EFFECT OF PACLOBUTRAZOL (PP333) AND FLURPRIMIDOL (EL500) ON VEGETATIVE GROWTH, FRUIT CHARACTERISTICS AND STORAGE OF 'GOLDEN DELICIOUS' AND 'RED DELICIOUS' APPLE

by

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DEDICATION

In the name of Allah, Most Gracious,

Most Merciful.

Thy Lord hath decreed that ye worship none but Him, and that ye be kind to parents. whether one or both of them attain old age in thy life, say not to them a word of contempt, nor repel them, but address them in terms of honour.

And, out of kindness lower to them the wing of humility, and say: My Lord: bestow on them thy mercy even as they cherished me in childhood.

This thesis is dedicated to my parents, who had to suffer the real price of this degree.

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INTRODUCTION

In the past it was the usual practice to encourage fruit trees to grow vegetatively in their early years in order to fill their allotted space in the orchard as quickly as possible. For the first five or six years trees were heavily pruned, which discouraged early cropping but before densities increased, it became imperative to get the tree into crop earlier, both to check excessive growth and to enable the grower to recoup his investment (35).

To prevent biennial bearing, the delicate balance between fruit set, flower-bud formation and shoot growth must be adequately controlled. Especially with respect to economic considerations, the alternation of light crops of un usually large fruits with poor storage quality and heavy crops with too many undersized fruits is highly undesirable (59). To control fruit cropping and vegetative growth, a number of cultural techniques are avaliable such as dormant and summer pruing, fruit thinning by hand, and of course, the use of dwarfing rootstocks but the proper choice of rootstock/scion combination for each soil is difficult. Optimum levels of fertilizers are important to give a proper balance between vegetative grwoth, fruit load and return bloom. Culture practices such as limb spreading or tying are useful to retard vigorous up right growth and increase spur development but are expensive and generally limited to training young trees.

As trees get older heavy dense canopies shade lower portions of the trees and results in low vigor spurs with inferior flowers and fruits, and growers are at a loss to know how to manage them. These delicate balancing acts performed by growers each year become expensive and are often difficult to do because of weather and other factors over which there is little control.

Apple growers throughout the world wish to control, but not completely inhibit extension of shoot growth on their trees. By limiting this growth they should be able to reduce pruning costs, improve fruit color by adding exposure to light, and possibly channel some of the tree's reserves away from shoot growth and into fruit and floral bud production. Complete inhibition of extension growth, and the development of trees which fruit only on old spurs may by undesirable on many varieties. It is belived that some shoot growth is desirable early in the season on, for example, the cultivar 'Cox' because over-exposure of the fruit may increase the incidence of skin russet (64).

The ability to control excessive shoot growth on the apple would be of considerable benefits to the fruit industry. Some of the observed benefits are, less pruning required, increased fruit set, easier control of insects and disease, stronger spurs in lower half of trees because of increased exposure to light, pack of extra fancy red varieties because of more exposure to light, and easier harvesting with fewer limb rubs and handling bruises (70).

Since the discovery of plant hormones in the late twenties it has become clear that these substances play a key role in the integration and coordination of growth and differentiation in the various plant parts. Furthermore, because plant response to environmental conditions and cultural measures, is mediated via small amount of these chemical substances, it is not surprising that attempts have long been made to regulate plant behaviour by chemicals.

Chemical pinching agents are potentially useful in fruit production if they can alter the morphology of a tree without jeopardizing its ability to produce a crop. Two main purposes which might be served by a chemical pinching agent are: (1) stimulation of spur development on cultivars which are slow to begin bearing, and (2) induction of primary branches (feathers) on one-year old trees in nurseries. These pinching agents act by halting or interrupting meristematic activity of the shoot tips (59).

Apples with an annual world production of over 35 million tons, are by far the most important fruit of the temperate regions and for this reasons, have attracted more research and are better understood than most other perennial fruit crops. The study of the use of two new growth retardants paclobutrazol (PP333) and flurprimidol (EL500) is helping us to understand and overcome some of the problems previously mentioned. Much effort over the last two years has been put into identifying the optimal timing and dosage rate for PP333. Single sprays with high concentration or lower concentration sprays applied several times during the seasons have been compared. Research with flurprimidol

(EL500) on tree fruits has been less extensive, carried out at Pennsylvania State University and limited largely to the apple (62). Further work is required to optimize the application method, rate and timing to support commerical recommendations for both PP333 and EL500. Most research with PP333 that has been done was carried out in the Eastern and Western United State. Therfore it is necessary to test these chemicals in the Midwest which are still in the experimental stage.

Objectives of this research were to compare effects of foliar and ground applications of the growth regulators flurprimidol and paclobutrazol made to two apple cultivars 'Golden Delicious' and 'Red Delicious' on the following factors:

1. Vegetative growth
2. Fruit characteristics
3. Fruit storage

LITERATURE REVIEW

Plant Hormones

Plant hormones are of universal occurrence in plants. They act at extremely low concentrations to promote or inhibit the growth of cells and tissues, to cause the differentiation of organs such as leaves, root or flowers, and to control the reaction of the plant to envirnomental factors such as gravity, temperature, light, day-length and water stresses. Five clearly defined types of plant hormone are at present recognised, each of regulate plant behaviour (36). The five types include: gibberellins, auxins, cytkinins, ethylene, and growth retardants such as abscisic acid.

Plant Growth Regulators

Growth regulators are synthetic compounds applied exogenously to the plant in order to modify its growth pattern. More specifically, a plant growth regulator is any non-nutrient chemical, either natural or synthetic, that markedly influences the development and growth of the plant to which it is applied (26). The compound, of necessity, must be systemic, i,e, absorbed by some portion of the plant and translocated within the plant to where it will elicit its effect on plant growth and development.

Plant Growth Retardants

There are many categories of plant growth regulators. The most widely used category is that of the growth retardant. These are defined as any synthetic organic compound that reduces the rate of stem elongation in responsive plants by inhibiting the activity of the subapical meristem without markedly influencing leaf production and development or inducing other growth deformities(14). This reduction in height is accomplished predominatly by reducing the subapical meristems rate of cell division and elongation (8).

Physiological Role

The physiological role of growth retardants in plant growth and development has received wide attention. The growth inhibitor maleic hydrazide acted as an anti-auxin in that the apical meristem was also markedly inhibited (44). This is not generally true of growth retardants, whose mode of action involves inhibition of cell division and cell expansion in the sub-apical region of the stem. There is direct evidence that growth retardants function by inhibiting the biosynthesis of GA precursor (43,14).

Most retardants are thought to act by inhibition of gibberllin biosynthesis either by the cyclisation of geranyl-geranyl pyrophosphate, or at the oxidation of ent-kaurene (14). Recent evidence indicated that growth retardants also influenced the conversion-deactivation of the elaborated GAs and biosynthesis of triterpenoid phytosterols. Experiments with Fusariummoniliforme have indicated that Amo-1681, chlorphonium, and chlormequat inhibited the biosynthesis of GAs in this organism (14).

The function of gibberellins has been particularly associated with the elongation of plant internodes, as well as many other processes. Gibberellins and growth retardants are highly mutually antagonistic. The effect of growth retardants has been reversed by properly timed applications of GA of the proper molarity (8,44).

Luckwill (33) proposed that growth retardants have a two fold effect, cause cessation of shoot growth and an accumulation of cytokinins. He also suggested that if flowering is associated with a critical gibberellin-cytokinins balance, an excessive amount of growth retardant applied to early in the season might actually stop growth and prevent flowering.

General Growth Retardant Effect on Plants

Branching in Nursery Trees

For modern fruit-growing, nursery trees having an adequate number of lateral shoots (feathers) that are not inserted too low and make a wide angle with main stem are greatly preferred to unfeathered trees. Feathers form the basis for the primary branch system, and they provide room for early production of flower buds. Properly feathered trees may start to bear fruit a year earlier. VanOosten (71) found a positive relationship between the number of feathers at planting time and total yield from the second and third year.

In attempts made in apple and pear to induce branching chemically, tests were performed with a variety of systemic growth regulators all having the ability, depending on the concentration used, to damage young tissues without killing the apex (45).

Control of Growth Vigor

In some cultivars of apple and pear, especially when not budded on dwarfing rootstocks, vegetative growth is so pronounced in the first few years after planting that cropping is delayed.

The first attempt to control size with chemicals was reported by Batjer (3). The chemical used was referred to as B-9 which later was given the common name daminozide or SADH and the trade name Alar. Some excellent uses have been developed for SADH such as increasing spur development, flowering, fruit set and improved red color and firmness of the fruit. However, very high rates of SADH were necessary to achieve satisfactory control of shoot growth and the result was an excessive reduction of fruit size (69).

SADH and chlormequat have proven to be reasonably good alternatives. Both of these retardants inhibit internode extension and to a somewhat lower degree, node formation, thus giving the tree a compact shape. The SADH treatment leads to a typical thickening of the growing shoot. SADH is usually used in apple, but in pear chlormequat is preferred. Due to the undesirable side-effect of reduced fruit size and poor keeping quality of the fruits of cultivars such as 'Cox Orange Pipin' the use of retardants is avoided in more mature orchards where growth vigor is not usually a major problem (59). Growth regulator 2-chloro ethyl phosphonic acid (ethephon) is a potent growth retardant. Post harvest application of ethephon effectively retarded terminal growth the following season.

Spring application of ethephon alone and in combination with SADH at lower rates, increased spur and flower formation without causing flower abortion (66).

Growth retardants such as SADH and ethephon were effective in suppressing growth especially on pruned trees and induced early flowering and cropping (18,35,42,69). Growth retardants such as SADH have only limited use in European orchards, mainly because of undesirable side effects on fruit size when applied early in the season to control shoot growth, in addition, fruit storage quality may be adversely affected (47). SADH at 1000 to 2000 ppm applied shortly after petal fall has given significant reduction in shoot growth. In addition to reducing growth, early application can increase fruit set if young fruits are present (19).

Flower-Bud Formation, Fruit Set, and Shoot Growth

In fruit trees these three phenomena are closely interrelated, and any attempt to affect one of them without affecting the others has hardly any chance of success. In view of the necessity to keep a balance between flower-bud formation, fruit set, and shoot growth, special attention is given to the reduction of flowering by gibberellins, the promotion of flowering by growth retardants. via reduction-growth competition (59). However, for convenience the following considerations are dealt with in seperate sections.

Flower-Bud Formation and Shoot Growth

The concept of an antagonism between vegetative growth and flowering is widely accepted not only for fruit trees (13) but also in a more general sense in all plants. Since young developing leaves in the shoot tip are rich sources of gibberellins, and the inhibiting effect of applied gibberellins has been demonstrated in many experiments, it seems obvious to ascribe this antagonism to the action of gibberellins.

Luckwill (34) pointed out the first irreversible steps leading to flower initiation in an apple bud are bound to a critical number of about 20 nodes per bud. It is not surprising that application of gibberellins to reduce flowering is most effective early in the season, i.e., long before the actual flower initiation occurs. This was clearly shown in an experiment on two-year-old potted apple trees 'Golden Delicious' that were sprayed 3 times with either GA3 or GA3+7. GA3 sprayed at full bloom or 2 weeks later reduced flowering on spurs and shoot, but had little effect when sprayed 4 weeks after full bloom. In work done by Tromp (58), GA3 applied just after shoot-growth cessation did not affect flowering in young apple trees. Therefore, the conclusion that gibberellins are hardly or not at all involved in the actual formation of flowers seems justified.

Fruit Set and Shoot Growth

It is normal for many fruit species that, due to unsuccessfull competition for metabolites between fruitlets and growing shoots, a large proportion of the initially set fruits drop prematurely. This early drop, the so-called June drop is particularly pronounced at high temperatures (22), undoubtedly due to stimulation of shoot-tip activity. Shoot-fruit competition and consequently fruit drop can be reduced by removing the shoot tips by hand (49), which of course, is unsuitable for commercial orchards. Fortunately comparable results can be obtained by the application of growth retardants early in the season, as has been shown in numerous experiments (38). However, the results are often inconclusive and, in apple effects on storage behaviour, have prevented general use of this method in the Netherlands so far, at least to obtain a large crop.

Soluble Solids and Firmness

Fruit growers use growth regulators to improve the quality of apple fruits during ripening and storage (25). SADH applied 70 to 80 days after bloom on most varieties at 1000 ppm provides drop control, increases firmness and delays water-core development (9). Ethephon is used for increased efficiency in mechanical harvesting of apples, coloring apples more uniformly and hastening maturity for one picking. Fenoprop and NAA are used to decrease the preharvest drop of apple fruits.

Plant and fruit response to ethylene as reviewed by Edgerton (17), include increased respiration, hastened maturity, reduced or eliminated fruit set, and improved fruit color. The growth regulator fenoprop was used for many years to delay the harvest drop of apples (16). In some screening tests involving numerous growth regulators, fenoprop had a longer period of effectiveness than NAA on 'McIntosh' and it came into extensive commerical use on several cultivars.

Ethephon at 250 and 500 ppm 3 weeks before harvest increased soluble solids of 'Red Delicious' and 'McIntosh' apple fruits (10,23,32).

Several reports indicated that apple fruits (23), and pear (31), treated with SADH had higher firmer flesh than the control. This may be associated with delayed ripening since Looney (30) found that application of SADH 1000 and 5000 ppm, 2 weeks after full bloom maintained fruit firmness and delayed the ripening of 'McIntosh' apple 2 weeks. Looney (29) found that 'Delicious' fruits treated with SADH 1000 and 5000 ppm, 2 weeks after full bloom and harvested one month after the normal picking date were firmer than the control fruits harvested at the normal time.

Couey and Williams (10) found that ethephon 500 ppm, 3 weeks before normal harvest increased soluble solids of 'Red Delicious' apple fruits at harvest time but after storage, amount were similar to checks. Greene (23) noted that 'Delicious' apples treated with ethephon 500 ppm, July, had more soluble solids than the control after storage period. Greene (23) showed that ethephon 500 ppm, July, had no effect on flesh firmness of 'Red Delicious' apple fruits compared to check fruits. After a storage period at 0°C, Blanpied (5) noted that 'McIntosh' apples treated with combination of SADH 1000 ppm 60 days before harvest, ethephon 1500 pmm 2 weeks before the harvest and NAA 20 ppm 2 weeks before harvest were slightly softer after storage than those sprayed with SADH only but firmer than the control.

Paclobutrazol (PP333)

Vegetative Growth

PP333 is a broad spectrum growth retardant, effective on a wide range of species including grasses (54, 56), cereals (21), sugar beet (28), sunflower (63), chrysanthemum (40), bulbs (41), and ornamental plants (52,53).

PP333 is being investigated by several researchers as a mangement and production aid in orchard crops. Most of the tree fruit research with PP333 has been on apple, but some has been done on peaches, plums, cherries. Besides United State studies are being made in Europe, especially in England, where growers have had orchard trials.

PP333 continues to live up to its early promise by providing excellent shoot growth control on varieties of both pome and stone fruit (11,46,47,60,68,69). It controls the tree size and significantly reduces pruning requirements. The control of growth was so effective that dwarfing rootstocks, with their inherent problems, can be substituted for with the less problematic and higher vigor seedling rootstocks (55,68).

Soil treatments of PP333 have proved most effective in controlling the shoot growth of sweet cherry. It is not known why cherries responded better than apple to soil application of PP333 in the United Kingdom possibly the root of cherries are produced nearer the soil surface, take up the chemical more rapidly, or are more sensitive to PP333 (64).

PP333 has shown a marked delay in maximum effectiveness, as evidenced by the carry-over effect on apple (46,60,68). Williams (68) reported that spur 'Red Delicious' on seedling rootstock and 'Golden Delicious' on M7 sprayed to drip with 1000 and 2000 ppm a,i, (0.5 to 1.0 g a.i. m of soil surface) showed a 10% to 20% reduction in growth the year of application and an 80% to 90% reduction the following year. When similar trees were treated using a ground spray at the rates of 0.25, 0.5, 1.0, and 2.0 g, a.i. m, growth reduction was minor during the year of application and ranged from 5% to 90% in the following year. Percent reduction correlated highly with increased concentration. The 2.0 g rate caused excessive retardation (almost 100% two years after application). Twenty-five year old 'Topred Delicious' were treated with ground sprays in bands two feet wide just inside the outer edge of the tree canopy at 1.0 g a.i. m (15 cm total area treated per tree). The first year there was little to no reduction in shoot elongation. However, the following year shoot elongation was reduced 90% as compared to the control. A single application of 20.0 g a.i., per tree effectively reduced the terminal growth of two years. Annual application of 2.5 and 5.0 g a.i., per ft consistently reduced growth by 50%. The particularly vigorous standard nonspur cultivars 'Topred Delicious' and 'Granny Smith' were adequately kept in check by ground treatments of 0.5 and 1.0 g a.i. m, over a 2.0 m area around the base of the trunk.

'York Imperial' apple seedlings were grown for 66 days in aerated nutrient solution which contained 0.2 mg PP333. GA was applied 25 mg as a foliar spray on days 1, or 35 after the initial PP333 treatment. PP333 effectively reduced shoot elongation and leaf area expansion but had little affect on leaf number (57).

Much effort, over the last two years, has been put into identifying the optimal timing and dose rate for these sprays on several of our more important scion cultivars. Initial trials tested a single spray treatment of 1000 ppm to 2000 ppm, applied 3 to 4 weeks after full bloom or petal fall. Although these treatments were often most effective in controlling initial extension shoot growth, they occasionally induced russeting of the fruits and often the shoots grow away again towards the end of the season. On cultivars such as 'Bramley Seedling' and 'Cox' such treatments are producing most promising results. 1, 2, or 4 spray applied in each of two season to 6-year-old 'Bramley Seedling' on MM 106. The most effective shoot control was achieved in both years using four sprays of 500 ppm PP333 and yield were increased by all treatments (64).

Reasearch has shown that although the addition of wetters or oils to PP333 foliar sprays will improve uptake and response considerably, many of these additive may induce fruit russeting. Current experiments are aimed at identifying safe wetters of additives to use with PP333 (64).

'Gardner Delicious' showed favorable growth reduction throughout the season of application when PP333 was applied as a foliar sprays at 1500 and 3000 ppm at the full bloom 21 days or

38 days stage (24). PP333 was found be as effective as SADH in controlling current season growth on four year old 'Bramley Seedling' apple when both were applied as a foliar spray three weeks after full bloom. Shoot elongation was least during the following season on PP333 treated trees (46).

In fruit trees, a direct result of the reduced shoot elongation was increased light penetration into the plant. This led to stronger, healthier spurs especially in the lower half of the tree for apples and pear (55,68). The more open structure of the tree allowed for easier and more effective pesticide application and reduced herbicide usage for controlling weeds and rootsuckers (50). The reduced density of the foliage also desirability of the microclimated to fungal diseases (55,68), and provided less tender young shoots to act as a food source for psylla on pear (55).

Fruit Characteristics

Research with PP333 on fruit characteristics has been less extensive. The year of foliar application at 1500 and 3000 ppm, fruit flesh firmness increased, fruit weight and seed number decreased, and no effect was had on fruit soluble solids while fruit L/D ratio increased. The year following treatment, PP333 increased fruit set and yield. No treatment influenced flesh firmness at harvest and soluble solids were comparably reduced by both concentrations of PP333. Fruit weight was not influenced by treatments whereas bitter pit and corky spot were reduced by foliar application of PP333 (24).

Three vigorous 25-year-old trees of 'Top Delicious' on seedling roots were treated by applying PP333 at rate of 1.0 g per m in a band 0.7 m wide just inside the outer edge of the tree canopy. The fruit was harvested from the treatment and adjacent control trees and graded on a commercial fruit packing line. There were 10% more extra fancy fruit, because of the increased red color and 40% more fruit of size 100 and larger from the treated trees. The percentage of cull fruit was 0.06 and 0.4, respectively, for the treated and control fruit (70).

Foliar application of PP333 was applied to apple trees at 100 to 500 ppm in multiple application about 3 weeks apart, or usually from 1000 to 2000 ppm to a maximum of 8000 ppm, in single applications. These were timed at petal fall and/or at 3, 6, 9, and/or 12 weeks after petal fall. In the year of treatment, yield from the various plots were unaffected by PP333 application. Fruit form, fruit size and the number of seeds per fruit also were unaffected, as compared to fruit from control trees. However, there was a suggestion that fruits were slightly shorter in length when applications were timed at petal fall-0 or petal fall-3 especially in multiple applications. The year following treatment, yields were 3 times greater than for control trees, especially where a total of 1000 ppm or a greater quantity of PP333 was applied, and where natural flower bud formation and fruit set were low (61).

Application and Persistence

The methods of application of growth retarding compounds to apple and pear trees should be influenced by the biochemical or physiological mode of action, the environmental persistence as well as the type of tree/rootstock combination and planting system to which it is applied (12).

Different sites and/or methods of application were used, foliar sprays, soil drench, soil surface banding, sub-soil injection, basal trunk sprays, painting stem only, painting fully developed leaves only and trunk soil-line drench were compared (62). The latter method was an effective technique for obtaining root absorption, based on the quantity of active chemical necessary to produce a given response, a trunk-soil line approach was used to placed the chemical into the fibrous root zone located on the trunk of the rootstock under the soil, below the union.

The soil activity of PP333 conferred certain properties of the compound. Activation was immediate. When applied to amenity grasses there was 10 to 20 day delay from the time of application and the first visible retardation of growth. With pear, trees there was no obvious effect on growth or yield during the season of application, but only during the following season (50).

Foliar sprays may reduce growth during the current year, however the effect could be enhanced the following year due to drip from the tree leaching through the soil and being taken up by the roots (12). Soil application of PP333 is generally ineffective on apple in the United Kingdom. Summer foliar treatments gives the best control of tree growth particularly when applied sequentially during early summer (48). Soil treatment with PP33 has shown considerable promise in trials in Washington State (69) and Pennsylvania (61) however, in Britian soil application to apples have in most instances provided rather disappointing . The reason for these differences is response between Britian and United State are not know but many of the trials in Washington were carried out on sandy, free-draining soil, all of which received some form of irrigation (64). Soil mulches have improved the response of young trees to PP333 soil treatment (2), possibly by encouraging more surface rooting.

Flurprimidol (EL500)

The chemical compound is an experimental a growth retardant structurally similar to ancymidol (1). This growth retardants is presently being marketed under the name Cutless as a turfgrass inhibter to reduce mowing (1).

The mechanism of action of EL500 is not completely known at present, However, since it has properties and growth reducing abilities similiar to ancymidol. it is likely that its action is related to disruption of GA synthesis the same as ancymidol (8, 27). Woody plants treated with GA sprays after EL500 drenches resumed normal growth within thirty-six days after treatment with GA (51). EL500 appeared to be a persistent, effective subapical growth retardant on woody and herbaceous plants (8,7).

While PP333 has received the lion's share of attention from growers and researchers. EL500 has great potential for fruit growers. It offers many of the same benefits PP333 does, but has some unique properties (62). One of the most important differences is that EL500 can inhibit shoot growth in the year it is applied with PP333, effects are not seen untill the year after treatment. Another important consideration is that EL500 is a far less persistent chemical than PP333. While the half-life of PP333 in the soil may be 18 months, EL500 has a half-life of only about six months. Yet another difference is that while PP333 is strictly root-absorbed, EL500 is absorbed both by root and foliage. This means that foliar sprays of EL500 can be effective in fact, EL500 must be applied as a foliar spray to get a response the same year. It can be applied in a soil drench or in a solution poured around the trunk, but results will not be seen until the following year (62).

Foliar sprays of EL500 have lasted only about 3 weeks before inhibited shoots begin to elongate, necessitating a repeat spray to hold back growth. To date, enhanced flowering and cropping have not occurred with EL500. Petal fall and earlier timed foliar sprays have inhibited fruit sizing, especially lengthening (62).

MATERIALS AND METHODS

This study was conducted at the Horticultural Experimental Farm, Manhattan, Kansas. Forty-six 14-year old 'Golden Delicious'/'Malling Merton 111' and forty-six 14-year old 'Red Delicious'/'Malling Merton 111' trees were used as test plants. All trees were in good condition and in uniform shape. Both PP333 and EL500 were applied to the trees in various ways and various concentrations on June 15, 1984.

Both chemicals were applied by two methods foliar and ground applications. Foliar applications were made in an aqueous solution to which Tween-20 was added at the rate of 1 cc/gal as an wetting agent. Trees were sprayed to the dripping point with hand gun from a field sprayer. The concentrations were 1000 and 1500 ppm for PP333 and 750 and 1000 ppm for EL500.

Ground applications of both PP333 and EL500 were applied by three different methods, drenching, banding, and injection. In drenching, aqueous solution was poured around the base of the tree trunk. In banding, the water solution was poured in a six inch-band which encircled the tree dripline. The injection method involved use of a Chem-trol/hand applicater, the solution containing the growth retardants was injected at a depth of 30 cm in the soil at four points around the trunk equidistant from trunk and dripline. Both chemicals were applied at either 1 g, 2 g, or 3 g, per tree regardless of the application method. After applications were made measurement were taken of the trunk circumference, terminal shoot growth and fruit characteristics.

Trunk Circumference

By using a tree tape, two measurements of the trunks circumference were taken. The first one was on June 10, 1984 before chemical applications were made. The second measurement was on December 15, 1984 after the leaves had fallen.

Terminal Shoot Growth

Terminal shoot growth was measured in December 1984 by use of a meter stick after the leaves had fallen. After dividing the tree into quadrants, 6 terminal shoots were chosen at random, three at approximately eye level and three about 1 meter above eye level for each quadrant for a total of 24 shoot per tree.

Fruit Measurements

Thirty apples from 'Red Delicious' from each tree and twenty apples from each 'Golden Delicious' tree were randomly chosen during the normal harvest date, October 4, 1984. The apples were divided into group of ten. Then apples from each cultivar were evaluted for weight, L/D ratio, flesh firmness, soluble solids, and seed number.

The remaining twenty apples from each 'Red Delicious' and ten apple from each 'Golden Delicious' tree were stored separately in regular cold storage at 0^oC. Ten apples from each cultivar for each treatment were stored for three months and the ten from 'Red Delicious' were stored for six months. Both groups, when taken out of cold storage were evaluated for flesh firmness and soluble solids.

Apple weight were measured by use of a Dial-gram balance.

The L/D ratio was measured by use of a digital caliper. Flesh firmness was measured with a Magness-Taylor Pentrometer, a mechanical force gauge pressure tester with an 0.78 cm dip. A satum point was the average of two tests per peeled apples for the ten apple sample. Soluble solids were determined with a hand refractometer, for each sample a drop of juice was squeezed from the flesh onto the prism surface.

The experimental design was a randomized complete block design with 11 treatments for each growth retardant, PP333 and EL500 plus controls for each cultivar (23 treatments - 4 trees), thus, 92 trees were used.

RESULTS AND DISCUSSION

A-Trunk Circumference

The data presented in Table 1 shows the effect of foliar and ground applications of PP333 and EL500 on trunk circumference of 'Golden' and 'Red Delicious' apple trees.

There were significant effects of foliar and ground applications of PP333 and ground applications of EL500 on trunk circumference of 'Golden Delicious'. Trunk circumference of 'Golden Delicious' was increased by 1500 ppm foliar and 3 g ground application (injection) of PP333 compared with the control. The increases in trunk circumference of 'Golden Delicious' from PP333 applications was in disagreement with results reported by Webster (65) who indicated that 1500 mg of PP333 applied twice reduced the trunk girth slightly. The 1 g ground drench application of EL500 reduced trunk circumference of treated 'Golden Delicious' apple trees, the only significant effect observed from treatment with this chemical. However, there were no significant effect from foliar and ground application of PP333 and EL500 on trunk circumference of ' Red Delicious'. This is in agreement with results found by Greene (24) who noted that foliar applications of PP333 at 1500 and 3000 ppm had no significant effect on trunk circumference of 'Gardiner Delicious' apple trees the year sprays were applied.

B-Shoot Growth

The influence of foliar and ground applications of PP333 and EL500 on shoot growth of 'GoldenDelicious' and 'Red Delicious'

Table 1. Effect of foliar and ground applications of PP333 and EL500 on growth of trunk circumference of 'Golden' and 'Red Delicious' apple trees.

Treatments			'Golden Delicious' (cm)	'Red Delicious' (cm)
Control			5.11 cd[z]	4.49 a
PP333	Foliar	1000 ppm	5.40 bcd	5.29 a
		1500 ppm	6.09 ab	5.49 a
	Ground Drench	1 gm	4.70 ed	4.87 a
		2 gm	5.27 bcd	5.25 a
		3 gm	5.64 bc	5.31 a
	Band	1 gm	5.05 ced	4.56 a
		2 gm	5.68 bc	5.11 a
		3 gm	5.75 bc	5.19 a
	Injection	1 gm	5.31 bcd	5.33 a
		2 gm	5.46 bcd	5.32 a
		3 gm	6.71 a	5.48 a
EL500	Foliar	750 ppm	5.25 bcd	5.24 a
		1000 ppm	5.32 bcd	5.57 a
	Ground Drench	1 gm	4.14 e	4.66 a
		2 gm	4.70 ed	4.63 a
		3 gm	5.31 bcd	4.70 a
	Band	1 gm	5.25 bcd	4.54 a
		2 gm	5.13 cd	5.09 a
		3 gm	5.45 bcd	4.95 a
	Injection	1 gm	5.03 cde	4.66 a
		2 gm	5.21 bcd	4.67 a
		3 gm	5.38 bcd	4.28 a

[z] Means within the same column having the same letter are not significantly different (LSD .05).

Table 2. Effect of foliar and ground applications of PP333 and EL500 on shoot growth of 'Golden' and 'Red Delicious' apple trees.

Treatments			'Golden Delicious'	'Red Delicious'
			cm	
Control			27.47 a [z]	33.17 a
PP333	Foliar	1000 ppm	19.02 h	20.39 h
		1500 ppm	16.64 i	18.79 h
	Ground Drench	1 gm	25.50 b	32.65 ab
		2 gm	24.89 bc	31.41 abc
		3 gm	23.06 efg	27.92 edf
	Band	1 gm	24.92 bc	31 52 abc
		2 gm	24.29 bcdef	28.39 de
		3 gm	23.81 cdef	29.33 cde
	Injection	1 gm	24.83 bc	30.54 abcd
		2 gm	23.16 defg	28.61 de
		3 gm	22.86 efg	27.66 ef
EL500	Foliar	750 ppm	22.07 g	25.31 fg
		1000 ppm	19.06 h	23.54 g
	Ground Drench	1 gm	25.86 ab	32.11 ab
		2 gm	24.50 bcde	29.91 bcde
		3 gm	22.91 efg	28.34 de
	Band	1 gm	25.92 ab	32.93 a
		2 gm	24.45 bcde	30.63 abcd
		3 gm	23.36 cdefg	29.09 cde
	Injection	1 gm	24.73 bcd	32.26 ab
		2 gm	23.76 cdef	29.19 cde
		3 gm	22.70 fg	27.40 ef

[z] Means within the same column having the same letter are not significantly different (LSD .05).

apple trees is shown in Table 2.

Foliar applications of PP333 reduced shoot growth more than ground applications of PP333 and ground applications of EL500, and the control treatment. The foliar sprays of PP333 at 1500 ppm significantly shortened terminal shoot growth of 'Golden Delicious' compared to those sprayed at the 1000 ppm rate. However, there were no significant differences in shoot growth of 'Red Delicious' between 1000 and 1500 ppm spray treatments of PP333. All ground applications of PP333 reduced shoot growth of 'Golden Delicious' and 'Red Delicious' apple trees, except for the 'Red Delicious' trees treated at the 1 g rate for each ground method of application (drench, band, and injection) and the 2 g rate from drenching which were not significantly shorter than those on control trees.

Foliar applications of EL500 significantly reduced shoot growth of 'Golden Delicious' and 'Red Delicious' contrasted with ground applications of EL500 and the control treatment except for the 'Golden Delicious' trees treated at the 3 g rate for each ground method of application (drench, band, and injection). The highest concentration of EL500 significantly reduced shoot growth of 'Golden Delicious' compared to the lower concentration, but there were no significant differences between foliar sprays on shoot growth of 'Red Delicious'. Neither 1 g drench or band applications of EL500 influenced shoot growth of 'Golden Delicious'. However, 1 g injection, 2 and 3 g rate for all methods of ground application caused a reduction in shoot growth compared to the control. All methods of ground applications at 2 and 3 g rate of EL500 except for the 2 g rate applied in bands significantly reduced in shoot growth of 'Red Delicious'.

The reduction in shoot growth from foliar application of PP333 was in agreement with the results found by Greene (24) Marini (39) and Quinlan (48) Webster (65). The decrease in shoot growth by both foliar and ground applications of PP333 and EL500 differed from results reported by Tukey (62).

The results of ground applications of PP333 in our study was in agreement with a study conducted by Williams etal (70). They reported that 2.5, 5, 10, and 20 g of PP333 applied to the base of vigorous 25-year-old trees of 'Spur Delicious' reduced shoot growth significantly compared to the control.

Quinlan (48) indicated foliar sprays of PP333 to be more effective than soil applications in controlling shoot growth in the season of application because the chemical may move slowly in the soil or be slowly absorbed and transloacted from the roots. Tukey (62) reported that the general avenue of entry of plant growth regulators into apple trees is through the above ground portion of the tree, eg, leaves, wood, bud. flowers, and fruits. However, some of the plant growth retardant chemicals are effective only when absorbed by the tree's roots even if foliar applied. In this case, the chemical is leached from the foliage to the soil by rain where chemical absorption can occur either through the above ground portions of the tree or through the root system, the avenue of entry appears to affect the expression of growth modification in the top of the tree. For these chemicals, foliar absorption has produced an almost immediate effect on growth. Barret (4) noted that it would also seem, likely that the activity from a whole plant spray may come primarily from absorption by stems, petioles, or leaf veins as leaf blade application has been shown to have limited effect. Tukey (62) reported that degree and type of response were related to the total quantity of chemical applied rather than to the concentration used in each application in a multispray treatment, to the site of application, but not to the time of application.

The physiological basis of controlling shoot growth may be explained by temporary decrease of the acid and neutral gibberellin-like substance in the shoot tips, as shown by biological tests (70). The lowering levels of auxin-and gibberellin-like substances in shoot apices by PP333 treatment may account for the growth reduction.

C-Fruit Weight

The data concerning the effect of foliar and ground applications of PP333 and EL500 on fruit weight of 'Golden Delicious' and 'Red Delicious' are given in Table 3.

Results indicate that none of PP333 and EL500 treatments had any significant effect on fruit weight of 'Golden Delicious'. This finding is in disagreement with the results reported by Greene (24) who showed that in the year of treatment, fruit weights were decreased by PP333. We found that foliar application of PPP333 resulted in a slight increase in fruit weight of 'Red

Table 3. Effect of foliar and ground applications of PP333 and EL500 on fruit weight of 'Golden' and 'Red Delicious' apples.

Treatments			'Golden Delicious'	'Red Delicious'
			gm	
Control			178.87 a[z]	222.23 abc
PP333	Foliar	1000 ppm	184.27 a	233.06 ab
		1500 ppm	185.83 a	236.20 a
	Ground Drench	1 gm	187.62 a	224.45 abc
		2 gm	185.39 a	220.41 abcd
		3 gm	181.60 a	226.39 abc
	Band	1 gm	183.02 a	222.79 abc
		2 gm	182.10 a	220.42 abcd
		3 gm	185.13 a	219.01 abcd
	Injection	1 gm	187.17 a	201.61 d
		2 gm	180.10 a	225.43 abc
		3 gm	177.46 a	228.31 abc
EL500	Foliar	750 ppm	186.45 a	220.13 abcd
		1000 ppm	183.16 a	218.68 abcd
	Ground Drench	1 gm	181.21 a	224.27 abc
		2 gm	178.20 a	224.42 abc
		3 gm	185.26 a	211.39 cd
	Band	1 gm	182.72 a	228.63 abc
		2 gm	175.01 a	220.46 abcd
		3 gm	179.40 a	219.38 abcd
	Injection	1 gm	186.58 a	221.16 abc
		2 gm	179.34 a	220.64 abcd
		3 gm	182.10 a	217.03 bcd

[z] Means within the same column having the same letter are not significantly different (LSD .05).

Delicious' but the values were not significantly different from the control treatment. Treatment with 1 g soil injection of PP333 resulted in significant lower fruit weight than the control treatment. This probably was due to large increase in fruit set on the trees (69). Foliar and ground applications of EL500 had no significant influence on fruit weight of 'Red Delicious'. This result was consistent with Tukey (62), who indicated that in the year of appliction EL500 had no significant effect on fruit weight.

D-Soluble Solids

Table 4 shows the effect of foliar and ground applications of PP333 and EL500 on soluble solids of 'Golden Delicious' and 'Red Delicious' apple fruit.

Fruit soluble solids of 'Golden Delicious' and 'Red Delicious' sprayed with 1000 and 1500 ppm of PP333 were not significantly different from the controls. Neither were there differences in soluble solids found in 'Golden Delicious' fruit receiving ground applictions of PP333 compared with those sprayed and the unsprayed control. However, in 'Red Delicious' there was a significant decrease in soluble solids associated with the 2 g drench and 2 and 3 g band rates. Williams (70) and Greene (24) also found the same response to PP333 among apple cultivars. Most likely explanation is that the reduced leaf area per spur reduced soluble solids. It has been shown that a reduction in leaf area around fruit will lower soluble solids at harvest (24). None of the rates of applications of EL500 caused a significant

Table 4. Effect of foliar and ground applications of PP333 and EL500 on soluble solids of 'Golden' and 'Red Delicious' apples.

Treatments			'Golden Delicious'	'Red Delicious'
			%	
Control			15.00 abcdefg[z]	13.40 abc
PP333	Foliar	1000 ppm	15.15 abcdef	12.85 cde
		1500 ppm	14.95 abcdefg	12.95 cde
	Ground Drench	1 gm	14.70 bcdefg	12.95 cde
		2 gm	15.40 abcd	12.70 de
		3 gm	14.90 abcdef	13.05 bcde
	Band	1 gm	14.60 cdefg	12.85 cde
		2 gm	14.85 abcdefg	12.80 de
		3 gm	14.60 cdefg	12.75 de
	Injection	1 gm	14.95 abcdefg	12.95 cde
		2 gm	14.80 abcdefg	13.65 a
		3 gm	14.65 bcdefg	12.85 cde
EL500	Foliar	750 ppm	14.40 efg	13.40 abc
		1000 ppm	15.55 ab	12.80 de
	Ground Drench	1 gm	15.10 abcdef	13.00 bcde
		2 gm	14.35 fg	13.15 abcd
		3 gm	14.50 defg	13.55 ab
	Band	1 gm	15.30 abcde	13.05 bcde
		2 gm	15.50 abc	13.15 abcd
		3 gm	14.25 fg	13.25 abcd
	Injection	1 gm	15.65 a	12.95 cde
		2 gm	14.15 g	12.50 e
		3 gm	14.95 abcdef	12.95 cde

[z] Means within the same column having the same letter are not significantly different (LSD .05).

change in soluble solids of 'Golden Delicious' compared to control treatment regardless of method of application. In 'Red Delicious' foliar application of EL500 at 1000 ppm reduced soluble solids compared to the controls and foliar spray at 750 ppm. The changes in soluble solids due to ground application of EL500 were not significant, except that the 2 g injection significantly decreased soluble solids of 'Red Delicious'. Limited research has been done on the effect of EL500 on apple fruits. Most of research has been done on effects of other growth retardants such as fenprop, SADH and ethephon on apple fruits. Luckwill (37) noted that the increase in soluble solids in fenprop treated fruits is likely associated with rapid maturation frequently observed with this growth regulator. However, Dilley and Austin (15), found decreases in soluble solids of fruit treated with SADH plus fenprop.

E-Seed Number

Seed number of 'Golden Delicious' and 'Red Delicious' as influenced by foliar and ground applications of PP333 and EL500 is shown in Table 5.

Foliar sprays of PP333 regardless of concentration produced a significant reduction in seed number of 'Golden Delicious' and 'Red Delicious' as compared to controls. Also we had a significant reduction in seed number of both cultivars from the 3 g drench, 2 g band, and 2 and 3 g injention application of PP333. Foliar sprays of EL500 a significantiy decreased seed number in 'Golden Delicious' while, foliar sprays at both rates decreased

Table 5. Effect of foliar and ground applications of PP333 and EL500 on seed number of 'Golden' and 'Red DElicious' apple's.

Treatments			'Golden Delicious'	'Red Delicious'
Control			8.90 a[z]	6.20 a
PP333	Foliar	1000 ppm	7.60 ef	4.95 de
		1500 ppm	7.25 f	4.50 e
	Ground			
	Drench	1 gm	8.35 abcde	5.85 abc
		2 gm	8.20 abcde	5.70 abcd
		3 gm	7.75 def	5.35 bcd
	Band	1 gm	8.45 abcd	5.85 abc
		2 gm	8.05 bcde	5.00 de
		3 gm	8.10 bcde	5.65 abcd
	Injection	1 gm	8.50 abcd	5.85 abc
		2 gm	8.10 bcde	5.40 bcd
		3 gm	8.00 bcdef	5.10 cde
EL500	Foliar	750 ppm	8.15 abcde	5.35 bcd
		1000 ppm	7.80 cdef	5.10 cde
	Ground			
	Drench	1 gm	8.65 ab	5.95 ab
		2 gm	8.55 abc	5.65 abcd
		3 gm	8.20 abcde	5.55 abcd
	Band	1 gm	8.75 ab	5.70 abcd
		2 gm	8.60 ab	5.85 abc
		3 gm	8.35 abcde	5.40 bcd
	Injection	1 gm	8.70 ab	5.95 ab
		2 gm	8.15 abcde	5.35 bcd
		3 gm	8.25 abcde	5.25 bcde

[z] Means within the same column having the same letter are not significantly different (LSD .05).

seed number in'Red Delicious'. 'Golden Delicious' trees treated with ground application of EL500 showed no significant change in seed number from the control. In 'Red Delicious' only 3 g band and 2 and 3 g injection applications significantly reduced seed number. A reduction in seed number from foliar application is in agreement with Greene (24). He stated that 1500 and 3000 ppm of PP333 caused reduction in seed number in 'Gardiner Delicious'. Tukey (61) however reported that a foliar treatment of 750 and 1000 ppm of PP333 had no effect on the seed number of 'Red Delicious' fruit in the year of treatment.

F-Fruit Firmness

The effect of foliar and ground applications of PP333 and EL500 on fruit firmness of 'Golden Delicious' and 'Red Delicious' at harvest is presented in Table 6.

Fruit from 'Golden Delicious' trees sprayed with either PP333 or EL500 were not different from the controls in measured firmness also none of the 'Golden Delicious' fruit from trees reiceving the various ground applications differed in firmness from fruit collected from control trees although these were minor differences between some chemical treatments.

Neither chemical regardless of rate or method of application had any measureable effect on 'Red Delicious' fruit firmness. Our results which indicated that fruit firmness was not affected by foliar application of PP333 were in agreement with findings of Greene (24) who noted that fruit firmness was not affected by 1500 and 3000 ppm foliar application of PP333.

Table 6. Effect of foliar and ground applications of PP333 and EL500 on firmness of 'Golden' and 'Red Delicious' apples as measured with pressure tester.

Treatments			'Golden Delicious'	'Red Delicous'
Control			11.03 abc [z]	8.30 a
PP333	Foliar	1000 ppm	11.92 abc	8.91 a
		1500 ppm	13.32 a	9.20 a
	Ground			
	Drench	1 gm	10.41 c	8.51 a
		2 gm	11.17 abc	8.31 a
		3 gm	10.81 bc	8.40 a
	Band	1 gm	11.27 abc	8.36 a
		2 gm	11.08 abc	8.35 a
		3 gm	11.64 abc	8.71 a
	Injection	1 gm	11.05 abc	8.40 a
		2 gm	11.14 abc	8.46 a
		3 gm	11.52 abc	8.87 a
EL500	Foliar	750 ppm	11.52 abc	8.61 a
		1000 ppm	13.02 ab	8.90 a
	Ground			
	Drench	1 gm	10.94 bc	8.26 a
		2 gm	10.88 bc	8.21 a
		3 gm	11.58 abc	8.10 a
	Band	1 gm	11.12 abc	8.21 a
		2 gm	11.01 abc	8.65 a
		3 gm	10.91 bc	8.06 a
	Injection	1 gm	10.52 c	8.13 a
		2 gm	10.56 c	8.43 a
		3 gm	11.00 bc	8.41 a

[z] Means within the same column having the same letter are not significantly different (LSD .05).

G-Length/Diameter (L/D) Ratio

Data presented in Table 7 indicate the effect of foliar and ground applications of PP333 and EL500 on length/dimeter (L/D) ratio of apple of 'Golden Delicious' and 'Red Delicious'.

Foliar application of PP333 had no significant effect on L/D ratio of 'Golden Delicious' fruits, while, the low concentration of 1000 ppm of PP333 resulted in a significantly higher L/D ratio of 'Red Delicious' fruit than the 1500 ppm spray and control treatment. The L/D ratios of 'Golden Delicious' and 'Red Delicious' fruit showed no significant response to rate or methods of ground application of PP333. The L/D ratio of 'Golden Delicious' fruit was significantly different from control only from the 1 g drench and 3 g band applications of EL500, both were reduced compared with controls. There were no significant effects on L/D ratio of 'Red Delicious' from EL500 soil applications. The reduction in L/D ratio in 'Golden Delicious' in response to 1 g drench and 3 g band applications of E1500 was probably due to reduction in endogenous GA. Curry (12) indicated that the effect of PP333 on reduction of the fruit L/D ratio of 'Golden Delicious' may be due to reduction in endogenous GA, since the effect may be reversed by an application of either GA3 or GA3+7 and 6-benzyl adenine.

H-Soluble Solids After 3 Months Storage

Table 8 shows the effect of foliar and ground applications of PP333 and EL5oo on soluble solids of 'Golden Delicious' and 'Red Delicious' after 3 months of storage at 0°C.

Table 7. Effect of foliar and ground applications of PP333 and EL500 on Length/Diamter (L/D) ratio of 'Golden' and 'Red Delicious' apples.

Treatments			'Golden Delicous'	'Red Delicious'
			cm	
Control			.88 a[z]	.83 b
PP333	Foliar	1000 ppm	.86 abc	.92 a
		1500 ppm	.86 abc	.83 b
	Ground			
	Drench	1 gm	.86 abc	.83 b
		2 gm	.88 a	.83 b
		3 gm	.88 a	.83 b
	Band	1 gm	.86 ab	.83 b
		2 gm	.85 abc	.84 b
		3 gm	.87 ab	.85 b
	Injection	1 gm	.88 a	.82 b
		2 gm	.84 abc	.81 b
		3 gm	.88 a	.83 b
EL500	Foliar	750 ppm	.85 abc	.83 b
		1000 ppm	.85 abc	.85 b
	Ground			
	Drench	1 gm	.81 c	.83 b
		2 gm	.85 abc	.85 b
		3 gm	.86 abc	.83 b
	Band	1 gm	.86 abc	.84 b
		2 gm	.86 abc	.84 b
		3 gm	.82 bc	.83 b
	Injection	1 gm	.83 abc	.84 b
		2 gm	.86 abc	.83 b
		3 gm	.85 abc	.82 b

[z] Means within the same column having the same letter are not significantly different (LSD .05).

'Red Delicious' after 3 months of storage at 0°C.

Neither Foliar nor ground applications of PP333 had significant effects on soluble solids of 'Golden Delicious' apple fruit after 3 months of storage at 0°C. Foliar sprays of P333 at 1000 and 1500 ppm had no effect on soluble solids of 'Red Delicious' apple after 3 months storage at 0°C, but the 2 g drench method significantly reduced the soluble solids. Foliar and ground applications of EL500 had no significant effect on soluble solids of 'Golden Delicious' and 'Red Delicious' apple fruits after 3 months.

I-Firmness of Apple Fruit After 3 Months Storage

Results presented in Table 9 show the firmness of apple fruit after 3 months of storage at 0°C as influenced by foliar and ground applications of PP333 and EL500.

Firmness values of apple fruits of 'Golden Delicious' were significantly higher in apples from trees sprayed with PP333 at 1500 ppm than the controls. This result differs from the finding of Greene (24) who noted that the flesh firmness following storage was not influenced by foliar application of PP333. Ground applications of PP333 did not affect firmness when compared to the controls. Both foliar rates of PP333 increased 'Red Delicious' apple fruit firmness compared with the controls. Spray application of EL500 at 1000 ppm to 'Red Delicious' was the only foliar treatment which resulted in significantly higher fruit firmness values . No ground applications of EL500 had significant effect on firmness of 'Golden Delicious' and 'Red Delicious'

Table 8. Effect of foliar and ground applications of PP333 and EL500 on soluble solids of 'Golden' and 'Red Delicious' apples after 3 months of storage at 0ºC.

Treatments			'Golden Delicous'	'Red Delicious'
			%	
Control			15.35 a [z]	13.95 abc
PP333	Foliar	1000 ppm	15.25 a	13.30 cd
		1500 ppm	15.15 a	13.50 bcd
	Ground Drench	1 gm	14.70 a	13.50 bcd
		2 gm	15.55 a	13.05 d
		3 gm	14.25 a	13.85 abc
	Band	1 gm	14.05 a	13.60 abcd
		2 gm	15.05 a	13.55 abcd
		3 gm	15.40 a	13.90 abc
	Injection	1 gm	14.65 a	13.70 abcd
		2 gm	14.35 a	14.10 ab
		3 gm	14.65 a	13.70 abcd
EL500	Foliar	750 ppm	14.60 a	13.90 abc
		1000 ppm	15.60 a	13.70 abcd
	Ground Drench	1 gm	15.25 a	13.85 abc
		2 gm	15.55 a	13.85 abc
		3 gm	14.50 a	14.00 abc
	Band	1 gm	15.25 a	13.80 abc
		2 gm	15.70 a	14.25 a
		3 gm	14.45 a	14.05 ab
	Injection	1 gm	15.10 a	13.70 abcd
		2 gm	14.35 a	13.75 abcd
		3 gm	15.05 a	13.70 abcd

[z] Means within the same column having the same letter are not significantly different (LSD .05).

Table 9. Effect of foliar and ground applications of PP333 and EL500 on firmness of 'Golden' and 'Red Delicious' apple after 3 months of storage storage at 0°C.

Treatments			'Golden Delicious'	'Red Delicious'
Control			10.40 bc[z]	6.17 e
PP333	Foliar	1000 ppm	11.54 abc	7.96 a
		1500 ppm	12.61 a	8.08 a
	Ground			
	Drench	1 gm	9.94 c	6.42 cde
		2 gm	10.78 abc	6.60 cde
		3 gm	10.21 c	6.26 de
	Band	1 gm	10.71 abc	6.41 cde
		2 gm	10.59 abc	6.51 cde
		3 gm	10.88 abc	7.13 bc
	Injection	1 gm	10.42 bc	6.56 cde
		2 gm	10.67 abc	6.76 cde
		3 gm	10.76 abc	6.93 cde
EL500	Foliar	750 ppm	11.24 abc	6.91 cde
		1000 ppm	12.53 bc	7.05 cd
	Ground			
	Drench	1 gm	10.43 bc	6.52 cde
		2 gm	10.51 abc	6.57 cde
		3 gm	10.29 abc	6.22 de
	Band	1 gm	10.72 abc	6.37 cde
		2 gm	10.64 abc	6.52 cde
		3 gm	10.36 c	6.36 cde
	Injection	1 gm	10.00 c	6.87 cde
		2 gm	10.06 c	6.50 cde
		3 gm	10.47 bc	6.99 cde

[z] Means within the same column having the same letter are not significantly different (LSD .05).

after 3 months of storage at 0oC.

J-Soluble Solids After 6 Months Storage

The influence of foliar and ground applications of PP333 and EL500 on soluble solids of 'Red Delicious' apple fruit after 6 months of storage at 0oC is shown in Table 10.

Soluble Solids of 'Red Delicious' of apple fruit after 6 months storage at 0oC was not affected by any treatment of PP333 or EL500.

K-Firmness of Apple Fruit After 6 Months Storage

The influence of foliar and ground applications of PP333 and EL500 on firmness of apple fruits of 'Red Delicious' after 6 months at 0oC is given in Table 11.

The results indicated that apples from trees receiving foliar sprays of PP333 were significantly firmer after 6 months storage at 0oC than the control fruit, as well as fruit from trees receiving other chemical treatment. Also fruit from trees receiving 1500 ppm sprays were firmer than those sprayed at 1000 ppm concentration. It seems likely that PP333 is influencing ripening and reducing fruit disorders indirectly by raising the level of calcium in fruit (24). Calcium can delay the on-set of the respiratory climacteric (20). Internal break down in apple is lowest in high calcium fruit and the amount of internal break down can be reduced by spray application of calcium (6). Bitter pit and loss of firmness are associated with low level of fruit calcium (54).

Apples from trees receiving 1 g of PP333 applied in a band

Table 10. Effect of foliar and ground applications of PP333 and EL500 on soluble solids of 'Red Delicious' apple after 6 months of storage at 0°C.

Treatments			'Red Delicious' %
Control			14.20 a [z]
PP333	Foliar	1000 ppm	13.80 a
		1500 ppm	13.95 a
	Ground Drench	1 gm	13.70 a
		2 gm	13.65 a
		3 gm	14.10 a
	Band	1 gm	13.90 a
		2 gm	13.60 a
		3 gm	14.05 a
	Injection	1 gm	14.10 a
		2 gm	14.40 a
		3 gm	14.35 a
EL500	Foliar	750 ppm	13.90 a
		1000 ppm	13.95 a
	Ground Drench	1 gm	13.90 a
		2 gm	14.10 a
		3 gm	14.15 a
	Band	1 gm	14.00 a
		2 gm	14.45 a
		3 gm	13.50 a
	Injection	1 gm	13.75 a
		2 gm	14.05 a
		3 gm	13.70 a

z Means within the same column having the same letter are not significantly different (LSD .05).

Table 11. Effect of foliar and ground applications of PP333 and EL500 on firmness of 'Red Delicious' apple after 6 months of storage at 0°C.

Treatments			'Red Delicious'
Control			5.44 de [z]
PP333	Foliar	1000 ppm	6.54 b
		1500 ppm	7.40 a
	Ground		
	Drench	1 gm	5.84 bcde
		2 gm	5.59 cde
		3 gm	5.71 cde
	Band	1 gm	6.20 bc
		2 gm	5.50 cde
		3 gm	6.10 bcd
	Injection	1 gm	5.83 bcde
		2 gm	5.72 cde
		3 gm	6.12 bcd
EL500	Foliar	750 ppm	5.99 bcd
		1000 ppm	5.65 cde
	Ground		
	Drench	1 gm	5.60 cde
		2 gm	5.99 bcd
		3 gm	5.52 cde
	Band	1 gm	5.54 cde
		2 gm	5.72 cde
		3 gm	5.20 e
	Injection	1 gm	5.75 cde
		2 gm	5.68 cde
		3 gm	5.84 bcde

[z] Means within the same column having the same letter are not significantly different (LSD .05).

were firmer after 6 months of storage at 0oC than fruit from the control trees but lower in fruit firmness than apples sprayed with 1500 ppm of PP333.

Summary and Conclusions

This study was conducted to determine the effect of foliar and ground applications of PP333 and EL500 on growth, fruit quality and storage potential of 'Golden' and 'Red Delicious' apples.

A. Trunk Circumference

Trunk circumference of 'Golden Delicious' was increased by 1500 ppm foliar and 3 g ground application (injection) of PP333 compared with control. The 1 g ground drench application of EL500 reduced trunk circumference of treated 'Golden Delicious' apple trees. However, there were no significant effects from foliar and ground applications of PP333 and EL500 on trunk circumference of 'Red Delicious'.

B. Shoot Growth

Foliar applications of PP333 caused greater reduction in shoot growth of 'Golden Delicious' and 'Red Delicious' than ground application of PP333, foliar and ground applications of EL500, and the control treatment. The foliar sprays of PP333 at 1500 ppm significantly shortened terminal shoot growth of 'Golden Delicious' compared to those sprayed at 1000 the ppm rate.

C. Fruit Weight

None of the PP333 and EL500 treatments had any significant effect on fruit weight of 'Golden Delicious'. Foliar application of PP333 resulted in a slight increase in fruit weight of 'Red Delicious' but the values were not significantly different from the control treatment. Foliar and ground applications of E1500 had no significant influence on fruit weight of 'Red Delicious'.

D. Soluble Solids

Fruit soluble solids of 'Golden Delicious' and 'Red Delicious' sprayed with 1000 and 1500 ppm of PP333 was not significantly different from the controls. Neither were there differences in soluble solids found in 'Golden Delicious' fruit receiving ground applications of PP333 and those sprayed and the unsprayed control. However, in 'Red Delicious' there was a significant decrease in soluble solids associated with the 2 g drenching and 2 and 3 g banding rates.

E. Seed Number

Foliar sprays of PP333 regardless of concentration produced a significant reduction in seed number of 'Golden Delicious' and 'Red Delicious' as compare to controls. Increase, in the concentration of EL500 gave a significant decrease in seed number of 'Golden Delicious' as compared to the control.

F. Fruit Firmness

Fruit from 'Golden Delicious' trees sprayed with either PP333 or EL500 were not different from the controls in measured firmness also none of the 'Golden Delicious' fruit from tree receiving the various ground applications differed in firmness from fruit collected from control trees although these were minor differences between some chemical treatments.

G. Length/Diameter (L/D) Ratio

Foliar application of PP333 had no significant effect on the L/D ratio of 'Golden Delicious' fruits. The L/D ratio of 'Golden

Delicious' and 'Red Delicious' fruit showed no significant response to rate or methods of ground application of PP333. There were no significant effects on L/D ratio of 'Red Delicious' from EL500 soil applications.

H. Soluble Solids After 3 Months Storage

Foliar and ground application of PP333 had no significant effect on soluble solids of 'Golden Delicious' and 'Red Delicious' apple fruit after 3 months of storage at 0oC, except the 2 g drench method of PP333 which reduced the soluble solids of 'Red Delicious'.

I. Firmness of Apple Fruit After 3 Months Storage

Firmness values of apple fruits of 'Golden' and 'Red Delicious' were significantly higher in apple from trees sprayed with PP333. Foliar application of EL500 at 1000 ppm was the only treatment which significantly increased fruit firmness values of 'Red Delicious' than the controls.

J. Soluble Solids of Apple Fruit After 6 Months Storage

Soluble solids of 'Red Delicious' of apple fruits after 6 months storage at 0oC was not affected by any treatment of PP333 and EL500.

K. Firmness of Apple Fruit After 6 Months Storage

'Red Delicious' apple's from trees receiving foliar sprays of PP333 and 1 g ground band application were significantly firmer after 6 months of storage at 0oC than the control fruit, as well as fruit from trees receiving other chemical treatment.

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EFFECT OF PACLOBUTRAZO (PP333) AND FLURPRIMIDOL (EL500) ON VEGETATIVE GROWTH, FRUIT CHARACTERISTICS AND STORAGE OF 'GOLDEN DELICIOUS' AND 'RED DELICIOUS' APPLE

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ABSTRACT

This study was conducted to investigate the influence of flurprimidol (EL500) and paclobutrazol (PP333) on (a) terminal shoot growth (b) fruit characteristics and (c) fruit storage of two apple cultivars 'Golden Delicious' and 'Red Delicious'. EL500 and PP333 were applied by two methods, foliar and ground applications. At foliar application trees were sprayed to the dripping point with a hand gun from a field sprayer. The concentrations were 1000 and 1500 ppm for PP333 and 750 and 1000 ppm for EL500. Ground applications of both PP333 and EL500 were applied by three different methods, drenching, banding, and injection. Both chemicals were applied at either 1 g, 2 g, or 3 g, per tree regardless of the aplication method. Apple fruits placed in storage at 0°C were examined after 3 and 6 months.

Trunk circumference of 'Golden Delicious' was increased by 1500 ppm foliar and 3 g ground injection application of PP333. The 1 g ground drench application of EL500 reduced trunk circumference of treated 'Golden Delicious' apple trees. Foliar applications of PP333 caused greater reduction in shoot growth than ground application of PP333, foliar and ground applications of EL500, and the control treatment.

None of the PP333 and EL500 treatments had any significant effect on fruit weight of "Golden Delicious". Fruit soluble solids of 'Golden Delicious' and "Red Delicious" sprayed with 1000 and 1500 ppm of PP333 was not signifecantly different from the controls at harvest . Foliar sprays of PP333 regardless of

concentration produced a significant reduction in seed number of 'Golden Delicious' and 'Red Delicious' as compared to controls. Fruit from 'Golden Delicious' trees sprayed with either PP333 or EL500 were not different from the controls in measured firmness at harvest. Also none of the 'Golden Delicious' fruit from trees receiving the various ground applications differed in firmness from fruit collected from control trees although these were minor differences between some chemical treatments. Foliar application of PP333 had no significant effect on length/dimeter (L/D) ratio of 'Golden Delicious' fruits, while, the low concentration of 1000 ppm of PP333 resulted in a significantly higher L/D ratio of 'Red Delicious' fruit than the 1500 ppm spray and control treatments.

Foliar and ground applications of PP333 and EL500 had no significant effect on soluble solids of 'Golden Delicious' apple fruit after 3 months of storage at 0°C. Firmness value of apple fruits of 'Golden Delicious' were significantly higher in apples from trees sprayed with PP333 at 1500 ppm than the controls after 3 months of storage at 0oC. Soluble solids of 'Red Delicious' apple fruit after 6 months storage at 0oC was not affected by any treatment of PP333 and EL500. Apples from trees receiving foliar sprays of PP333 were significantly firmer after 6 months of storage at 0oC than the control fruit, as well as fruit from trees receiving other chemical treatment.