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# Feathered Nursery Plants: A New Perspective for Raising High Density Plants

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## Introduction

Feather is a branch that is produced in the same year as the leader. Feathers are sometimes produced in strong growing first year budded trees (although usually not enough feathers) or by a Knip-boom tree technique (where the one-year nursery tree is cut at the 60 cm (24”) height and re-grown a 2nd year, producing feathers on a strong-growing leader. For a high quality tree, the presence of a good number of feathers is desirable because they form flower buds in the second year of nursery production and enable the tree to bear fruit in the first year. Also feathered trees enable an earlier formation of a canopy structure. Feathering: It is a technique for developing lateral branches in nursery plants by making use of either practice or plant growth regulators or both. Feathers are sometimes first year budded trees. Many temperate fruit crop growers are looking hard at making the investment in new orchards. With the large investment of money and management required to be successful, it is important to plan well & consider all details. Any mistake made at the beginning about: Site selection, Choice of rootstock or cultivars, Pollination, Soil preparation, Training system etc., have long term detrimental effects on the orchards performance & profitability.

Important factors in feathering are:

- Apical dominance.
- Nutrient availability.
- Ecological conditions.

**1. Apical dominance :** Apical dominance is a term referring to the control that the terminal bud exerts over the development of lateral buds. This dominance establishes certain branching patterns characteristic of each woody plant species. There are several hypotheses which try to explain the mechanism of apical dominance. The hormonal hypothesis, the photosynthetic hypothesis, the hypothesis of water and mineral nutrient transport. The hormonal hypothesis stresses the growth importance of auxins in the apical growth dominance & importance of cytokinins in overcoming apical dominance. With apples, Benzyl Adenine (BA) and the combination of BA and Gibberellins play an important role in overcoming apical dominance and in the production of well-feathered apple nursery trees.

**2. Nutrient availability:** If adequate nutrients are provided to plants at early stage then plants grow healthy and they produced more feathers at early stage, they give high yield and early economic returns.

**3. Ecological conditions:** This factor also helped in producing enhanced feathering. If ecological conditions are best then they produced more feathers at early stage. Sometimes due to ecological conditions, feathers are less produced and then that year yield becomes less. So, that we also manage ecological conditions for feathering.

## Why we need feathering?

Now-a-days intensive orchards/HDP are in a wave and feathered trees are preferred

because non-feathers are non-precocious bearing i.e., bearing starts in 3-4 years after planting and maximum production occurs after 5 years (late economic returns). But feathered plants show precocious bearing and start to give yield from second year of planting resulting in early economic returns. It is more profitable at early stage. Feathered plants are acknowledged as a building block/key factor for an early crop in the orchard. Well-feathered nursery plants greatly contribute to plant architectural engineering and shorten the investment period. Future pruning is consequently simple and management costs are reduced.

#### **Type of branches using in feathering**

- **Vertical branches :** These branches are inhibiting flower bud formation. These branches are lean and weak.
- **Horizontal branches :** These branches stimulate flower bud formation and are thick and strong.

In feathering, we prefer horizontal branches because they accumulate more carbohydrates and they produce more spur, it gives early yield and early economic returns.

#### **Propagation techniques in feathering**

**Budding:** Budding is the form of grafting in which only one bud is inserted in the rootstock. This method is generally employed during spring and rainy season.

**Grafting :** It is a method of vegetative propagation where two plants parts are joined together in such a manner that they unite and continue their growth as one plant. In this method scion twigs have more than two buds on it.

Feather formation is superior and vigorous on budded plants than on grafted plants. In budding, chip-budding has been found to be more effective. The use of chip-budding produced larger and more uniform feathers on one year old trees with more and longer lateral

branches compared with T-budding. The superior growth of trees budded by chip-budding was associated with the formation of a better union between scion and rootstock. We prefer budding plants in feathering because they are more desirable as compared to grafted plants for developing feathers.

#### **Advantages**

- Feathering is governed by apical dominance.
- Feathering leads to early flower bud formation.
- Plant architecture is easy.
- Early economic returns.
- Thick & strong crotch angles.

#### **Disadvantages**

- More costly
- Due to dense feathering, fruit quality is reduced because interception of light does not occur at lower branches.

#### **Nursery trees for the new orchard**

Starting an orchard with high quality nursery trees is the first key to a successful planting. High quality trees will quickly establish to the desired height & fill their space. The right trees will be ready to produce fruit in the 2nd year & will reach full production a few years later. Planting the right trees means early cropping which is the profitability of new orchard. Trees of lesser quality can eventually fill their space & produce good yields but the early returns are lost, so profitability over the life of planting will be less.

#### **Characteristics of an ideal apple plant nursery**

At least 1.7 m (5 ft) tall, preferably 2-2 m (6-7 ft). An abundance of healthy roots. Consider 6-10 “feathers” that are 12-25 cm (6-12”) long. The bottom feather no lower than 24” (60 cm) above the soil when the tree is in place in the orchard. Remove crisis cross and

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diseases branches. Nursery plant should be diseases free for well feathers. Feathers are sometimes produced in strong growing first year budded trees (although usually not enough feathers) or by a Knip-boom tree technique (where the one-year nursery tree is cut at the 60 cm (24”) height and re-grown a 2nd year, producing feathers on a strong-growing leader).

#### **Sailent features of feathered plant**

- A well feathered tree should have at least four to five branches in all the directions.
- It should be more than 12cm.
- A crotch angle of more than 45 degree.

#### **Components of feathering plants**

- Feathers / spreading branch.
- Crotch angle.
- Propagation technique.

#### **Spreading branch**

In any tree training system, the aim is to fill the trees space as quickly as possible. When you bend a branch or shoot below the horizontal position so that the tip is at the lowest point-the dominant bud. Before you spread branches with narrow crotch angles. Effect of branch spreading – the way that shoots or branches are spread and positioned and the time of year when this is done, affect growth and cropping. When you bend a branch or shoot below the horizontal position- so that the tip is at the lowest point – dominant bud. Encourages and increases flower bud formation Allows light penetration onto all portions of a limb.Increases fruit-setting.

#### **Crotch angle**

The angle made by scaffold limbs to the trunk or the secondary branch to scaffold limb is called crotch. The crotch should be broad and not narrow. The crotch angle measures the distance between the trunk and the base of the branch. An upright branch has a narrow

crotch angle of less than 45 degrees. A sturdy, wide-angled branch has a 45 to 60 degree crotch angle. The crotch angle plays a role in light interception within the canopy. The crotch angle is particularly important for red skinned varieties because anthocyanin development is influenced by light intensity and duration. The best production comes from branches trained to grow at about 45 degree angle from the vertical position.

#### **Feather Development**

- Physiological Concept
- Hormonal Concept

#### **Physiological Concept**

- Feathering of nursery trees is controlled by apical dominance.
- Due to apical dominance plant exerts control over the development of the lateral buds.
- In order to produce a well-branched, highly marketable tree, apical dominance must be interrupted.

It has been a common observation in many vascular plants especially the tall and sparsely branched ones that if the terminal bud is intact and growing, the growth of the lateral buds just below it remained suppressed. Removal of the apical bud results in the rapid growth of the lateral buds. This phenomenon in which the apical bud dominates over the lateral buds and does not allow the later to grow is called as apical dominance. The apical dominance might be under the control of auxin produced at the terminal bud and which is transported downward through the stem to the lateral buds and hinders their growth.

Auxin induces vascular differentiation in plants. This has also been confirmed in tissue culture experiments and form studies with transgenic plants. Cytokinins are also known to participate in differentiation of vascular tissue and it is believed that vascular

differentiation in plants is probably under the control of both auxin and cytokinins.

### Hormonal concept

Auxins play a role in apical growth dominance, which can be overcome by various growth regulators like cytokinins.

The application of 6-benzylaminopurine (BA) affects the flow of auxins and temporarily impedes the main shoot growth which helps overcome apical dominance and creates favourable conditions for feather formation.

### Technique

#### How to develop feathering

##### PGRs

- Benzyl adenine
- Gibberellins
- BA+GA

#### Benzyl adenine

- Benzyl adenine are hormones that stimulate cell division, or cytokinesis.
- These hormones may also be involved in controlling leaf senescence and the growth of lateral branches.
- The most active, naturally-occurring cytokinin is zeatin.
- Benzyl adenine occurs in most plants including mosses, ferns, conifers, algae and diatoms.
- Benzyl adenine is the one of the chemical form of cytokinin.

#### Site of synthesis

- Synthesized primarily in the meristematic region of the roots.
- This is known in part because roots can be cultured (grown in artificial medium in a flask) without added cytokinin, but stem cells cannot.
- Cytokinins are also produced in developing embryos.

### Transport

- Via xylem (transpiration stream).
- Zeatin ribosides are the main transport form; converted to the free base or glycosides in the leaves.
- Some cytokinin also moves in the phloem.

### Benzyl adenine Actions

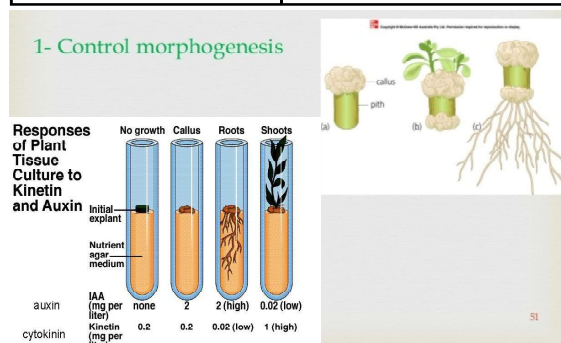
#### a. Control morphogenesis

• In plant tissue cultures, cytokinin is required for the growth of a callus (an undifferentiated, tumor-like mass of cells):

The medium	The callus differentiation
Callus + auxin + no cytokinin	Little growth of callus
Callus + auxin + cytokinin	Callus grows well, undifferentiated

• Ration of cytokinin and auxin are important in determining the callus

The concentration	The callus differentiation
Callus+low (cytokinin/auxin)	Callus grows well, / forms roots
Callus + high (cytokinin/auxin)	Callus grows well, forms meristem & shoots



#### b. Regulates the cell cycle/cell division

- (Hence, the name "cytokinins") -

especially by controlling the transition from G2 mitosis.

- This effect is moderated by cyclin-dependent protein kinases (CDK's) and their subunits, cyclins.

#### c. Bud development

- Direct application of cytokinin promotes the growth of axillary buds.
- Exogenous cytokinin and auxin are thus antagonistic in their effects on axillary bud growth

#### d. Delay senescence

- Senescence is the programmed aging process that occurs in plants.
- Loss of chlorophyll, RNA, protein and lipids.
- Cytokinin application to an intact leaf markedly reduces the extent and rate of chlorophyll and protein degradation and leaf drop.

#### e. Greening

- Cytokines promotes the light-induced formation of chlorophyll and conversion of etioplasts to chloroplasts (greening process).

#### f. Promote cell expansion

- Cytokinins stimulate the expansion of cotyledons.
- The mechanism is associated with increased plasticity of the cell wall, not associated with acidification.

### Gibberellins

#### Site of synthesis

Young leaves, roots, and developing seeds (developing endosperm) and fruits.

#### Transport

- I. Made in the tissue in which it is used.
- II. Transport occurs through xylem, phloem, or cell-to-cell.

III. Phloem seems to be most important transport route.

IV. Transport is not polar, as it is for auxin.

### Gibberellins Actions

#### Promotes stem elongation

- When applied to intact plants, GA usually causes an increase, unlike auxin.
- It overcomes dwarfism in mutants that have a mutation in the GA synthesis pathway.

#### Dwarf = short

Wild type = tall

Dwarf + GA = tall.

Thus, GA application.

- stimulates elongation.
- Acts on intact plants.
- Promotes stem elongation.



Dwarf  
Mutant gas

Dwarf  
Mutant plus  
Gibberellin

**The Model plant Arabidopsis has been used to understand gibberellin biosynthesis**

- Root growth
- Elongation of the internodes
- Dormancy of buds

#### Root growth

Gibberellins have little or no effect on root growth. At higher concentration in some plants, however, some inhibition of root growth may occur. The initiation of roots is markedly inhibited by gibberellins in isolated cuttings.

**Elongation of the internodes :** Most pronounced effect of gibberellins on the plant growth is the elongation of the internodes, so much so that in many plants such as dwarf varieties of apple, pear, cherry etc. They overcome the genetic dwarfism.

### **Dormancy of buds**

In temperate regions the buds formed in autumn remain dormant until next spring due to severe colds. This dormancy of buds can be broken by gibberellins treatment.

### **Mechanism of Gibberellin**

- Of the 136 different known gibberellins only GA<sub>3</sub>, GA<sub>4</sub>, GA<sub>7</sub> are important
- Promote cell expansion or cell division or both of plant.
- Extensibility changes in GA treated tissues: height reduced the extensibility of hypocotyls tissues while darkness and GA overcome this inhibition.
- GA<sub>3</sub> Synthesis of RNA Proteins: An increase in level of RNA and protein cause an
- Increase in total metabolites in plant cell.

### **Method of PGR Application**

- Spray PGR 10 to 14 days after bud break to green tissue on the un-branched leader from the tip down to the existing branches or to 24 inches above the soil line on 1-year-old trees.
- Apply the PGR in white latex paint with a roller to the leader at bud swell, before any green tissue is showing.
- Notch the leader at bud swell before bud break with a hack saw or double-edged clippers.

### **Recommendations for Nurseries**

First leaf apple trees where the leader has no buds broken but just prior to bud swell. For example, newly planted nursery tree whips. Second-leaf apple trees where leaders have

vegetative blind wood with no visible buds or branches. Existing young, tall-spindle or vertical-axis apple orchards with limited branching in the tops of the trees. The key to branching trees is to start early and make multiple applications (3 to 5) of a PGR, depending on location. When the whip reaches 36 inches in height, treat the growing tip with a PGR. Repeat this application every 5 to 7 inches of new growth (7 to 14 days) for 4 to 5 applications. The use of feathered trees combined with high planting densities and minimal pruning has resulted in a significant improvement in yield of new orchards over the first 5 years. The larger the initial calliper of the tree at planting, the greater the growth and yield in the first 4-5 years. The greater the number of feathers at planting, the greater the yield especially in the second and third years. Feathered nursery trees are a critical component of most high-density apple planting systems including the Tall Spindle

### **Role of plant growth regulators in feathering on apple**

In apple, BA and the combination of BA and GA play an important role in overcoming Apical dominance and in the production of well feathered apple nursery tree. The total no. of feathers increased with an increase in the concentration of BA and BA + GA. The highest no. of feathers was obtained with BA + GA 400 microlitr/liter treatments while in 2012 it was obtained with BA and GA 450 and 400 treatments. Increase in the concentration of BA and BA+ GA to a certain limit leads to an increase in the number of feathers.

The main factor responsible for tree branching potential is apical dominance is thought to be controlled by the interaction of endogenous growth hormones especially auxins & gibberellins. Additionally feathering may be influenced by other factors such as plant density, cultural practice & climate. For a high quality tree, the presence of a good no.

**Table 1. : Effects of BA and BA + GA4+7 applications on feather length and tree height in Golden Delicious one-year-old trees (year 2011)**

Treatment	Total feather length (cm)	Average feather length (cm)	Tree height (cm)
BA+GA <sub>4+7</sub> 450 <sup>1</sup>	172.6a <sup>2</sup>	25.8bcd	143.2d
BA+GA <sub>4+7</sub> 400	164.3a	22.2cd	151.0cd
BA+GA <sub>4+7</sub> 350	99.0c	25.8bcd	158.5abc
BA+GA <sub>4+7</sub> 300	40.8e	20.4cd	155.0abc
BA+GA <sub>4+7</sub> 250	23.4e	17.9de	159.6ab
BA+GA <sub>4+7</sub> 200	32.5e	32.5ab	155.8abc
BA 450	137.3b	23.6cd	159.4ab
BA 400	105.8c	26.0bcd	157.0abc
BA 350	99.2c	27.1bc	153.3bc
BA 300	41.2e	18.8cde	159.0ab
BA 250	71.5d	35.0a	153.8abc
BA 200	18.0e	11.2e	154.7abc
Control	25.0e	19.9cd	161.4a

of feathers is desirable because they form flower buds in the 2nd year of nursery production & enable the tree bear fruit in the first year. Also feathered trees enable the tree bear fruit in the first year. Also feathered trees enable an earlier formation of a canopy structure. The application of BA phytohormones in higher concentration can negatively affect the tree height.

Neutralizing their negative effect on tree height is intensive irrigation accompanied with the provision of nutrients during the period of intensive growth of the main shoot, which should maintain an adequate growth rate.

One-year-old Golden Delicious apple trees untreated with phytohormones formed a small number of feathers at 62-64cm above ground in a standard nursery production method for one-year-old unbranches trees. Phytohormones BA and BA+GA<sub>4+7</sub> significantly affected the formation of feathers. Increasing concentrations of BA and BA+GA to a certain limit leads to an increase in the number and the total length of feathers. In agro ecological conditions prevalent in Serbia, and with standard planting technologies, it is necessary to use BA

and GA in concentrations of 400 micro litre/litre. BA so that a sufficient number of feathers is formed. If used in higher concentrations, the result may be trees shorter than 150cm due to negative effect of BA. A possible method of obtaining an adequate number of feathers with the application of BA and BA+GA while neutralizing their negative effect on the tree height is intensive irrigation accompanied with the

provision of nutrients during the period of intensive growth of the main shoot, which should maintain an adequate growth rate

### Role of PGRs in feathering of pear

**Table 2. Total number of feathers, length of feathers and percentage of feathers in Maiden trees as influenced by different bioregulators.**

Treatments	Number of feathers	Total length of feathers	Percentage of feathers
Control	4.13abc	71.5ab	48a
Arbolin 036SL-7.5 (ml/l) (2x)	5.26bc	79.4ab	90d
Arbolin 036SL-12.0(ml/l)	5.24bc	72.7ab	84cd
Arbolin 036SL – 25.0ml/l	5.00bc	71.8ab	90d
Arbolin 038SL-25.0 (ml/l) + amin	7.90de	119.2bc	90d
Arbolin 038 SL-12.0 (ml/l) + amin	5.95e	89.19ab	72b
Arbolin 038 SL-12(ml/l)	10.13e	143.4c	100e

The investigated pear cultivars differ in the degree of apical dominance. The use of BA and GA mixtures is an effective measure for promoting lateral branching of conference pear. Further investigation is needed to improve branching.

### Role of PGRs in feathering of cherry

**Table 3. The effect of Perlan treatment on the number, length, percentage and crotch angle**

Treatments	Mean lateral number (no./tree)	Mean lateral length (cm/tree)	Crotch angle	Percentage (%)
Control	2.0ab	31.1 c	43.0c	58.3c
100ppm	2.8ab	34.4 bc	44.0c	83.3b
250ppm	2.3ab	48.6a	54.0ab	100.0a
500ppm	3.2a	47.6a	44.0c	91.6b
750ppm	3.0a	44.7a b	55.0a	100.0a
1000ppm	1.7b	45.0a b	46.0bc	50.0c

Most cultivated fruit species and cultivars do not produce enough lateral branches in the nursery because of strong apical dominance. However early high yields in intensive plantings are possible with branched trees having wide-angled lateral. Based on the first year data of our trials, 500 and 750ppm seem to be the most successful. Perlan treatments for sweet cherry, taking into account chemical cost, 300ppm could be suggested for inducing lateral branching on 0900 ‘Ziraat’ nursery trees. Generally, Perlan also increased tree height and diameter. Application did not cause any phototoxic symptom on leaves or any damage on the tree. Additional trials with more cultivars under different conditions should be continued to ultimately establish a reliable and practical method to propagate branched trees in the nursery.

### Pinching

Pinching is a form of pruning that encourages lateral branching on the plant.

#### Mechanism of Pinching

- Pinch-back the shoot two inches using your thumb and finger or pruners.
- Pinching will do two things: weaken the growth of the developing shoot so it is not likely to compete with the leader, and promote the development of a fruit bud in the vicinity of the pinch.
- Pinching should be done in the month of early July.

**Table 4. Effect of different plant growth regulators and pinching on the number of feathers in Apple**

	Treatments	No. of the feathers
T1	BA@450ppm(2x)	3.02
T2	BA@450 ppm (3x)	3.17
T3	BA+GA @450ppm(2x)	3.18
T4	BA+ GA @450ppm (3x)	4.01
T5	Pinching (2x)	1.18
T6	Pinching (3x)	1.42
T7	BA@450ppm(2x) + pinching	3.52
T8	BA @450 (3x) + pinching	3.83
T9	BA + GA @450ppm (3x)+ pinching	4.82
T10	BA + GA @450ppm (3x) + pinching	6.52
T11	Control	0.64

The results presented in this Table show that incremental height was significantly affected by both branching chemicals and



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pinching. The untreated plants (control) resulted in maximum incremental height (26.16 cm), while as, the minimum increment in height (12.99 cm) were recorded under the treatment BA @ 450 ppm (three times) + pinching. The treatments BA+GA<sub>3</sub> @ 450 ppm (two times) + pinching (17.42 cm) and BA+GA<sub>3</sub> @ 450 ppm (three times) + pinching (17.15 cm) and BA @ 450 ppm (two times) + pinching (19.18 cm) were at par to each other in final plant height. The results presented in Table also further show that the percent increase in height was significantly affected by both branching chemicals and pinching. The untreated plants (control) resulted in maximum percent increase in height (54.13%), while as, the minimum percent increase in height (25.47%) was recorded under the treatment BA @ 450 ppm (three times) + pinching. The percent increase in height was at par under BA+GA<sub>3</sub> @ 450 ppm (three times) + pinching (33.75%) and BA +GA<sub>3</sub> @ 450 ppm (two times + pinching (33.62%) with each other.

### **Conclusion**

The use of strong, well-branched nursery trees is a prerequisite of early and high yields because they are precious bearing i.e., bearing starts in 3-4th year. High quality nursery trees

is the first key to a successful planting. High quality trees will quickly establish grow to the desire height and fill their space. The right trees will be ready to produce fruit in the second year and will reach full production a few years later. Planting the right trees means early cropping which is the profitability of new orchard. The quality of nursery tree can be enhanced by mechanical method or PGRs. The mechanical methods like heading, top twisting or removal of apical leaves are not so effective as plant growth regulators: PGRs are most effective when applied at the appropriate times to regulate plant growth or development. PGRs used in fruit crops are those that enhance branching, including Benzyl adenine, Gibberellins and benzyl adenine + Gibberellins. These PGRs are frequently called chemical pinchers because they generally inhibit the growth of the terminal shoots or enhance the growth of the lateral buds, thereby increasing the development of lateral buds, thereby increasing the development of lateral branches. Plant growth regulators can be used to enhance flowering. The use of PGR like BA and GA alone or in combination is an effective measure for promoting lateral branching to meet the growing demand of feathered plants.

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