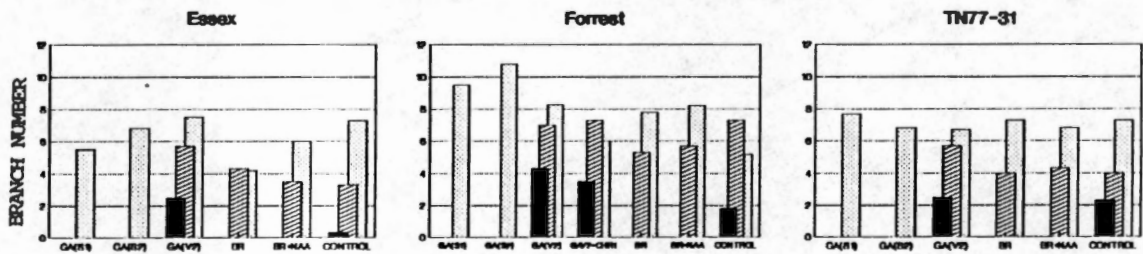
Number of Branch Nodes

Growth retardants: Although chlorflurenol applied alone at R1 (CHR1) did not significantly affect number of nodes per branch of any

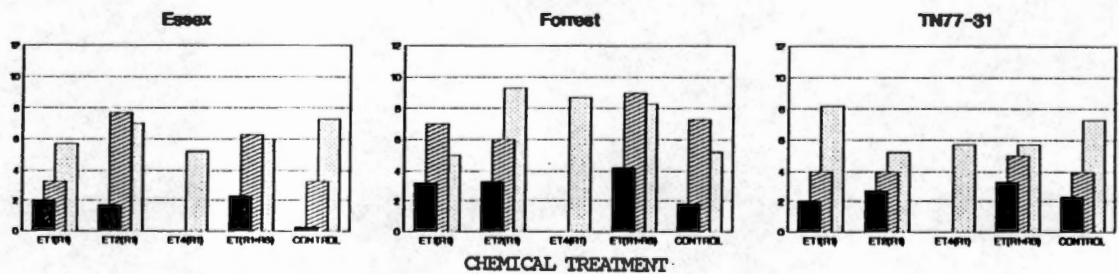
Growth Retardants



Growth Promoters



Ethephon[§]



■ 1983 ▨ 1984 □ 1985

[§]1985 ET rates different from 1983 and 1984.

Fig. 20. Growth regulator effects on mean number of branches of three soybean varieties planted in June 1983-1985.

variety, when applied with gibberellic acid (GAV2+CHR1), it increased the number for Forrest all three years with a significant increase occurring in 1985 (Table 16). The growth retardants applied to TN77-31 did not significantly ($P>0.05$) affect number of branch nodes any year.

Ethephon treatments: For the variety Essex, all the ethephon treatments (ET1R1, ET2R1, ETR1+R3) increased the number of branch nodes significantly in 1983 (Table 16), but these concentrations in 1984 and the higher concentrations in 1985 did not alter node number significantly. The application of 1000 ppm of ethephon (ET2R1) on Forrest significantly decreased branch node number in 1983, but produced a significant increase in 1985. Ethephon treatments did not significantly alter node number of TN77-31 (Table 16).

The significant increase in Essex branch number produced by 500 ppm and 1000 ppm ethephon in 1983 diminished the significant differences between Essex and the two other varieties that existed for the control treatment, making branch node number for all varieties equal (Table 16). The ET(R1+R3) treatment (1983) produced no significant differences between Essex and TN77-31 branch node numbers, but both were significantly different from Forrest's.

Growth promoters: Gibberellic acid applied at V2 (GAV2) consistently increased branch node number of all varieties although significant increases occurred only in 1985 for Forrest and TN77-31 (Table 16) and for Essex in 1983 and 1985. The significant increase in branch node number of Essex in 1983 produced by GA(V2) application,

resulted in no significant differences among varieties with respect to node number; whereas initially (control) there were differences. The other growth promoters did not significantly affect number of branch nodes.

Leaf Area Measurements:

In 1985 it was observed that ethephon-treated plants appeared more compact with smaller leaves than the control; therefore, leaf area measurements were taken to determine if this was the case. The results for the leaf area measurements taken for the varieties Essex and TN77-31 are presented in Tables 17 and 18. The three ethephon treatments significantly reduced leaf area for the May planting; whereas, for the June planting, only ET(R1+R3) and ET4(R1) reduced leaf area significantly (Table 17). Further analyses indicated that the varieties responded differently to ethephon treatments. Whereas Essex did not respond to ethephon treatments in the May planting, the indeterminate variety, TN77-31, did respond to the ethephon treatments because leaf areas were significantly reduced (Table 18).

Delayed planting resulted in larger leaves for Essex and smaller leaves for TN77-31, and in general, the ethephon significantly decreased the leaf area of both varieties (Table 18).

The treatment ET2(R1) resulted in larger leaves, while ET(R1+R3) resulted in significantly smaller leaves than those of the control of Essex plants in the June planting (Table 18). On the other hand, all

Table 17. Comparisons of mean[†] leaf size following treatment with different rates of ethephon (1985)

Chemical Treatment	Leaf Area(cm ² per leaf)	
	May Planting	June Planting
Control	99.5a [‡]	105.84a
ET1(R1)1000	84.7b	97.3abc
ET2(R1)2000	85.9b	104.7ab
ET4(R1)4000	-	94.5bc
ET(R1+R3)	84.9b	89.1c

[†]Means of all replications of the strains, Essex and TN77-31.

[‡]Means with a common letter within columns are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test.

Table 18. Mean leaf size of the two varieties, Essex and TN77-31 for the May and June plantings following treatment with different rates of ethephon (1985)

Chemical Treatment	Variety	Leaf Area(cm ² per leaf)	
		May Planting	June Planting
Control	Essex	93.3abc [†]	121.0b
ET(R1)1000	Essex	93.0abc	123.1ab
ET2(R1)2000	Essex	91.4abc	136.8a
ET4(R1)4000	Essex	-	122.0ab
ET(R1+R3)	Essex	94.6ab	105.3c
Control	TN77-31	105.8a	90.6d
ET1(R1)1000	TN77-31	76.4bc	71.4e
ET2(R1)2000	TN77-31	80.4bc	72.6e
ET4(R1)4000	TN77-31	-	67.0e
ET(R1+R3)	TN77-31	75.2c	72.9e

[†]Means with a common letter within columns are not significantly different at $P \leq 0.05$ based on Student-Newman-Keul test.

the ethephon-treated plants produced smaller leaves than the control plants of TN77-31 in the June planting.

CHAPTER 4

DISCUSSION

The results of this study indicate that the different varieties of soybeans responded differently to the plant growth regulator treatments. Even the two determinate varieties did not always respond similarly to the same treatment. Plant growth regulators did not produce consistent results through the years even on the same variety. Only those effects that were significantly different from the control will be discussed.

Gibberellic acid, a growth stimulant, when applied at beginning flowering (R1) increased Essex plant height in 1983 and 1985 and that of Forrest in 1985. This increase in height was not accompanied by either increase in node number or internode length, although a trend towards increased internode length existed. The increased height did not translate into increased yield for either variety. When applied at V2, GA increased the number of branches on Essex in 1985 and increased nodes per branch of both Essex and TN77-31 in 1984 and of Forrest in both 1984 and 1985. With delayed planting (June), as occurs for double-cropped soybeans, only the application of gibberellic acid at V2 produced any effects. For Essex, a decrease in node number together with an increase in internode length occurred in 1985. These two effects appeared to negate each other because no increase in Essex plant height occurred

that year. In 1983 and 1985, the treatment increased nodes per branch when no such effects occurred in the earlier planting.

Similar response of Forrest occurred for the June planting as occurred for the earlier one, but the responses occurred in different years. Whereas TN77-31 plants were shortened by application of GA(V2) in the delayed planting in 1985, the number of nodes per branch was increased.

The high gibberellic acid concentrations applied to soybean seeds in the earlier years led to excessive elongation, lodging, and death of most plants before maturity. In 1985 the lower concentrations used--98 ppm (S1) and 390 ppm (S2)--did not produce such drastic effects. In the earlier planting, the treatment GA(S1) increased the number of Forrest branches, and GA(S2) increased the Forrest internode length, and GA(S2) increased number of branches in the June planting.

Ethephon is a source of ethylene and has been found to stimulate further ethylene production in plants (Urwiler and Stutte, 1986; Ware, 1983). The higher ethephon concentrations of 4000 ppm [(ET4R1), ET(R1+R3)] decreased plant height of all three varieties in the 1985 May planting, and the lower concentration of 2000 ppm decreased the plant height of TN77-31. Ethylene is thought to inhibit auxin movement in stem tissue, probably reducing the ability of auxins to promote stem elongation (Dahnous et al., 1982). The inhibition of auxin transport, probably interfering with apical dominance, could be the reason for the increase in Essex's branch number in 1983.

The ethephon treatments had no effects on plant height when planting was delayed, but low concentrations (500 ppm or 1000 ppm) erratically increased Essex branch number, nodes per branch and leaf area and decreased nodes per branch of Forrest. It appears that the ability of ethylene to inhibit auxin transport is modified by environmental conditions (e.g. planting date) under which soybean plants are grown.

Even though no ethephon treatment affected Essex's leaf size in the May planting, in the delayed planting, the 2000 ppm rate increased leaf size, and the double application (ETR1+R3) decreased leaf size. Both low and high ethephon concentrations decreased leaf size of TN77-31 in both the May and June plantings.

Chlorflurenol shortened plant height of Essex and TN77-31 in the May planting. Nooden and Nooden (1985) obtained similar results with 'Anoka' soybeans. The decrease in height occurred consistently all three years for TN77-31. The suppression of Essex mainstem elongation in 1985 was a result of decrease in internode length; whereas, for TN77-31, the suppression of mainstem elongation was due to decreases in both internode length and mainstem node number (1983 and 1985). This consistent decrease in the height of the indeterminate line (TN77-31) by chlorflurenol seems promising, suggesting the use of a growth retardant to reduce height and probably prevent lodging of an indeterminate variety, but as Oplinger (1985) also found, this reduction was accompanied by a reduction in seed yield. The growth retardant reduced

vegetative growth (shortened plants), but did not result in an increase in the availability of photosynthate to the reproductive parts as expected by Peat and Jeffcoat (1982) since no increase in seed yields occurred. Chlorflurenol is a morphactin, and according to Schneider (1980), morphactins most probably act by affecting IAA enzyme systems and by inhibiting the transport and distribution of IAA.

Application of chlorflurenol in the delayed planting decreased plant height of Forrest by shortening internode length (in 1984), but had no effect on height of TN77-31, although the treatment shortened TN77-31's internode length. The interaction of a growth regulator with the environment (in this case planting date) is apparent once again.

All chlorflurenol-treated plants were very dark green, and senescence delayed. Prolonged photosynthesis did not result in increased yields, a possibility suggested by Abu-Shakra et al. (1978). It can be argued, however, that the dark green leaves (increased chlorophyll content) did not necessarily mean increased photosynthesis and that in fact, photosynthetic rates might have decreased, as observed by Mondal et al. (1978) in their work with "desinked" Hodgson plants. Photosynthetic rates were not investigated in this study.

The combination treatment of chlorflurenol and gibberellic acid (GAV2+CHR1) shortened Forrest plants, and in 1983, this was a result of decreased internode length. In 1985 this reduction in vegetative growth did not result in the channeling of photosynthate to reproductive parts

to translate into higher yields, but rather produced a decrease in seed yield.

CHAPTER 5

SUMMARY

Growth regulators did not produce consistent results over the three years of the study. The varieties evaluated responded differently to the growth regulator treatments. Response to growth regulators also was dependant on planting date.

Gibberellic acid applied at R1 increased plant height of the determinate varieties in certain years only. Applied at stage V2, GA affected branch numbers and nodes per branch of Essex, but these responses occurred in different years.

Of the growth retardants evaluated, chlorflurenol consistently shortened plants of TN 77-31, the indeterminate line, but did not consistently shorten plants of the determinate varieties. Chlorflurenol produced dark green plants and delayed senescence for all varieties.

Very high concentrations of ethephon decreased plant height of all varieties, but this occurred in only one year.

The plant growth regulators induced modifications in plant size and shape, but these changes did not result in an increase in soybean yield.



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APPENDIX

Table A-1. Abbreviation, common and chemical names of plant growth regulators used in this study

Abbreviation	Common Name	Chemical Name
GA	gibberellic acid	2, 4a, 7-trihydroxy-1-methyl-8-methylene-gibb-3-ene-1, 10-carboxylic acid-1,4-lactone
BA	6-benzyladenine	6-benzylaminopurine
ET	ethephon	2-chloroethylphosphonic acid
AN	ancymidol	a-cyclopropyl-9-(p-methoxyphenyl)-5-pyrimidine methanol
DA	daminozide	succinicacid-2,2-dimethyl hydrazine
CH	chlorflurenol	methyl-2-chloro-9-hydroxyfluorene-9-carboxylate
MC	mepiquat chloride	1,1-dimethyl-piperidinium chloride
BR	brassinosteroid 1105	2 α , 3 α , 22 α , 23 α -tetrahydroxy-24 β -methyl-B-homo-7-oxa-5 α -cholestan-one

VITA

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