AN ABSTRACT OF THE THESIS OF

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Title: INFLUENCING FLOWER INITIATION AND FLOWER CLUSTER SET IN THE 'BARCELONA' FILBERT WITH GROWTH REGULATORS

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The alternate bearing cycle in the 'Barcelona' cultivar poses a major problem to the filbert industry. This study was conducted to alleviate this problem in one of two ways: by (1) increased floral initiation in the "on" year, and (2) increased cluster set in the "off" year. Growth regulators were selected on the basis of their effectiveness when applied to other alternate bearing crops. These growth regulators were then applied to 'Barcelona' trees at the times corresponding to floral initiation and cluster set in this cultivar.

During April and May, trees were treated with two concentrations (15 and 50ppm) of GA_3 to influence cluster set. The GA_3 applications caused a large number of clusters to abscise in the season applied, however, female flower production was quadrupled for the following season. These results suggest that when applied to filbert trees in the spring, GA_3 may have a hormonal effect on cluster abscission. The first GA_3 application (April 20) significantly increased catkin

production, indicating that the initiation of the catkins was in progress during this month. Gibberellic acid's influence on vegetative growth was minimal, with no substantial increase in shoot length or node number observed. Increased floral initiation is suggested to be the outcome of hormonal and carbohydrate level changes rather than through any dramatic change in vegetative growth. In the year following treatment, yield increases were due to the greater number of flowers initiated rather than an increase in percent cluster set.

Gibberellic acid (50ppm), TIBA (25ppm), and ethephon (500ppm) were also applied to 'Barcelona' filbert trees during the floral initiation process (July-August). Hand-thinning of nut clusters was also done during the initiation process. All of these treatments, except GA_3, resulted in increased female flower clusters the following spring. Gibberellic acid did not affect female flower initiation, however, catkin drop was accelerated. The average number of nuts per cluster, percent set, and yield were not affected by TIBA, ethephon, or GA_3 sprays in the year applied. Increased yield in the following year was attributed to the increased floral initiation brought about by the TIBA, ethephon, and hand-thinning treatments. Yield was also increased by GA_3 through greater percent set, and it is suggested the latter may be linked to the catkin abscission. The carbohydrates that would have been utilized in catkin production may have been made available to the developing nut clusters and vegetative structures, and may account for the resulting increase in yield.

Influencing Flower Initiation and Flower Cluster Set in the Barcelona Filbert with Growth Regulators

by

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A DEDICATION

When He was with us He gazed at us and at our world with eyes of wonder, for His eyes were not veiled with the veil of years, and all that He saw was clear in the light of His youth.

Though He knew the depth of beauty, He was for ever surprised by its peace and majesty; and He stood before the earth as the first man had stood before the first day.

We whose senses have been dulled, we gaze in full daylight and yet we do not see. We would cup our ears, but we do not hear; and stretch forth our hands, but we do not touch. And though all the incense of Arabia is burned, we go our way and do not smell.

We see not the ploughman returning from his field at eventide; nor hear the shepherd's flute when he leads his flock to the fold; nor do we stretch our arms to touch the sunset; and our nostrils hunger no longer for the roses of Sharon.

Nay, we honor no kings without kingdoms; nor hear the sound of harps save when the strings are plucked by hands; nor do we see a child playing in our olive grove as if he were a young olive tree. And all words must needs rise from lips of flesh, or else we deem each other dumb and deaf.

In truth we gaze but do not see, and hearken but do not hear; we eat and drink but do not taste. And there lies the difference between Jesus of Nazareth and ourselves.

His senses were all continually made new, and the world to Him was always a new world.

To Him the lisping of a babe was not less than the cry of all mankind, while to use it is only lisping.

To Him the root of a buttercup was a longing towards God, while to us it is naught but a root.

Kahlil Gibran

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My travels and education have left me with friends all over the world and each one has had a special impact upon my life. It is not possible to express my appreciation to or acknowledge each one by name but, certainly, they are remembered here. And then there is someone in each of our lives who will always be more than a friend, who we are in a very real sense, bonded to. I would recognize him here as well.

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INTRODUCTION

Alternate bearing is a major problem in filbert production, creating unstable marketing situations and economical and managerial problems. A heavy crop year will often be followed by a year of low crop production because the trees are not able to mature the crop and at the same time produce vigorous twig growth and an abundance of large flower buds for the following year's crop.

During the "on" year, high nut production influences flower bud formation. In the spring of the "off" year this creates one of two situations, a reduced number of pistillate flowers or varying amounts of weak pistillate flowers that tend to abort.

One of the most desirable characteristics sought in the 'Barcelona' cultivar, which accounts for about 85% of the annual filbert production in the United States, is increased yield. Larger numbers of female flowers, increased set, more nuts per cluster and per tree, a larger nut and lack of alternate bearing are all variables pertaining to increased yield.

Manipulation of hormone levels in the filbert by growth regulator treatments may provide a method to achieve these yield-increasing characteristics. The treatments may also reduce the amplitude of variation in yield the alternate bearing cycle produces. The present study was initiated to determine this.

The variables examined include the effect of treatments on set, cluster size, nut weight, kernel weight, blanks, yield, flower number,

and terminal shoot growth. The effect of branch orientation and stem diameter on flower number, set, and cluster size was also investigated.

Filbert Floral and Vegetative Differentiation and Development

Reproductive Development

To directly influence set and the floral initiation process in the filbert, the application of growth regulators has to occur at a time corresponding to these processes. As such, an adequate knowledge of filbert floral differentiation, initiation, and development is essential.

Floral Initiation

In Oregon, the male flowers of the filbert are initiated in April or May during active shoot growth. By July they can be seen as rudimentary small catkins in the axils of leaves of current season's growth (109). Female flowers are initiated in August after shoot growth has ceased (108). It is November before any external evidence of female flowers is apparent.

In several crop species (34, 52, 62, 98) male flowers are differentiated in late spring while gibberellin levels in the buds are high and abscisic acid and auxin levels are low. On the other hand, female flowers are differentiated in late summer when gibberellic acid levels are very low and abscisic acid and auxin levels are quite high. Corresponding levels of hormones during male and female flower differentiation and initiation may be present in the filbert as well.

Anthesis and Pollination

The female flower cluster is part of a compound bud. Overlapping bud scales surround the flower cluster and primordial shoot axis which extends later in the spring into a leafy shoot terminated by the nut cluster (107).

Within a single "flower bud" are found 4-16 florets, each with two styles. Female anthesis, noticeable by the emergence of these red stylar tips from the enclosing bud scales, is at its maximum in January and February (40, 107, 110). This time of "receptive maturation" is important in its relation to pollen availability and has been a subject of debate (3, 32, 33, 45, 110). Recent observations indicate receptivity extends to three months and longer (120).

When pollination is prevented or delayed, the styles continue to elongate and generally remain fresh and red for several weeks. Non-pollinated clusters drop from late April through the end of May.

The male catkin is composed of multiple bracts attached to a central vascular strand. Elongation of the catkin's central vascular system separate the bracts, each subtended by eight anther sacs. As the anthers dehisce, a tremendous amount of pollen is shed and carried by wind to the stigmatic surfaces of the female flowers. This process, depending on variety and season, may occur from early December to February in Oregon.

Following pollination the pollen tube germinates rapidly and grows down the style, taking 4-7 days to reach the base (107). Various sites have been suggested as the location of the resting stage for the pollen

while the female flower develops. Rimoldi (83) stated a cyst formed from the tube nuclei and a small amount of cytoplasm in the basal region of the stigma. Trotter (110) found the tube reached the primitive ovarian cavity where a period of quiescence followed. Arikan (3) suggested it remains in the fissures in the carpel wall of the ovary. Thompson (107), from recent studies with fluorescent microscopy suggests the resting stage is a filamentous structure, not a cyst, and is in the very base of the stigmatic style where it rests until June.

Fertilization

Within the first few weeks of June the pollen tube with its two generative nuclei penetrates from the ovarian cavity into the ovule between the chalala and the micropyle. According to Thompson (107), the most obvious indication of fertilization is the multiplication of acellular endosperm nuclei. Concomitant with rapid endosperm nuclei divisions, the embryo sac enlarges significantly.

As the embryo forms it is nourished by the disintegration of the endosperm (40). If double fertilization does not occur to form this tissue, the embryo aborts and no kernel (a blank) is formed. Defective egg or sperm and poor genetic combinations may also lead to the formation of blanks (57).

Nut Development

Four to five months elapse between pollination and fertilization, during which time the ovary develops from a minute bit of meristematic tissue to a mature organ.

The ovary, which has a single locule, contains two parietal placenta, each of which typically bear two ovules. There is apparently no vestige of the ovule present at the time of pollination of the filbert but by early March the young ovules appear as small protuberances at the base of the stylar canal (3, 10, 40, 83, 107, 110). As a rule, only one of the four ovules develops into a nut.

During the month of April flower clusters begin to swell externally, the ovarian diameter doubling from 0.5 to 1.0 mm. Ovarian growth rate steadily increases but it isn't until the end of May the ovaries enter a period of extremely rapid growth. In June the ovaries complete the remaining 90% of diameter increase.

Maturation of the embryo sacs is also in progess during the first few weeks of June. Shortly thereafter fertilization occurs and the development of the nut proceeds rapidly. Full size is reached by early August, followed by shell hardening.

Although developmental events such as the onset of vegetative growth, fertilization, or growth of the embryo have been reported to have a stimulative effect on ovarian growth rate in certain other plants, no such correlation exists in filberts (107). The rapid period of growth of the ovary does not commence until the latter part of May, some two months after leaves begin emerging and when the leaves are already expanded. The act of fertilization apparently does not provide a significant growth stimulus because the process occurs at about the middle of the most rapid six week flush (107). Furthermore, in blank nuts, the ovary reaches full size without fertilization of the egg. The

young embryo does not start to grow until the nut shell has practically reached full size.

In essence, pollination is necessary to stimulate ovarian development while fertilization is necessary to initiate the embryo (107). If pollination occurs but fertilization fails, of if the embryo aborts, the nut shell will grow to full size but remain empty.

Vegetative Development

Shoot length increment measurements relative to crop load and flower production have been investigated in the filbert. These measurements indicate there is a direct correlative relationship between vegetative and reproductive growth and development. Shoots exceeding 15 centimeters in length have 93% set and a low mortality rate (93). Long shoots also produce more buds that set a higher percentage of large clusters.

Painter and Hartman (76) found 11.3% of the stems they measured produced 70% of the nuts; these stems were over 15 centimeters in length. The longer stems resulted in a greater number of flower clusters, in more clusters set, more nuts produced, and larger nuts. However, the number of nuts per cluster and the number of blanks produced were not effected by shoot length.

A similar study was conducted on young filbert trees (76). Fifty-five percent of all the stems evaluated were over 15 centimeters in the light crop year. In the following year, a heavy crop year, 89% of the stems were over 15 centimeters.

The results of these studies are indicative of two things:

(1) In a heavy crop year the maturation of the crop and the production of vigorous twigs for the following year's crop cannot occur simultaneously, and (2) insuring vigorous shoot growth in the "on" year is essential if the "on" and "off" cycle of production is to be modified.

Alternate Bearing

In the filbert there exists a high correlation between shoot length and the number of female flowers (72). As would be expected, long filbert shoots provide a greater potential bearing surface than short shoots. Shoots under 14 centimeters in length bear substantially fewer flowers per centimeter of wood than longer wood (77, 86). The alternating short and long shoot production during years of heavy and light crops is a major factor in creating and maintaining the alternate bearing cycle.

In a number of crop species, and to some extent in the filbert, the presence of fruit is also a dominant factor in flowering behavior. In light crop years a relatively large proportion of spurs, regardless of length, tend to form flowers. During years of heavy crop production only a small proportion of spurs of any length differentiate flowers (29).

Investigations of the alternate bearing cycle in the pecan and pistachio nut crops have also revealed correlative relationships between vegetative and reproductive growth and development. During the on year in pecan, shoot length (grown in the previous year) is long and pistillate flower production is high (99). A high percentage fruit set results due to less drop of female flowers from long shoots. During the off year the reverse occurs; shoot length is short and pistillate flowers are either not produced or a high proportion of weak pistillate flowers are produced.

Fluctuating carbohydrate levels are implicated as a causative factor (99). Increased yield in the on year suppresses carbohydrate accumulation in vegetative structures of the tree, resulting in shorter shoot growth the following year. These shorter shoots produce weak, inferior flowers, leading to massive floral bud abscission in the off year.

In the pistachio, alternate bearing is the result of abscission of inflorescence buds during a heavy crop year rather than lack of bud formation (26). Abundant inflorescence buds are produced every year, however a majority of them abscise during kernel development in the on year. Since abscission increases progressively as leaf area decreases or number of nuts per branch increases (24), bud abscission may be due to competition for carbohydrate between developing seeds and flower buds (24).

Hormones, but particularly a hormone originating in the leaves of pistachio, may be involved in flower bud abscission as well. In the absence of nuts, reducing the leaf area to only 27% of normal does not affect abscission (24). This indicates the flower buds either require low levels of carbohydrate or the leaves are producing and exporting a flower bud abscission inhibitor. The production of such a flower bud abscission inhibitor by the leaves is evident when nut number is held constant, as it causes a progressive increase in the percentage of abscising buds with each decrease in leaf area (24).

Based on these investigations a partial answer to the biennial bearing problem would have to involve: (1) maintenance of tree vigor to induce consistent year to year growth, (2) promotion of superior flower

formation in the on year, and (3) increased cluster set in the off year.

Fruit thinning, fertilization, pruning, superior maintenance of trees, and use of growth regulator sprays are potential methods of combating the alternate bearing problem in these crops.

INFLUENCING FRUIT SET WITH GROWTH REGULATORS

Gibberellic Acid

Over thirty years ago evidence was presented confirming the importance of growth regulators in fruit set and development (38). Small quantities of GA_3 became available for fruit set research about 1956. A wide range of concentrations of GA_3 applied to small flowering branches and individual flowers resulted in extremely large increases in fruit set and yield (47, 55), but applications to whole trees were less successful.

Applications of GA_3 have increased fruit set in a wide range of navel orange cultivars in the United States and several other countries (30, 31, 81, 95). Coggins, Hield, and Garbor (21) reported that gibberellic acid applied in spring to 'late Valencia' trees increased fruit set. Gibberellin sprays of 200 to 500 ppm applied to 'Washington Navel' trees two weeks after full bloom increased fruit set (73, 92). Maximum fruit set in the varieties 'Jaffa' and 'Pineapple' was obtained with GA at 75 and 100 ppm applied at full bloom (83).

By spraying GA on Valencia orange trees just before heavy flowering commenced, there was a slight reduction in the number of oranges produced in the heavy crop year (2). However, in the next anticipated light crop year, the number of oranges was greatly increased. Along with more oranges, the treated trees produced better-sized fruit in both the light and heavy crop years.

Rappaport (82) and Wittwer et al (116) reported gibberellin stimulated growth, flowering, and both normal ard parthenocarpic fruit set in

tomatoes. Weaver and McCune (111) found gibberellin increased set of Black Corinth and Thompson Seedless grapes. Crane et al (25, 27) reported GA-induced parthenocarpy and hastened maturity in Calimyrna figs, almonds, apricots, and peaches.

An investigation (67) was also initiated to determine the effect of gibberellic acid on the fruiting of the filbert. GA_3 (10 ppm) was applied to the trees at the time the ovule was differentiated in the center of the ovary and still developing, and again when fertilization had occurred and the embryo was beginning to form. The early application increased yield and marketing value due to increased nut weight, nut volume, and nuts per cluster. The late application only increased the production of blanks.

Kelley (53) applied gibberellic acid (50 ppm) at various times from April 24th through May 29th, 1977, to improve cluster set in the Barcelona filbert. During the summer following application the treatments caused a reduction in set, an inhibition of catkin formation, and the formation of multiple female flower clusters. However, it was not determined whether the increase in the number of female flower clusters resulted from a greater number of nodes or from a greater proportion of nodes bearing flower clusters. The year following treatments, yield was increased as a result of the greater number of female flowers initiated (53). Fruit set, however, was not affected.

Auxin

Indoleacetic acid has also been implicated as a compound capable of

affecting fruit set and development. Numerous studies have been initiated to determine its role in these processes. Investigations (113, 114) of the role of auxin in fruit set of pear have yielded some of the most informative data on the subject.

Studies designed by Stephen (103, 104) to determine the effect of cross pollination on pear fruit set indicated there was a stable, diffusible substance being produced by pear seeds. This substance apparently remained in the tree from year to year, effectively increasing subsequent seedless set.

Westwood and Lombard (114) later initiated an investigation to determine the effect of seeded fruits and foliar-applied auxin on seedless fruit set of pear in the following year. When an Anjou pear tree was caged to prevent cross pollination over a two-year period, fruit production decreased markedly. Subsequent spraying of the tree with 2,4,5-TP caused a 10-fold increase in fruit set over that of the previous season. Apparently the synthetic auxin substituted for the setting stimulus normally produced by a previous crop of seeded fruit (114). Blossom bud and fruit set counts of Anjou trees on seedling rootstocks showed that differences in yield were consistently due to differences in fruit set rather than to percentage bloom or tree size (114).

INFLUENCING FLORAL INITIATION WITH GROWTH REGULATORS

Ethylene

Ethylene-releasing chemicals such as ethephon decompose to produce ethylene, phosphate, and hydrochloric acid in plant tissue. The ethylene evolved in the tissues of plants is capable of hastening ripening and color development; promoting abscission of leaves, fruits, and nuts; stimulating floral initiation; breaking rest in buds and seeds; and inhibiting stem elongation and lateral bud development.

Ethylene is also involved in the regulation of several types of differentiation. One type is the formation of a separation layer or abscission zone. Studies (42) of natural and induced abscission suggest abscission is regulated by a balance between auxin (a retardant of abscission) and ethylene (a stimulant).

Another type of differentiation under ethylene control is flowering. In pineapple, Rodriguez (85) observed that ethylene applications can induce flowering, and Clark and Kerns (19) described a similar control in that species with auxin. Later experiments revealed the auxin stimulation of pineapple flowering was a consequence of the stimulation of ethylene biosynthesis following auxin treatment (14). Several other species are induced to flower by ethylene as well (74, 105).

Ethephon has shown promise for increasing yields of various cucurbits through changes in sex expression. In monoecious cucumber, conversion from staminate to pistillate flowers at most nodes has been widely reported (35, 69, 96). In gynoecious cucumber cultivars, ethephon results in a higher fruit set and an apparent slowing of fruit growth.

The net result is a greater yield of the more valuable smaller size grades (48, 96). Lippert et al (63) reported ethephon increased the number of pistillate flowers formed but no commercial benefit resulted. Ethephon applied to winter squash cultivars resulted in greater numbers of marketable squash that tended to be smaller in size (8). These same applications resulted in pistillate flowers at most early nodes, however, they generally aborted.

Certain apple cultivars are strongly biennial and often a substantial reduction in fruit set with chemical thinning compounds does not result in sufficient bloom for a sizeable crop the following year. Subsequent experiments on these cultivars indicated that ethephon stimulates flower bud initiation in both young seedling and mature apple trees. Kender (54) found ethephon applied as a foliage spray at 1000 and 2000 ppm to 3-, 4-, and 5-year old nonbearing seedlings of apple significantly increased the percentage of trees flowering for the first time and the total number of flower clusters per tree. Ethephon at these concentrations also significantly reduced shoot growth below control trees (54).

Relatively high concentrations of ethephon were applied to mature 'Delicious' apple trees 53 to 60 days after full bloom (36). The applications resulted in increased flowering the following year. Such an increase in flowering was either a direct effect or a response to thinning. Apparently the increased flower bud initiation could not be solely attributed to thinning since ethephon caused no fruit abscission until September but did increase flower bud initiation (36). Increased flower bud initiation would not be expected the following year

from fruit removal or growth regulator sprays in September. The increased flower bud initiation was not accompanied by a corresponding increase in fruit set.

The physiological impact of ethylene on plant tissues elicits many effects opposite to those of gibberellin (94). GA_3 apparently antagonizes the response of cucumber to ethephon (84). Atsmon et al (5) demonstrated levels of gibberellin-like substances were lower in a gynoecious than monoecious cultivar of cucumber. These observations suggested ethephon's effect was related to its anti-gibberellin activity (5). However, the results of a similar experiment involving muskmelon did not support the contention that ethephon acts as an antigibberellin in affecting sex expression (65).

Splittstoesser (101) demonstrated gibberellic acid could not completely abolish the effect of ethephon on sex expression in pumpkin, but could elicit its normal enhancement of inter-node elongation in the presence of ethephon. Iwahori et al (50) reported similar results and concluded although ethephon and gibberellins have opposing effects on sex expression, they do not seem to be antagonistic. Rather, they possess different sites of action.

TIBA

In 1942, Zimmerman and Hitchcock (121) reported that 2,3, 5-triiodobenzoic acid (TIBA), a purely synthetic material, applied to tomato plants caused ordinary vegetative buds to produce flowers. It was later found to promote flowering in grape vines (7), induce

parthenocarpy (15), and increase the number of pistillate flowers in cucumrbits (70, 102, 117).

In a monoecious line of cucumber, the decrease in ratio of staminate to pistillate flowers was accompanied by both an increase in the number of pistillate flowers and a decrease in the number of staminate flowers in response to TIBA (58,117).

When Carica papaya, a dioecious plant, was treated with TIBA the sexual character of the plant became more female (51). The increase in femaleness was manifested by a reduction in the number of male plants and an increase in the number of female plants. Both the formation of flower buds at lower nodes and a marked reduction in plant height was also observed (51).

TIBA promoted flowering in several strains of young 'Red Delicious' trees as well (13). TIBA was applied two weeks after petal fall in the "on" year at the rate of 25 ppm. A 27% increase in bloom the following season resulted. The vigorous growing shoots around the periphery of these trees tended to bend outward, changing the growth habit from an upright position to an open type tree with numerous wide branch angles.

Sex expression in Cannabis sativa was not influenced by the chemical TIBA, however, the total production of flowers was increased in both sexes (46). Such an effect may have resulted from a reduction of the correlative inhibition of lateral buds. The TIBA treatment allowed the outgrowth of a large number of laterals, each of which differentiated a zone of flower production.

Almost all of the morphological responses of the vegetative plants to TIBA seem to indicate auxin levels are altered in the plant.

Disappearance of apical dominance, epinasty, shortened internodes and premature abscission are consistent with this belief. One mechanism of TIBA action appears to be the production of excess IAA oxidase, resulting in destruction of IAA (6). It also interferes with polar transport of auxin, causing auxin to increase in the branches, resulting in wider growth angles of trees (13).

Gibberellic Acid

To be active in floral initiation, application of gibberellic acid must temporarily alter the normal growth processes during the flower initiation period. The flower induction process is often associated with a temporary reduction of terminal shoot growth, either to allow utilization of available metabolites in the flower induction process or to provide for lower levels of gibberellins and auxins in potential flowering meristems. Allsopp (1) has proposed that an increased nutrient supply to the eumeristematic regions during development causes a change in the morphogenetic potential. High nutrient levels in the eumeristem should occur in cases of restricted stem elongation due to reduced consumption in the subapical regions.

It is interesting to note that gibberellic acid treatments prior to floral initiation inhibit flower formation in numerous crops (13, 23, 39), while sprays after floral initiation has occurred results in flower production (22). In order to understand the role of gibberellin in flower development, an understanding of its involvement in meristematic activity and stem growth is necessary.

The discovery and isolation of the gibberellins became a crucial

turning point in studies on dwarfism and stem elongation (79). Dwarf varieties often respond to GA by achieving the same height as normal varieties. Skjedstad's (97) research on maize indicated there are fewer as well as shorter cells in the shoots of dwarf as compared with normal corn; and cell number and length are restored to normal in gibberellin-treated dwarfs.

Changes in gibberellin metabolism are thought to be the physiological basis for dwarfing in most plants (78) but there are exceptions (66). Lang (59), Lona (64), and others found that gibberellins caused "bolting" (rapid stem elongation) in rosette plants. Microscopic examination of gibberellin-treated rosette plants reveals that shortly after application of GA there is a large increase in mitotic activity in all nonlignified tissues below the eumeristem (11, 61, 87, 89, 91); the induced subapical meristematic zone increases in size for several days, accompanied by an increase in stem elongation. There is no comparable effect upon the eumeristem. Evidently gibberellin induces the formation of a "new" meristematic region which is responsible for most of the cells which contribute to bolting in rosette plants.

Gibberellin-like substances may also control subapical meristematic activity in caulescent plants. Stem-growth retarding substances (AMO 16-18, CCC, Phosfon, and others) which cause rosette-type development in normally caulescent plants (17, 68, 115) severely inhibit subapical meristematic activity without similarly affecting the leaf- and flower-initiating functions of the eumeristem (16, 90). GA prevents or reverses the inhibition of stem elongation caused by the retardants through renewed subapical meristematic activity (88, 90). In essence,

GA restores cell division and elongation to normal in retardant-treated plants.

The effects of exogenously applied gibberellins on flowering varies with plant species and with date of application. Gibberellins have been shown to be powerful modifiers of sex expression, particularly in cucurbits, and their effect is one of favoring the production of staminate flowers (4, 41, 75, 101). By manipulation of the gibberellin level of cucurbit plants, either by application of GA or by addition of inhibitors of GA biosynthesis, the ratio of staminate to pistillate flowers can be changed (4, 41, 101). Since flower development involves the transformation of the vegetative apex to a reproductive structure by cell division and cell elongation, any change in floral morphology induced by GA results from change in both processes (75).

The role of GA in stimulating flower formation in Bryophyllum is directly on the production of the floral stimulus rather than on the growth of the stem (118). In the cold-requiring plant Chrysanthemum (43), gibberellin causes the formation of a graft-transmissable flower-inducing factor in nonthermoinduced plants. As such, the role of GA's in flowering of Chrysanthemum and Bryophyllum suggests its involvement in processes other than cell division and elongation.

Application of certain gibberellins to a number of rosette, long day plants stimulate flower formation under noninductive daylength conditions (60). It has been argued however, in such rosette plants this effect of GA on flowering is mediated through an effect on stem elongation and not on florigen synthesis per se (60).

The evidence against a direct effect of GA on flower formation has

been discussed by Lang (60) and can be summarized as follows: 1. Treatment of caulescent short day plants with gibberellins has no effect on flower formation (60). 2. The effects of GAs on long day plants are restricted to those having a rosette habit; application of GA to caulescent long day plants are without effect (60). 3. GAs are most effective when applied to the stem apex, suggesting an effect on stem growth, whereas processes related to photoinduction are known to occur in leaves (60, 188). 4. In the majority of cases where flower induction is mediated by changes in photoperiod, flower primordia are visible microscopically before a change in stem growth rate is evident. Similar plants treated with GA respond first by increased stem elongation and later, if at all, by flower and bud formation (60, 122). 5. Correlations between endogenous GA levels correlate more closely with stem and petiole growth rather than flowering (20, 119). 6. Treatment with inhibitors of gibberellin biosynthesis during photoinduction does not inhibit flower formation in all long day plants (9, 20, 106, 119).

The literature contains various references to stimulation of flowering of some plants after gibberellin application. Only recently have reports of inhibition of flowering or floral initiation by treatment with gibberellin been made. When plants of Kalanchoe blossfeldiana, a short-day plant, were treated with GA during noninductive conditions, flower buds appeared at about the same time as on controls in which budding was induced through short days; but few buds bloomed and reversal to a vegetative phase ensued (44). In Weigela (28), flowering was induced in control plants exposed to the appropriate short-day photoperiod, but

plants treated with gibberellin after exposure to that photoperiod failed to flower.

In a study conducted by Bradley and Crane (12) on various species of Prunus, development of both floral and vegetative buds was inhibited by the application (250, 500-mg/ppm) of gibberellin during full bloom. The development of the lateral meristem was blocked through inhibition of mitosis while the growth of certain other plant organs was stimulated. The higher the dosage the more extensive such growth and the greater the bud inhibition. Stem diameter increased in certain species. Length growth of spurs was stimulated by some gibberellin doses, resulting in about twice the number of nodes as in control spurs. Inhibition of cell division was an immediate effect of gibberellin, leading to restriction of lateral bud development. This is in contrast to the stimulated cell division implicit in excessive growth of terminal buds in the cherry after treatment. Apparently physiological or anatomical differences, or both, between terminal and lateral buds may influence the effects of gibberellin (12). In Prunus, lateral bud inhibition is not considered a matter of intensified apical dominance. Evidently, when excessive terminal growth of cherry shoots was stimulated, development of lateral vegetative buds was not blocked. The inhibition of floral bud development by considerably lower dosages than those required to suppress vegetative bud development indicates GA may have blocked floral initiation (12).

Huet (49) found on long shoots in pear, the major factor controlling floral initiation appeared to be the pattern of growth. The relative growth rate of shoots during the month before growth finally ceased was

inversely related to the average number of fruit buds per shoot. GA applied to de-fruited spurs one month after full bloom inhibited floral initiation (49).

Gibberellic acid at either 10 or 50 ppm causes inhibition of fruit-bud formation in apples without affecting bursting of buds in the following spring (39). The percentage of spurs bearing blossom clusters was reduced from 40% on unsprayed branches to 14.7% on sprayed branches. Greenhalgh and Edgerton (37) applied potassium gibberellate to trees of McIntosh cultivar of apple at 0, 100, 200, and 400 ppm at 2 and 25 days after full bloom. These treatments extended the period of apical meristem activity, increased shoot growth, and strongly inhibited flower bud formation.

GA sprays reduced flowering of 'Late Valencia' oranges by 44 to 75%, and fruit set by 16 to 41%, depending on the concentration and time of application (71). However, Moss and Bellamy (71) suggest it is possible gibberellin could indirectly increase flowering in the year following application. Spring flush vegetative shoots are the ones most likely to form flowers the following year and these are expected to be increased following GA-induced reduction in numbers of inflorescences (71).

Pecan fruit and foliage were sprayed with 200 ppm solution of potassium gibberellate applied either early (June 1) or late (August 8). In the spring following treatments, bud break was delayed slightly and catkin formation was inhibited by early applications (100). Sparks (100) found the number of catkins per terminal was reduced with increasing concentration of GA. At the time of the first application, differentiation of the catkins was well under way, suggesting GA interfered with

differentiation (100). August and September applications had no effect as catkin differentiation was already completed by late summer.

THE EFFECTS OF GIBBERELLIC ACID ON VEGETATIVE GROWTH, FLORAL INITIATION, AND CLUSTER SET OF THE 'BARCELONA' FILBERT[1/2/]

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Additional index words. Corylus avellana L., fruit thinning, branch orientation

Abstract. During April and May, 6-year old 'Barcelona' filbert trees were treated with either gibberellic acid at 15 or 50 ppm to influence cluster set. Four limbs on each tree were evaluated for various yield components. The GA_3 applications caused abscission of developing clusters and nuts following treatment (1979). This was followed by gradrupled female flower production for the 1980 season. Measurements of shoot length and node number indicated that the influence of GA_3 on vegetative growth played only a minor role in the increase of female flower clusters observed. Changes in hormonal and carbohydrate levels, brought on by massive fruit abscission, are suggested as being

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responsible for increased floral initiation. In the year following treatment, yield increases were due to the greater number of flowers initiated rather than an increase in percent cluster set.

Introduction

The most desirable characteristic sought in the 'Barcelona' cultivar, which accounts for about 85% of the annual filbert production in the United States, is increased yield. Factors influencing increased yield are larger numbers of female flowers, increased set, more nuts per cluster and per tree, larger nuts, and alternate bearing.

Investigations on a wide range of crops indicate that exogenous applications of gibberellic acid (GA_3) increase fruit set (4,5,6,7,12, 13,16,17,18). Such GA_3 applications are also capable of influencing floral initiation, depending upon the time of application. Treatments prior to floral initiation inhibit flower development in some crops (1,3,8), while sprays after floral initiation has occurred result in flower production (2).

Only one study has been conducted to determine the use of GA_3 as a method of influencing set in the 'Barcelona' filbert (10). The present investigation was initiated to confirm these results, and to determine if they were a result of changes in vegetative development, reproductive development, or a combination of the two.

Materials and Methods

Four individual limbs, oriented north, south, east, and west were selected for uniformity on each of 27, 6-year old 'Barcelona' filbert

trees, located at Corvallis, Oregon. On April 20, May 11, and May 25, 1979, the trees were treated with GA_3 at 15 and 50 ppm, or a control solution. Each treatment was replicated 3 times with each of the 4 flagged branches per tree representing an experimental unit. Sprays were applied with a one-gallon hand sprayer to cover the foliage to the point of run off.

Selected branches were identified by flagging tape tied to the branch at the point where diameter measurements were made. Distally from that point, the number of catkins and female flower clusters were counted before and after treatments. Nut clusters were harvested from these branches in both 1979 and 1980 just prior to normal nut drop, and placed in appropriately labelled paper bags. The samples were dried at 35 C for at least 48 hours. After drying, the number of clusters, nuts, kernels, blanks, and nut and kernel weight data were obtained.

The three most distal shoots of West branches were evaluated for length, node number, number of female flower clusters per node, and number of nuts per shoot.

A completely randomized block design was employed. Analysis of variance means were separated by Tukey's w-procedure. Linear correlation coefficients between branch diameter and flower number were calculated. Orthogonal partitioning of branch orientation sum of squares for the various yield components was undertaken to determine the effect of individual orientations on these components.

Results

Effect of GA_3 on vegetative growth in the year of application (1979)

The average length of the three measured shoots following GA_3 treatments was significantly different for each date of application. This is interpreted as an apical dominance response. The most distal shoot always exhibited the greatest growth despite the treatment applied. Compared to the control, the 15ppm GA_3 solution significantly increased the length of the most distal shoot. The 50ppm solution had no significant effect on any of the shoots as regards length.

Correlation coefficient values between the number of nodes and the number of female flower clusters on the three measured shoots were calculated to determine if the increase in flowers following GA_3 applications was due to an increase in the number of nodes. The higher coefficient values for the GA_3 treatments were not due to an increase in the number of nodes when compared to the control (Table 1), even though the shoots sprayed with the 50ppm solution of GA_3 possessed four times as many flower clusters as the control. The 15ppm concentration resulted in a doubling in the number of female flowers initiated on the shoots. These results indicate that the increased initiation of female flower clusters by GA_3 applications was due to a greater proportion of nodes bearing flower clusters. Multiple flower clusters were observed at many of the nodes.

Correlation coefficient values between branch diameter and flower number were also indicative of this type of relationship. An

increase in flower number was apparently not paralleled by a corresponding increase in branch diameter.

Orthogonal partitioning of orientation sum of squares for the various yield components revealed the latter were always in greater abundance on the North and South sides of the trees. Only the average nuts per cluster, percent set, and blank production were unaffected.

Effects of GA_3 on floral initiation and yield in the year of application (1979)

With one exception, GA_3 treatments did not affect the number of catkins initiated in the summer following applications (Table 2). The only significant increase in catkin number resulted from the application of GA_3 at 50ppm on April 20 (Fig. 1).

When compared to the control, GA_3 at 50ppm quadrupled the number of female flowers differentiated while the 15ppm concentration doubled the number (Table 2). The most significant increase in flower clusters occured following application of GA_3 at 50ppm on April 20 (Fig. 1). The 15ppm concentration also increased the number of flower clusters initiated, however not significantly different from the control.

The number of clusters retained and nuts set were seriously reduced by GA_3 concentrations during the summer of 1979, following application (Table 2). The early applications had the greatest detrimental effect on the number of clusters and nuts retained. The May 25 application was comparable to the control. The average number of nuts per cluster and blank production did not vary with treatment (Table 2).

Yield components in the year following GA_3 applications (1980)

In 1980, branches sprayed with GA_3 at 50ppm in 1979 possessed a significantly greater number of clusters and nuts than control branches (Table 2). The 15ppm concentration also increased cluster and nut number but it was not significantly different from control values. The average number of nuts per cluster was not changed in the year following applications.

Percent set was increased in all treatments over the previous year; however, the 50ppm-treated limbs had significantly less percent set than the controls in the year following treatment (Table 2). Nut and kernel weights from the GA_3, 50ppm treatment was slightly higher than controls. No weight differences resulted from the 15ppm sprays. The number of blanks that developed in the 1980 crop year were not effected by any of the previous year's treatments (Table 2).

Discussion

Only the April 20, GA_3 application significantly increased catkin production. At this time, initiation of the catkins was probably still in progress with the meristems receptive to changes (in morphogenetic potential). The May applications were ineffective, indicating that catkin differentiation was completed by that time.

In an earlier study, Kelley observed an inhibition of catkin formation following GA_3 applications at 50ppm to 'Barcelona' trees during April and May of 1977 (10). Our study indicated either no effect on catkin number or an increase in number, depending on

date of application. Kelley's estimation of catkin number was based on visual observationand the present results based on tabulated counts.

The GA_3 applications caused abscission of developing clusters and nuts following treatment (1979). This was followed by a marked increase in female flower production for the 1980 season. The increase in the number of clusters and nuts produced in 1980 was due to a greater number of flowers initiated rather than increased percent set.

While the original purpose of the GA_3 applications was one of increasing flower cluster set, as had been previously reported in so many other crops (5,9,11,13,17), these results suggest that when applied to filbert trees in the spring, GA_3 acts as a thinning agent.

The influence of GA_3 on vegetative growth, and the latter's influence on floral initiation played only a minor role in the substantial increase in female flower clusters recorded. The increase in the number of flower clusters did not result from a greater number of nodes but rather from a greater proportion of nodes bearing flower clusters. The reduction in set, brought on by the GA_3 treatments, evoked a subsequent increase in floral initiation either through hormonal or carbohydrate level changes.

One aspect of vegetative growth that is important to reproductive development in the filbert involves the close spacing of filbert trees in orchard rows. In this study, the east-west oriented rows resulted in heavily shaded areas on the east and west sides.

The resulting low light intensity had an inhibitory effect on reproductive development, as has been the case in other types of plants (15).

There is no apparent potential use for GA_3 as a means to increase set in the'Barcelona' filbert when applied in the spring. However, it might be utilized as an effective thinning agent if applied at the proper concentration. As a thinning agent, it might aid in reducing the amplitude of yield variation caused by alternate bearing.

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Table 1 . The relationship between total number of nodes and nodes with female flower clusters initiated. Linear correlation coefficients include all dates and all shoots within a given Spring gibberellic acid spray. Values obtained at the end of the 1979 growing season.

Treatments	Values of R	Number of Nodes with Female Flowers	Number of Nodes
GA 50 ppm	.55**	52	32
GA 15 ppm	.55**	27	38
Control	.40*	12	32

$P < .05$*; $P < .01$**

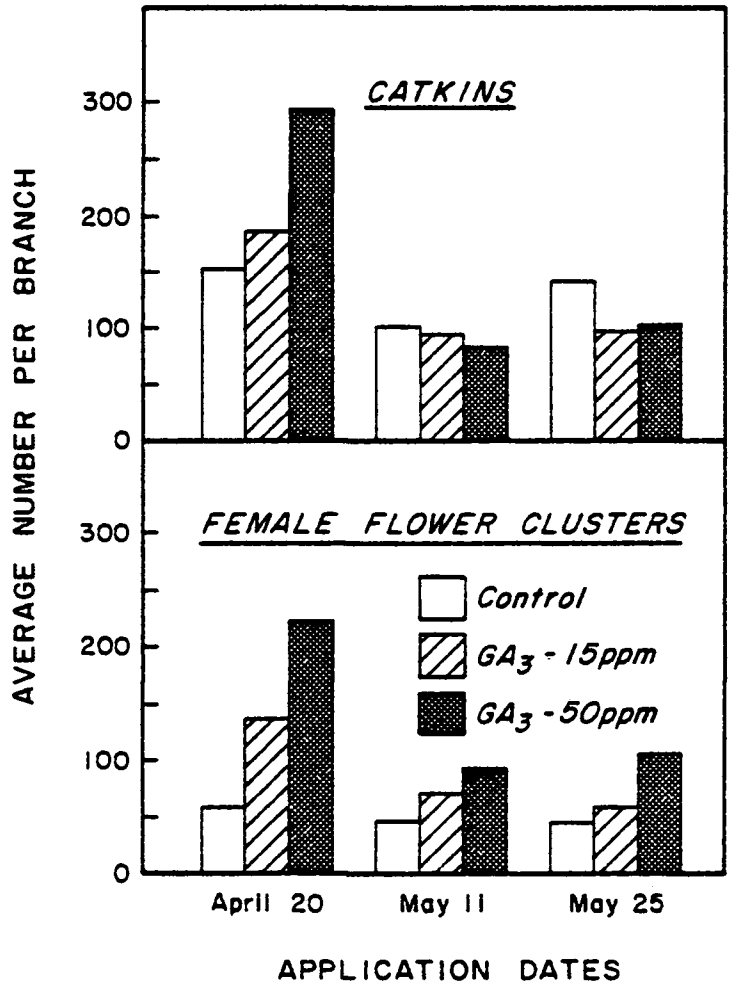
Table 2. Average values of various yield components on branches during two years, following Spring 1979 gibberellic acid treatments. The results from the three treatment dates are combined.

Treatments	Catkin Number	Flower Clusters initiated	Flower clusters set		Percent Set		Ave. nuts/ Cluster	
	1979	1979	1979	1980	1979	1980	1979	1980
Control	128.2 a*	50.3 a	15.7 a	23.2 a	41.2 a	51.5 a	1.6 a	2.1 a
GA 15 ppm	122.4 a	88.5 a	7.9 b	29.8 ab	18.5 b	34.5 b	1.6 a	1.9 a
GA 50 ppm	156.2 a	135.4 b	7.1 b	39.2 b	15.5 b	32.7 b	1.8 a	1.8 a

Treatments	Nut weight (g)		Kernel weight (g)		Blanks	
	1979	1980	1979	1980	1979	1980
Control	89.1 a	161.7 a	34.2 a	57.9 a	2.6 a	8.0 a
GA 15 ppm	46.9 b	198.1 a	16.8 b	75.7 a	1.8 a	7.6 a
GA 50 ppm	38.0 b	250.3 a	13.6 b	92.2 a	1.9 a	11.3 a

*Means not sharing the same letter within columns are significantly different at the 5% level, using Tukey's w-procedure.

Figure 1. Catkin and female flower cluster production following spring application of gibberellic acid. Counts made Dec., 1979.



INFLUENCING FLORAL INITIATION IN THE 'BARCELONA' FILBERT WITH GA_3, TIBA, ETHEPHON, AND HAND-THINNING[1/2/]

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Abstract. Application of 2,3,5-Triiodobenzoic acid (TIBA) and (2-chloroethyl) phosphonic acid (ethephon) during the time of floral initiation in the 'Barcelona' filbert (July-August) resulted in a slight increase in female flower clusters the following spring. Hand-thinning of nut clusters in August resulted in the largest increase in number of female flower clusters of any of the treatments. There was no significant effect on female flower initiation due to GA_3, however, catkin drop was accelerated by this treatment regardless of date applied. Percent set, the average number of nuts per cluster, and nut and kernel weights were not affected by the TIBA, ethephon, and GA_3 sprays in the year applied. In the following year, branches

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treated with TIBA and ethephon, and hand-thinning, had higher yields due to increased female flower initiation. Yield was also increased in the year following GA_3 treatment due to greater percent flower cluster set.

Introduction

A large annual variation in yield due to alternate bearing produces economic and managerial problems in filbert production. High nut production in the "on" crop year is followed by reduced pistillate flower formation which results in an "off" crop year.

Maintenance of tree health and vigor, promotion of superior flower formation during a heavy crop year, and increased cluster set in a light crop year are potential methods of reducing the problem of large annual yield fluctuations.

Flowering has been increased in a wide array of plants by application of growth regulating chemicals. Gibberellic acid (1,3,6,7), TIBA (2,4,8,14,19), and ethylene compounds (5,9,13) have all been effective in influencing the flowering process. In the "on" year, fruit thinning has also been used in crops that exhibit the alternate bearing pattern to insure an adequate return bloom the following season (12,17).

The present study was initiated to determine the effect of GA_3, TIBA, ethephon, and hand-thinning on floral initiation and yield parameters in the 'Barcelona' filbert.

Materials and Methods

Four scaffold branches oriented north, south, east, and west were selected on each of 45, 6-year old 'Barcelona' filbert trees. In July and August, 1979, trees were treated with either 50ppm GA_3, 25ppm TIBA, 500ppm ethephon, a control solution, or a hand-thinning procedure at 3 separate dates corresponding to the period of female flower initiation and differentiation in the filbert. The sprays, all containing a surfactant, were applied to the whole tree using a one-gallon hand sprayer. Each treatment was replicated 3 times with each of 4 flagged branches representing an experimental unit. A completely randomized block design was employed.

From the point where the flagging was attached, all portions of a scaffold branch were examined to determine the number of catkins and female flower clusters present before and after the treatments were applied. Nut clusters were harvested from these branches in both 1979 and 1980, just prior to nut drop. They were placed in labelled paper bags, and dried at 35 C for at least 48 hours. After drying, the number of clusters, nuts, kernels, blanks, and nut and kernel weight data were obtained.

Results

Floral initiation

Gibberellic acid had no statistically significant effect on female flower initiation on any of the dates of application (Fig. 1).

Conversely, the male flowers, the catkins, exhibited accelerated drop at all application dates. The GA-treated trees had less than one-half the number of catkins found on control trees (Fig. 1).

The TIBA and ethephon treatments caused the greatest increase in female flower initiation over the control at the July 29 applications (Fig. 1). Neither of these compounds affected catkin drop (Fig. 1).

Hand-thinning of nut clusters on August 14 caused the largest increase in female flowers and catkin retention (Fig. 1) of any of the treatments.

Yield components

1979. Gibberellic acid, TIBA, ethephon, and the control were not statistically different from one another in their effect on the various yield components measured (Table 1).

1980. The treatments, depending upon the date of application, were statistically different from one another in their effect on number of clusters (5% level), number of nuts (10% level), nut weight (10%), and kernel weight (5% level) in the year following application, (Fig. 2). Multiple comparison of means by Tukey's w-procedure for each treatment at each date did not reveal where the significant differences existed. Ethephon increased the number of clusters and nuts, and nut and kernel weights at the July 15 and 29 applications while TIBA was most effective at the July 29 application. Neither

blank production or the average number of nuts per cluster were significantly changed. The trees previously treated with GA_3 exhibited 64 percent set, compared to 43 percent set for control trees.

Orthogonal partitioning of orientations revealed that yield components were always in greater abundance on the north and south sides of the trees (data not shown). This confirms data from an earlier study (16).

Discussion

In Oregon, the male flowers of the 'Barcelona' filbert are initiated in April, while female flowers are initiated in late summer (20). Consequently, the timing of growth regulator applications in this study did not influence catkin initiation in 1979, but did effect their subsequent retention that year.

It would appear likely that there is a direct hormonal effect causing accelerated abscission of the male flowers while leaving the female flower clusters unaffected. Another possible explanation for the accelerated catkin drop could be increased stem elongation (11,15,18). The new growth may have occurred due to a diversion of carbohydrates essential to catkin development. Another indication of the involvement of carbohydrate levels in catkin growth and retention comes from the increase in the number of catkins found the spring following summer cluster-thinning treatments.

The GA_3 treatments had no statistically significant effect on female flower initiation or any of the yield components in the season

it was applied. In the following year, the trees that had been treated with GA_3 on July 29 and August 14 exhibited a greater percent set, a larger number of nuts, and higher nut and kernel weights than control trees.

These results may be linked to the catkin drop caused by GA_3 treatments. With premature catkin drop more food reserves may have been made available to other plant organs such as developing fruit and vegetative structures. This would be similar to observations made on a seedling Oregon filbert tree that annually sheds its crop of catkins before they mature (10). This tree is much larger than its siblings, is extremely vigorous and bears heavy nut crops annually.

Ethephon and TIBA treatments increased female flower initiation slightly in the year applied without adversely effecting the extant crop. Both of these compounds need to be tested at higher concentrations to determine the range at which they are most effective commercially.

Increasing percent set by GA_3 applications in late summer is another possible means of influencing the alternate bearing cycle in the filbert. Here, too, additional studies using higher concentrations should be made to establish commercial adaptability. Later dates of application of GA_3 could also be evaluated for effectiveness.

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Table 1. Average number of clusters, nuts, and blanks, average number of nuts per cluster, percent set, and nut and kernel weights (g) per branch in the year of treatment (1979). The results from the three treatment dates are combined.*

Sprays	Number of clusters	Number of nuts	Blanks	Ave. nuts per cluster	Percent set	Nut weight	Kernel weight
Control	16.6** a	25.6 a	2.5 a	1.5 a	44.6 a	91.4 a	35.7 a
H. R. Control	--	--	--	--	--	--	--
Ethephon 500 ppm	17.3 a	28.3 a	2.6 a	1.6 a	34.1 a	95.4 a	33.5 a
TTBA 25 ppm	18.4 a	28.1 a	2.4 a	1.5 a	40.8 a	102.3 a	40.2 a
GA 50 ppm	20.7 a	33.1 a	3.3 a	1.6 a	39.6 a	120.6 a	45.9 a

*The hand-removed control eliminated all the yield components on the flagged branches in 1979.

**Means not sharing the same letter within columns are significantly different at the 5% level, using Tukey's w-procedure.

Figure 1. Average number of flower clusters and catkins per branch at each application date in Spring (1980) following 1979 treatments.
Control, H.R. Control,
Ethephon-500ppm, TIBA-25ppm, GA-50ppm

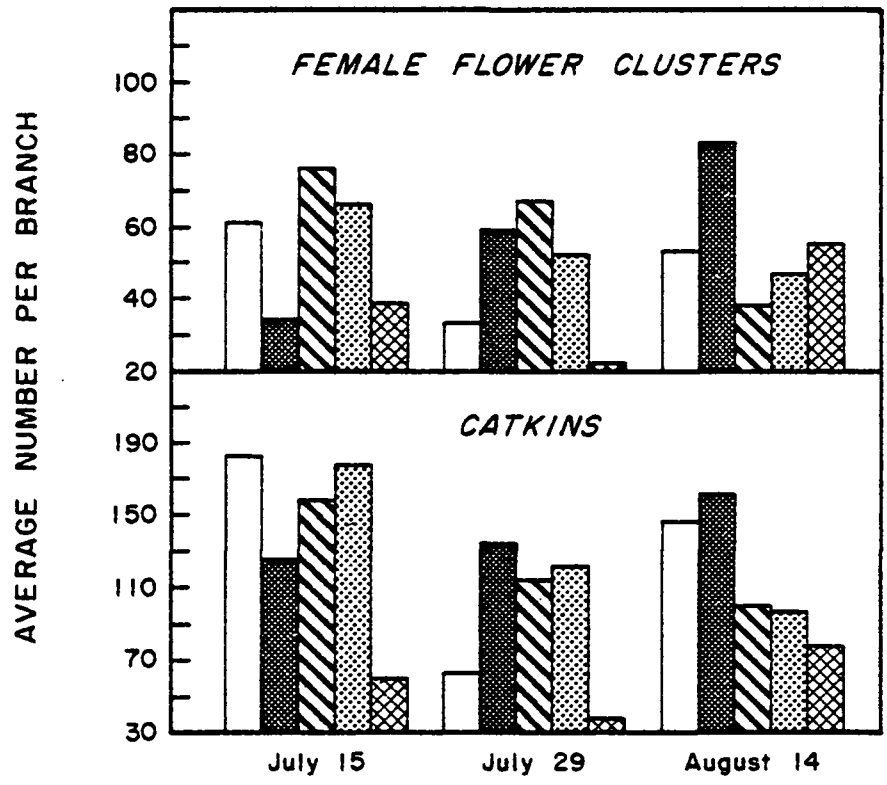
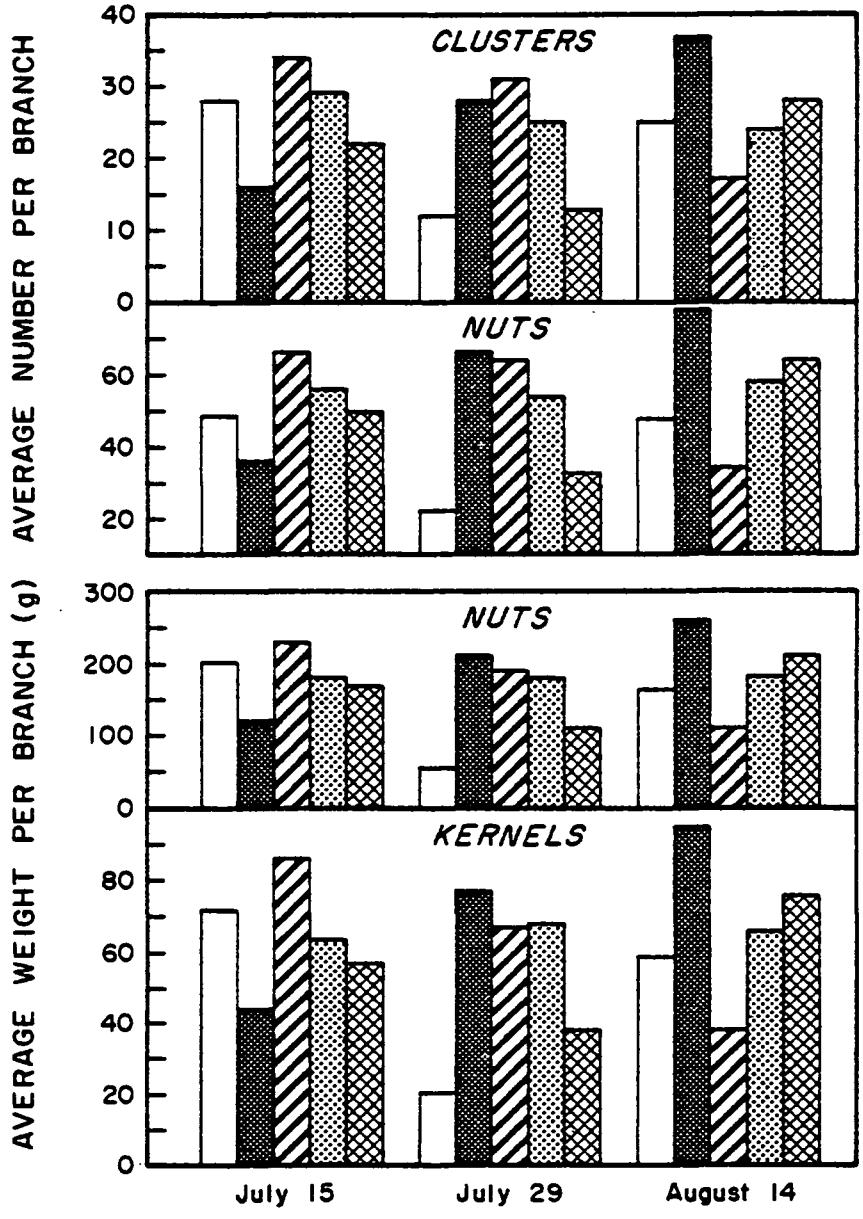


Figure 2. Average number of clusters and nuts, and nut and kernel weight (g) per branch, the year (1980) following 1979 treatments. Control, H.R. Control, Ethephon-500ppm, TIBA-25ppm, GA-50ppm



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First Paper

Table 1. Average shoot length in mm. measured at the end of the 1979 growing season following Spring gibberellic acid treatments. Arranged in ascending order.

Spray	Shoots	Shoot Length
GA 15 ppm	S_3	15.6* a
GA 50 ppm	S_3	29.8 ab
Control	S_3	32.7 ab
GA 50 ppm	S_2	46.1 abc
GA 15 ppm	S_2	54.2 abc
Control	S_2	57.1 bc
GA 50 ppm	S_1	76.3 cd
Control	S_1	85.3 d
GA 15 ppm	S_1	123.8 e

*Means not sharing the same letter are significantly different at the 5% level.

Mean separations based on Tukey's w-procedure.

S_1 = most distal position.

S_2 = intermediate position.

S_3 = most proximal position.

Table 2. Linear correlation coefficients between branch diameter and flower number in the 'Barcelona' filbert following Spring 1979 gibberellic acid treatments. Branch diameter measurements and flower counts taken in December of 1978 and 1979. Values obtained at all orientations.

	Branch Diameter					
	All orientations combined		North and South only		East and West only	
Flowers	1978	1979	1978	1979	1978	1979
Catkins	.19*	.40****	.46****	.44***	.10	.41***
Female flower clusters	.30***	.42****	.58****	.43***	.12	.41***

P < .10* P < .05** P < .01*** P < .001****

Table 3. Average number of clusters and nuts per branch following Spring (1979) gibberellic acid treatments. Values arranged in ascending order.

Spray	Date	Cluster Set	Nuts
GA 50 ppm	4/20	.9* a	2.0 a
GA 50 ppm	5/11	1.5 a	2.3 a
GA 15 ppm	5/11	5.5 ab	10.2 ab
GA 15 ppm	4/20	5.7 ab	10.5 ab
GA 15 ppm	5/25	12.6 abc	19.3 abc
Control	5/25	13.3 bc	21.8 abc
Control	4/20	16.3 bc	24.5 bc
Control	5/11	17.3 c	30.4 bc
GA 50 ppm	5/25	18.9 c	31.9 c

*Means not sharing the same letter within columns are significantly different at the 5% level, using Tukey's w-procedure.

Table 4. Percent set on branches following Spring (1979) gibberellic acid treatments. Values arranged in ascending order.

Spray	Date	Percent Set
GA 50 ppm	4/20	1.9* a
GA 50 ppm	5/11	5.3 a
GA 15 ppm	4/20	14.0 ab
GA 15 ppm	5/11	14.6 ab
GA 15 ppm	5/25	26.9 ab
Control	4/20	33.1 b
Control	5/25	35.7 b
Control	5/11	38.4 b
GA 50 ppm	5/25	39.4 b

*Means not sharing the same letter are significantly different at the 5% level. Mean separation based on Tukey's w-procedure.

Table 5. Average nut weight (g) per branch following Spring (1979) gibberellic acid treatments. Values arranged in ascending order.

Spray	Date	Nut weight (g)
GA 50 ppm	4/20	6.7* a
GA 50 ppm	5/11	7.4 a
GA 15 ppm	5/11	33.4 ab
GA 15 ppm	4/20	37.4 ab
GA 15 ppm	5/25	65.8 ab
Control	5/25	76.2 ab
Control	4/20	87.0 b
GA 50 ppm	5/25	99.8 b
Control	5/11	104.0 b

*Means not sharing the same letter are significantly different at the 5% level.

Mean separations based on Tukey's w-procedure.

Table 6. Average kernel weight (g) per branch following Spring (1979) gibberellic acid treatments. Values arranged in ascending order.

Spray	Date	Kernel Weight (g)
GA 50 ppm	4/20	1.6* a
GA 50 ppm	5/11	2.0 a
GA 15 ppm	4/20	12.6 ab
GA 15 ppm	5/11	12.7 ab
GA 15 ppm	5/25	25.2 abc
Control	5/25	29.5 abc
Control	4/20	32.8 bc
GA 50 ppm	5/25	37.1 bc
Control	5/11	40.4 c

*Means not sharing the same letter are significantly different at the 5% level.

Mean separations based on Tukey's w-procedure.

Table 7 . Tree yield (g) averages following Spring (1979) gibberellic acid treatments. Values arranged in ascending order.

Spray	Date	Yield (g)
GA 50 ppm	4/20	378.9* a
GA 50 ppm	5/11	685.6 ab
GA 15 ppm	5/11	745.3 abc
GA 15 ppm	4/20	1004.4 bcd
GA 50 ppm	5/25	1025.4 bcd
Control	5/25	1307.5 cd
Control	4/20	1310.3 cd
GA 15 ppm	5/25	1347.5 d
Control	5/11	1351.9 d

*Means not sharing the same letter are significantly different at the 5% level.

Mean separations based on Tukey's w-procedure.

Table 8. Percent set on branches the year following (1980) gibberellic acid treatments. Values arranged in ascending order.

Spray	Date	Percent set
GA 50 ppm	4/20	24.9* a
GA 15 ppm	4/20	28.9 b
GA 50 ppm	5/11	33.4 b
GA 15 ppm	5/11	36.0 b
GA 15 ppm	5/25	38.7 b
GA 50 ppm	5/25	39.8 b
Control	5/25	45.8 b
Control	5/11	52.2 b
Control	4/20	56.3 b

*Means not sharing the same letter are significantly different at the 5% level. Mean separation based on Tukey's w-procedure.

Table 9. Orthogonal partitioning of branch orientation sum of squares for male and female flowers into subcomponent parts to determing the effect of individual orientations on male and female flower production. Flowers counted prior (December, 1978) to growth regulator treatments.

Flowers	Source of Variation	df	SS	MS	Observed f	Required f(1, 54) .5%	Required f(1, 54) 2.5%
Catkins							
	Orientations	3	116688.77	38896.26	14.26	8.66	5.36
	N vs. S	1	462.30	462.30	.17		
	E vs. W	1	127.57	127.57	.05		
	N, S vs. E, W	1	116098.90	116098.90	42.58		
	Error	54	147231.83	2726.52			
Female Flowers							
	Orientations	3	6867.29	2289.10	6.41	8.66	5.36
	N vs. S	1	18.96	18.96	.00		
	E vs. W	1	174.24	174.24	.49		
	N, S vs. E, W	1	6674.08	6674.08	18.69		
	Error	54	19283.17	357.10			

Table 10. Orthogonal partitioning of branch orientation sum of squares for clusters and nut number into subcomponent parts to determine the effect of individual orientations on cluster and nut formation. Values obtained following Spring (1979) gibberellic acid treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f (1, 54) .5%	Required f (1, 54) 2.5%
Nuts set							
	Orientations	3	2054.18	684.72	3.25	8.66	5.36
	N vs. S	1	25.35	25.35	.12		
	E vs. W	1	26.74	26.74	.13		
	N, S vs. E, W	1	2002.08	2002.08	9.51		
	Error	54	11363.83	210.44			
Clusters							
	Orientations	3	680.18	226.72	3.37	8.66	5.36
	N vs. S	1	4.17	4.17	.06		
	E vs. W	1	6.00	6.00	.09		
	N, S vs. E, W	1	670.01	670.01	9.95		
	Error	54	3635.17	67.32			

Table 11. Orthogonal partitioning of branch orientation sum of squares for percent set into subcomponent parts to determine the effect of individual orientations on percent set. Values obtained the Spring (1979) following gibberellic acid treatments. All sprays, all dates combined.*

	Variation	df	SS	MS	Observed f	Required f (1,54) 5%	10%
Percent Set							
	Orientations	3	316.8706	105.62353	.81390	4.05	2.81
	N vs. S	1	2.53812	2.53812	.01956		
	E vs. W	1	8.85395	8.85395	.06823		
	N, S vs. E,W	1	305.47853	305.47853	2.35390		
	Error	54	7007.86250	129.77523			

*The orthogonal partitioning of branch orientation sum of squares for average number of nuts per cluster into subcomponent parts could not be done for the values obtained the Spring (1979) following gibberellic acid treatments. Gibberellic acid caused a substantial number of the branches to have no clusters retained, and so those nuts per cluster values were considered missing.

Table 12. Orthogonal partitioning of branch orientation sum of squares for nut and kernel weight (g) into subcomponent parts to determine the effect of individual orientations on nut and kernel weight. Values obtained following Spring (1979) gibberellic acid treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f(1,54) .5%	Required f(1,54) 2.5%
Nut weight							
	Orientations	3	27285.86	9095.29	3.57	8.66	5.36
	N vs. S	1	318.77	318.77	.12		
	E vs. W	1	502.94	502.94	.20		
	N, S vs. E, W	1	26464.15	26464.15	10.38		
	Error	54	137631.84	2548.74			
Kernel weight							
	Orientations	3	4028.25	1342.75	3.63	8.66	5.36
	N vs. S	1	6.41	6.41	.02		
	E vs. W	1	94.14	94.14	.25		
	N, S vs. E, W	1	3927.70	3927.70	10.62		
	Error	54	19975.06	369.91			

Table 13. Orthogonal partitioning of branch orientation sum of squares for blank production into sub-component parts to determine the effect of individual orientations on blank formation. Values obtained following Spring (1979) gibberellic acid treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f(1,54) .5%	Required f(1,54) 2.5%
Blanks							
	Orientations	3	51.21	17.07	3.42	8.66	5.36
	N vs. S	1	18.96	18.96	3.80		
	E vs. W	1	.02	.02	.00		
	N, S vs. E, W	1	32.23	32.23	6.45		
	Error	54	269.83	5.00			

Table 14. Orthogonal partitioning of branch orientation sum of squares for male and female flowers into subcomponent parts to determine the effect of individual orientations on male and female flower production. Flowers counted following (December, 1979) growth regulator treatments. All sprays, all dates combined.

Flowers	Source of Variation	df	SS	MS	Observed f	Required f(1,54) .5%	Required f(1,54) 2.5%
Catkins							
	Orientations	3	377513.29	125837.76	24.98	8.66	5.36
	N vs. S	1	9787.57	9787.57	1.94		
	E vs. W	1	6845.63	6845.63	1.36		
	N, S vs. E, W	1	360880.08	360880.08	71.63		
	Error	54	272049.50	5037.95			
Female flowers							
	Orientations	3	82978.30	27659.43	11.43	8.66	5.36
	N vs. S	1	174.24	174.24	.07		
	E vs. W	1	25.35	25.35	.01		
	N, S vs. E, W	1	82778.70	82778.70	34.21		
	Error	54	130677.33	2418.95			

Table 15. Orthogonal partitioning of branch orientation sum of squares for cluster and nut number, into subcomponent parts to determine the effect of individual orientations on cluster and nut formation. Values obtained the year (1980) following gibberellic acid treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f(1,54) .5%	Required f(1,54) 2.5%
Nuts set							
	Orientations	3	29881.36	9960.45	9.08	8.66	5.36
	N vs. S	1	668.52	668.52	.61		
	E vs. W	1	433.50	433.50	.40		
	N, S vs. E, W	1	28779.34	28779.34	26.22		
	Error	54	59259.00	1097.39			
Clusters							
	Orientations	3	10484.53	3494.84	13.96	8.66	5.36
	N vs. S	1	567.13	567.13	2.26		
	E vs. W	1	17.80	17.80	.07		
	N, S vs. E, W	1	9899.60	9899.60	39.53		
	Error	54	13522.50	250.42			

Table 16 . Orthogonal partitioning of branch orientation sum of squares for average number of nuts per cluster and percent set in order to determine the effect of individual orientations on nuts/cluster and percent set. Values obtained the year (1980) following gibberellic acid treatments. All sprays, all dates combined.

Source of Variation	df	SS	MS	Observed f	Required f (1,54) 5%	10%
Average nuts/cluster						
Orientations	3	.39592	.13197	.66986	4.02	2.80
N vs. S	1	.07889	.07889	.40044		
E vs. W	1	.18552	.18552	.94169		
N, S. vs. E, W	1	.13151	.13151	.66755		
Error	54	10.63855	.19701			
Percent Set						
Orientations	3	685.37237	228.45746	1.15527	4.02	2.80
N. vs. S.	1	263.84635	263.84635	1.33422		
E vs. W	1	406.24885	406.24885	2.05432		
N. S vs. E, W	1	15.27717	15.27717	.07725		
Error	54	10678.66048	197.75297			

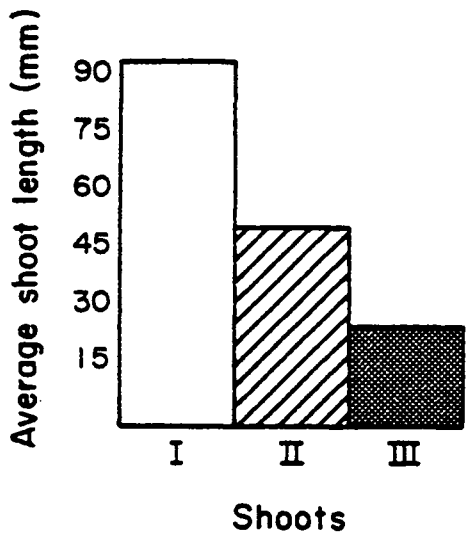
Table 17. Orthogonal partitioning of branch orientation sum of squares for nut and kernel weight (g) into subcomponent parts to determine the effect of individual orientations on nut and kernel weight. Values obtained th year (1980) following gibberellic acid treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f(1,54) .5%	Required f(1,54) 2.5%
Nut weight							
	Orientations	3	451610.67	150536.89	10.95	8.66	5.36
	N vs. S	1	6897.52	6897.52	.50		
	E vs. W	1	3368.56	3368.56	.24		
	N, S vs. E, W	1	441344.59	441344.59	32.12		
	Error	54	742080.80	13742.24			
Kernel weight							
	Orientations	3	64570.52	21523.51	11.36	8.66	5.36
	N vs. S	1	1991.08	1991.08	1.05		
	E vs. W	1	438.62	438.62	.23		
	N, S vs. E, W	1	62140.82	62140.82	32.81		
	Error	54	102263.64	1893.77			

Table 18. Orthogonal partitioning of branch orientation sum of squares for blank production into subcomponent parts to determine the effect of individual orientations on blank formation. Values obtained the year (1980) following gibberellic acid treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f (1,54) .5%	Required f (1,54) 2.5%
Blanks							
	Orientations	3	517.14	172.38	4.13	8.66	5.36
	N vs. S	1	3.13	3.13	.08		
	E vs. W	1	2.67	2.67	.06		
	N, S vs. E, W	1	511.34	511.34	12.26		
	Error	54	2251.50	41.69			

Figure 1. Average length of shoots I, II, & III per West branches. All dates and treatments combined.



Second Paper

Table 1. Average number of catkins per branch at each application date in the Spring (1980) following 1979 treatments. Values arranged in ascending order.

Spray	Date	Catkins	
GA 50 ppm	7/29	38.5*	a
GA 50 ppm	7/15	59.0	ab
Control	7/29	60.2	ab
Ga 50 ppm	8/14	77.5	abc
TIBA 25 ppm	8/14	97.7	abc
Ethrel 500 ppm	8/14	100.8	abc
Ethrel 500 ppm	7/29	113.5	abc
TIBA 25 ppm	7/29	123.2	abc
H.R. Control	7/15	125.6	abc
H. R. Control	7/29	135.3	abc
Control	8/14	147.2	abc
Zthrel500 ppm	7/15	159.2	abc
Ethrel 500 ppm	7/15	163.5	bc
H. R. Control	8/14	178.8	c
Control	7/15	183.2	c

*Means not sharing the same letter are significantly different at the 5% level.

Mean separations based on Tukey's w-procedure.

Table 2. Average number of female flower clusters per branch at each application date in the Spring (1980) following 1979 treatments. Values arranged in ascending order.

Spray	Date	Pistillate Flowers	
GA 50 ppm	7/29	21.8*	a
Control	7/29	33.1	ab
H. R. Control	7/15	34.6	abc
Ethrel 500 ppm	8/14	37.6	abc
GA 50 ppm	7/15	39.0	abc
TIBA 25 ppm	8/14	47.1	abc
TIBA 25 ppm	7/29	52.2	abc
Control	8/14	53.2	abc
GA 50 ppm	8/14	55.2	abc
H. R. Control	7/29	59.1	abc
Control	7/15	60.7	abc
TIBA 25 ppm	7/15	66.8	abc
Ethrel 500 ppm	7/29	67.2	abc
Ethrel 500 ppm	7/15	76.2	bc
H. R. Control	8/14	83.0	c

*Means not sharing the same letter are significantly different at the 5% level.

Mean separations based on Tukey's w-procedure.

Table 3. Average number of clusters per branch at each application date in the year (1980) following treatments. Values arranged in ascending order.

Treatment	Date	Number of Clusters
Control	7/29	11.83* a
GA 50 ppm	7/29	13.33 a
H. R. Control	7/15	16.17 a
Ethrel 500 ppm	8/14	16.67 a
GA 50 ppm	7/15	21.75 a
TIBA 25 ppm	8/14	23.67 a
TIBA 25 ppm	7/29	24.83 a
Control	8/14	24.92 a
H. R. Control	7/29	27.75 a
GA 50 ppm	8/14	27.92 a
Control	7/15	28.25 a
TIBA 25 ppm	7/15	28.92 a
Ethrel 500 ppm	7/29	31.08 a
Ethrel 500 ppm	7/15	33.75 a
H. R. Control	8/14	37.08 a

*Means not sharing the same letter are significantly different at the 5% level, using Tukey's w-procedure.

ANOVA	df	MS	F
Spray x Date	8	906.19	3.11*y
Error	28	291.66	

[Y]Significant difference at the 5% (*) level.

Table 4. Average number of nuts per branch at each application date in the year (1980) following treatments. Values arranged in ascending order.

Treatment	Date	Number of Nuts	
Control	7/29	22.00*	a
GA 50 ppm	7/29	33.42	a
Ethrel 500 ppm	8/14	33.58	a
H. R. Control	7/15	36.42	a
Control	8/14	48.00	a
GA 50 ppm	7/15	50.42	a
TIBA 25 ppm	7/29	54.25	a
TIBA 25 ppm	7/15	55.58	a
TIBA 25 ppm	8/14	58.00	a
Control	7/15	58.50	a
GA 50 ppm	8/14	63.92	a
Ethrel 500 ppm	7/29	64.00	a
Ethrel 500 ppm	7/15	66.00	a
H. R. Control	7/29	66.42	a
H. R. Control	8/14	78.83	a

*Means not sharing the same letter are significantly different at the 10% level, using Tukey's w-procedure.

ANOVA	df	MS	F
Spray x Date	8	3913.24	1.98*[Y]
Error	28	1979.67	

[Y]Significant difference at the 10% (*) level.

Table 5. Average nut weight (g) per branch at each application date in the year (1980) following treatments. Values arranged in ascending order.

Treatment	Date	Nut Weight	
Control	7/29	56.98*	a
GA 50 ppm	7/29	109.48	a
Ethrel 500 ppm	8/14	110.23	a
H. R. Control	7/15	120.26	a
Control	8/14	166.28	a
GA 50 ppm	7/15	170.32	a
TIBA 25 ppm	7/15	181.12	a
TIBA 25 ppm	7/29	181.98	a
TIBA 25 ppm	8/14	185.50	a
Ethrel 500 ppm	7/29	190.20	a
Control	7/15	198.90	a
H. R. Control	7/29	209.26	a
GA 50 ppm	8/14	209.29	a
Ethrel 500 ppm	7/15	230.78	a
H. R. Control	8/14	259.24	a

*Means not sharing the same letter are significantly different at the 10% level, using Tukey's w-procedure.

ANOVA	df	MS	F
Spray x Date	8	44563.24	2.14*[y]
Error	28	20841.99	

[y]Significant difference at the 10% (*) level.

Table 6. Average kernel weight (g) per branch at each application date in the year (1980) following treatments. Values arranged in ascending order.

Treatment	Date	Kernel Weight	
Control	7/29	19.62*	a
GA 50 ppm	7/29	37.53	a
Ethrel 500 ppm	8/14	38.01	a
H. R. Control	7/15	44.03	a
GA 50 ppm	7/15	58.46	a
Control	8/14	59.38	a
TIBA 25 ppm	7/15	64.47	a
TIBA 25 ppm	8/14	65.93	a
Ethrel 500 ppm	7/29	66.73	a
TIBA 25 ppm	7/29	68.34	a
Control	7/15	72.54	a
GA 50 ppm	8/14	75.92	a
H. R. Control	7/29	76.82	a
Ethrel 500 ppm	7/15	86.50	a
H. R. Control	8/14	94.68	a

*Means not sharing the same letter are significantly different at the 5% level, using Tukey's w-procedure.

ANOVA	df	MS	F
Spray x Date	8	6508.11	2.30*[y]
Error	28	2791.74	

[y]Significant difference at the 5% (*) level.

Table 7. Average number of nuts per cluster, percent set, and blanks per branch the year (1980) following treatments. The results from the three treatment dates are combined.

Treatment	Ave. nuts per cluster	Percent set	Blanks
GA 50 ppm	2.2* a	63.5 a	9.3 a
TIBA 25 ppm	2.1 a	50.9 a	9.5 a
Ethrel 500 ppm	2.0 a	47.7 a	8.7 a
H. R. Control	2.1 a	43.7 a	9.4 a
Control	1.9 a	42.6 a	7.1 a

*Means not sharing the same letter within columns are significantly different at the 5% level, using Tukey's w-procedure.

Table 8. Orthogonal partitioning of branch orientation sum of squares for male and female flowers into subcomponent parts to determine the effect of individual orientations on male and female flower production. Flowers counted prior (December, 1978) to growth regulator treatments.

Flowers	Source of Variation	df	SS	MS	Observed f	Required f (1,90) .5%	Required f (1,90) 2.5%
Catkins							
	Orientations	3	179056.90	59685.64	19.44	8.34	5.22
	N vs. S	1	4622.50	4622.50	1.51		
	E vs. W	1	1392.40	1392.40	.45		
	N, S, vs. E, W	1	173042.01	173042.01	56.38		
	Error	90	276250.50	3069.45			
Female Flower Clusters							
	Orientations	3	18241.66	6080.55	14.00	8.34	5.22
	N vs. S	1	134.44	134.44	.31		
	E vs. W	1	127.21	127.21	.29		
	N, S vs. E, W	1	17980.01	17980.01	41.39		
	Error	90	39097.67	434.42			

Table 9. Orthogonal partitioning of branch orientation sum of squares for cluster and nut number into subcomponent parts to determine the effect of individual orientations on cluster and nut number. Values obtained in the year of treatments (1979). All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f (1,72) .5%	Required f (1,72) 2.5%
Clusters							
	Orientations	3	3525.14	1175.05	14.73	8.48	5.28
	N vs. S	1	115.01	115.01	1.44		
	E vs. W	1	7.35	7.35	.09		
	N, S vs. E, W	1	3402.78	3402.78	42.65		
	Error	72	5744.00	79.78			
Nuts							
	Orientations	3	10206.80	3402.27	16.45	8.48	5.28
	N vs. S	1	506.68	506.68	2.45		
	E vs. W	1	30.68	30.68	.15		
	N, S vs. E, W	1	9669.44	9669.44	46.76		
	Error	72	14887.50	206.77			

Table 10. Orthogonal partitioning of branch orientation sum of squares for nut and kernel weights (g) into subcomponent parts to determine the effect of individual orientations on nut and kernel weight. Values obtained in the year of treatments (1979). All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f .5%	Required f 2.5%
Nut weight							
	Orientations	3	140454.21	46818.07	16.02	8.48	5.28
	N vs. S	1	5719.15	5719.15	1.96		
	E vs. W	1	754.66	754.66	.26		
	N, S vs. E, W	1	133980.40	133980.40	45.83		
	Error	72	210467.04	2923.14			
Kernel weight							
	Orientations	3	20003.82	6667.94	16.07	8.48	5.28
	N vs. S	1	1208.68	1208.68	2.91		
	E vs. W	1	135.58	135.58	.33		
	N, S vs. E, W	1	18659.56	18659.56	44.98		
	Error	72	29868.10	414.83			

Table 11. Orthogonal partitioning of branch orientation sum of squares for number of blanks into subcomponent parts to determine the effect of individual orientations on blank formation. Values obtained in the year of treatments (1979). All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f .5%	Required f 2.5%
Blanks							
	Orientations	3	74.14	24.71	5.73	8.48	5.28
	N vs. S	1	2.35	2.35	.54		
	E vs. W	1	2.35	2.35	.54		
	N, S vs. E, W	1	69.44	69.44	16.11		
	Error	72	310.33	4.31			

Table 12. Orthogonal partitioning of branch orientation sum of squares for male and female flowers into subcomponent parts to determine the effect of individual orientations on male and female flower number. Flowers counted following (December 1979) growth regulator treatments. All sprays, all dates combined.

Flowers	Source of Variation	df	SS	MS	Observed f	Required f (1,90) .5%	Required f (1,90) 2.5%
Catkins							
	Orientations	3	621666.99	207222.33	42.83	8.34	5.22
	N vs. S	1	24535.51	24535.51	5.07		
	E vs. W	1	49.88	49.88	.01		
	N, S vs. E, W	1	597081.61	597081.61	123.42		
	Error	90	435399.67	4837.77			
Female Flower Clusters							
	Orientations	3	36179.31	12059.77	13.82	8.34	5.22
	N vs. S	1	572.54	572.54	.66		
	E vs. W	1	214.68	214.68	.25		
	N, S vs. E, W	1	35392.09	35392.09	40.55		
	Error	90	78554.50	872.83			

Table 13. Orthogonal partitioning of branch orientation sum of squares for cluster and nut number into subcomponent parts to determine the effect of individual orientation on cluster and nut number. Values obtained in the year (1980) following treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Required f (1,90) .5%	Required f (1,90) 2.5%
Clusters							
	Orientations	3	8501.39	2833.80	14.59	8.34	5.22
	N vs. S	1	190.68	190.68	.98		
	E vs. W	1	1.11	1.11	.01		
	N, S vs. E, W	1	8309.60	8309.60	42.79		
	Error	90	17478.67	194.21			
Nuts							
	Orientations	3	28810.71	9603.57	7.93	8.34	5.22
	N vs. S	1	816.01	816.01	.67		
	E vs. W	1	69.34	69.34	.06		
	N, S vs. E, W	1	27925.36	27925.36	23.05		
	Error	90	109039.50	1211.55			

Table 14. Orthogonal partitioning of branch orientation sum of squares for average number of nuts per cluster and percent set in order to determine the effect of individual orientations on average number of nuts per cluster and percent set. Values obtained the year (1980) following treatments. All sprays, all dates combined.*

	Source of Variation	df	SS	MS	Observed f	Required f 5%	Required f 10%
Ave. nuts/cluster							
	Orientations	3	.07955	.02652	.12704	3.96	2.77
	N vs. S	1	.04446	.04446	.21297		
	E vs. W	1	.01848	.01848	.08853		
	N, S vs. E, W	1	.01661	.01661	.079.55		
	Error	87	18.16171	.20876	.07955		
Percent set							
	Orientations	3	143333.41000	47777.80400	.97399	3.96	2.77
	N vs. S	1	105.01887	105.01887	.00214		
	E vs. W	1	96095.98923	96095.98923	1.95899		
	N, S vs. E, W	1	47132.40580	47132.40580	.96083		
	Error	89	4365790.51410	49053.82600			

*Orthogonal partitioning of branch orientation sum of squares for average number of nuts per cluster and percent set could not be done for the values obtained the Summer (1979) following treatments. Branches that were hand-thinned caused too many missing values when all sprays, all dates were combined to compute nuts/cluster and percent set.

Table 15. Orthogonal partitioning of branch orientation sum of squares for nut and kernel weights (g) into subcomponent parts to determine the effect of individual orientations on nut and kernel weights. Values obtained in the year (1980) following treatments. All sprays, all dates combined.

Source of Variation	df	SS	MS	Observed f	Required f (1,90) .5%	Required f (1,90) 2.5%
Nut weight						
Orientations	3	416364.35	138788.12	11.13	8.34	5.22
N vs. S	1	7877.38	7877.38	.63		
E vs. W	1	107.36	107.36	.01		
N, S vs. E, W	1	408379.62	408379.62	32.75		
Error	90	1122360.55	12470.67			
Kernel weight						
Orientations	3	51764.34	17254.78	10.74	8.34	5.22
N vs. S	1	882.97	882.97	.55		
E vs. W	1	4.22	4.22	.00		
N, S vs. E, W	1	50877.15	50877.15	31.67		
Error	90	144594.82	1606.61			

Table 16. Orthogonal partitioning of branch orientation sum of squares for number of blanks into subcomponent parts to determine the effect of individual orientations on blank formation. Values obtained in the year (1980) following treatments. All sprays, all dates combined.

	Source of Variation	df	SS	MS	Observed f	Rquired f (1,90) .5%	Rquired f (1,90) 2.5%
Blanks							
	Orientations	3	537.71	179.24	3.43	8.34	5.22
	N vs. S	1	10.68	10.68	.20		
	E vs. W	1	13.61	13.61	.26		
	N, S vs. E, W	1	513.42	513.42	9.82		
	Error	90	4707.17	52.30			

Figure 1. Average number of catkins per branch in Spring (1980) following 1979 treatments. Results from the three treatment dates are combined.