



High Density Apple Production

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Outline

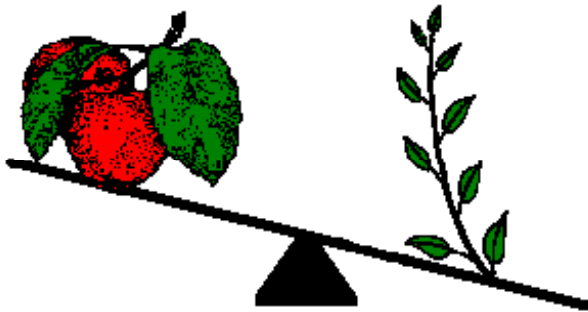
- Principles of High Density Apple Production
- Site selection/preparation
- Rootstocks
- Training Systems
- Tree Establishment and Nutrient Management
- Tree Management
 - Leader management
 - Lateral management

PRINCIPLES OF HIGH DENSITY APPLE PRODUCTION

Principles of High Density Apple Production

- High early yields = high tree density
- Balance vegetative and fruiting
- Grow fruit, not trees!

Balance Growth and Fruiting

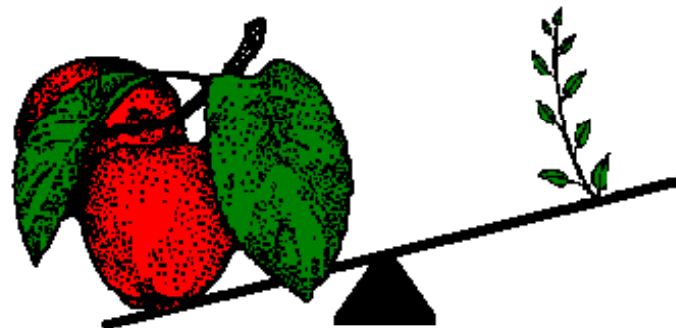


Excessive Fruit Load

Large yields
Small apples
Weak trees

Excessive vigor

Small yield
Larger fruit
Poor fruit color development



Pruning Can Be Dwarfing

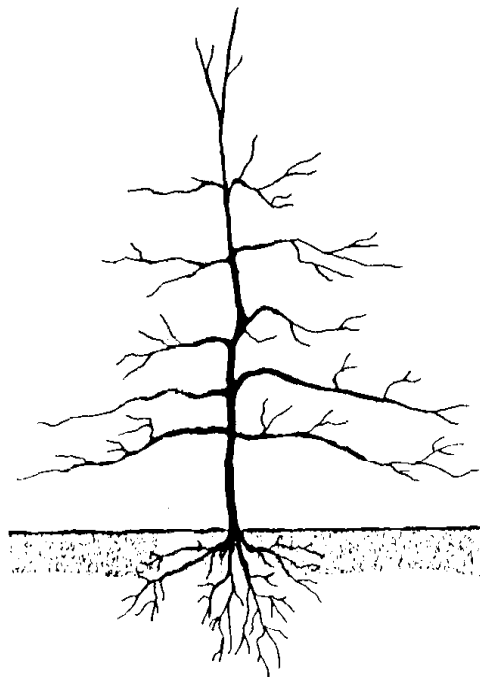
Root to Shoot Balance

Reduced water
and nutrients;
less shoot growth

Less leaf area
produces
fewer sugars

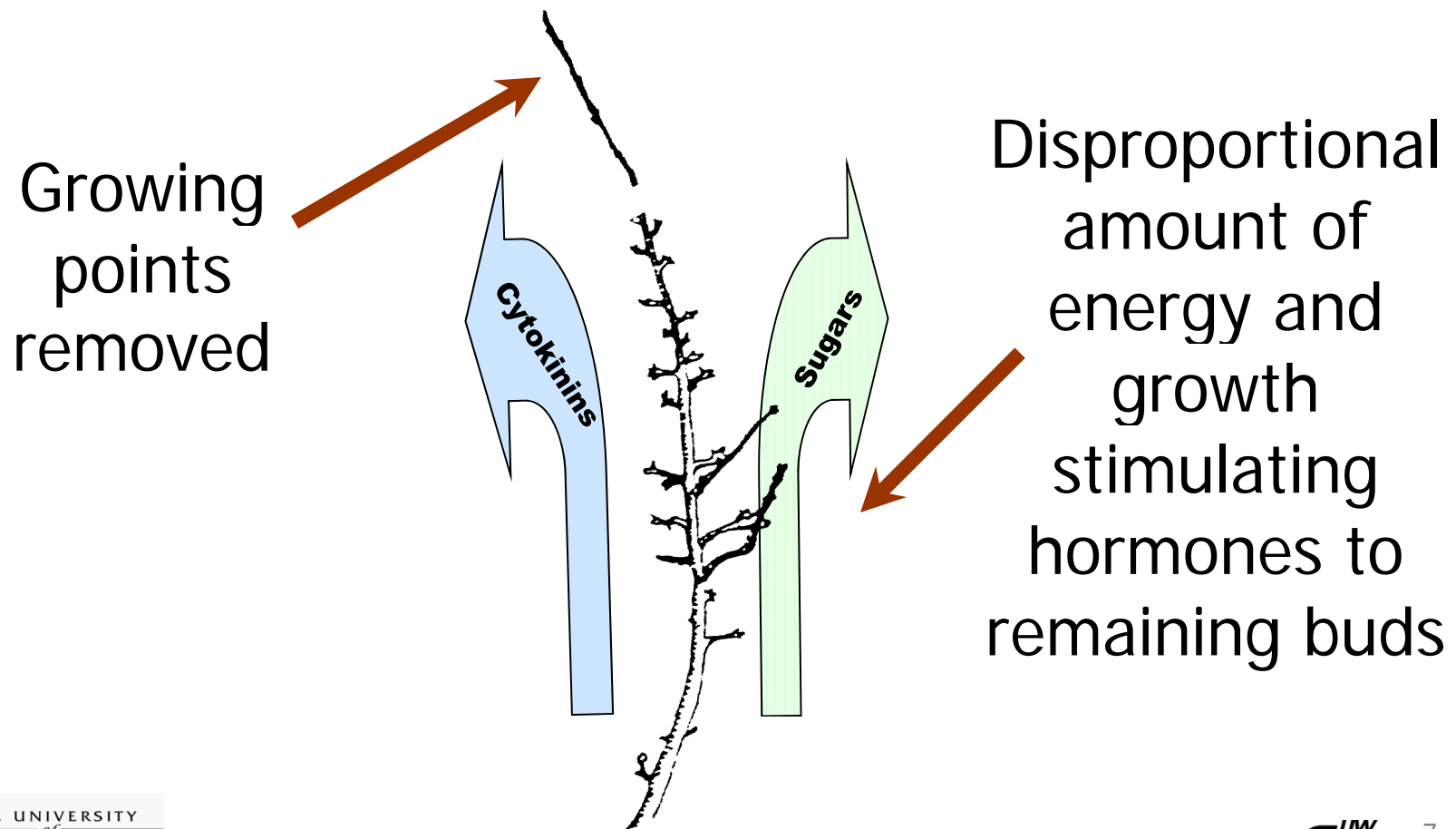
Less uptake
of water and
nutrients

Fewer sugars
are available
for storage



Root growth reduced

Pruning Can Be Invigorating



Role of Plant Hormones

- **Auxin**

- Produced in apical meristem
- Stimulate cell division
- Stimulate root production
- Move down stem and suppresses bud break on lateral buds

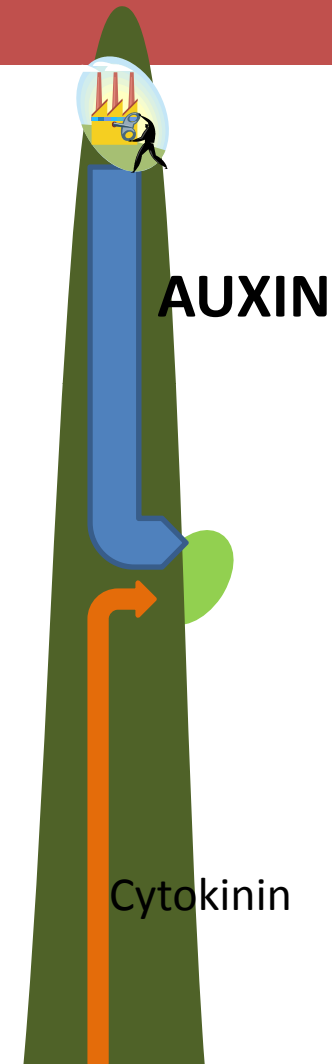
- **Cytokinin**

- Produced in the roots
- Suppress root growth
- Stimulate lateral bud growth

Apical Dominance

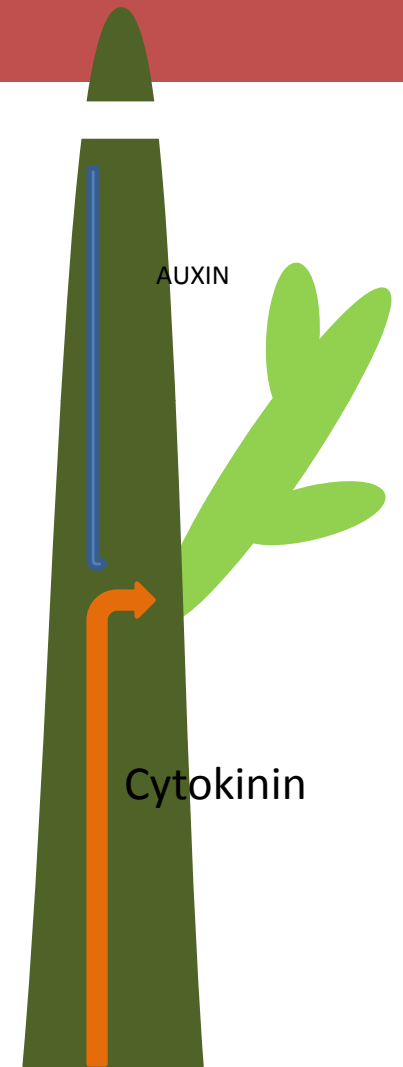
Inhibition of lateral buds by the terminal bud on a shoot

- Response to cytokinin suppressed by high amounts of Auxin



Apical Dominance

- Removal of terminal bud reduces Auxin concentration
- Buds become receptive to cytokinin and break



Vertical Growth

- Vigorous vegetative growth
- Not fruitful
- Weak crotch angles



Horizontal Growth

- Less vigorous
- Very fruitful
- Greatest flower production near base
- Strong crotch angle



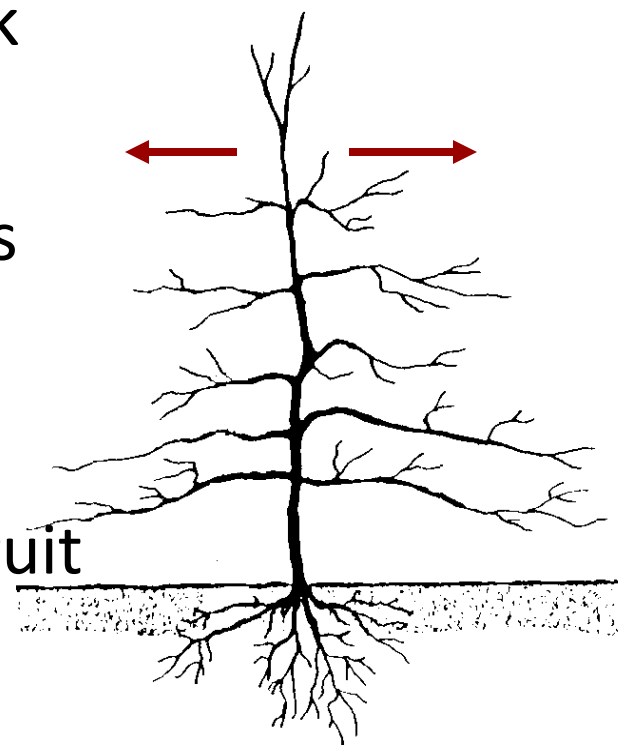
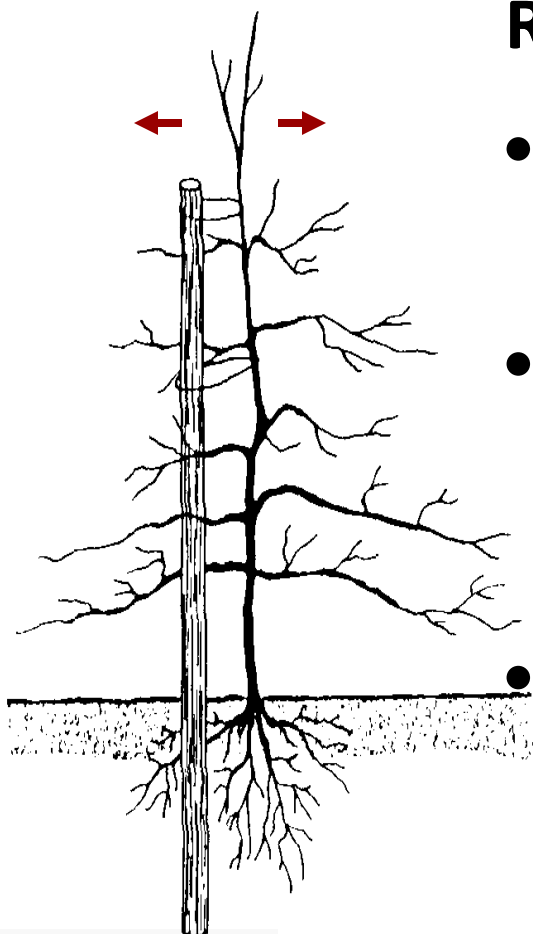




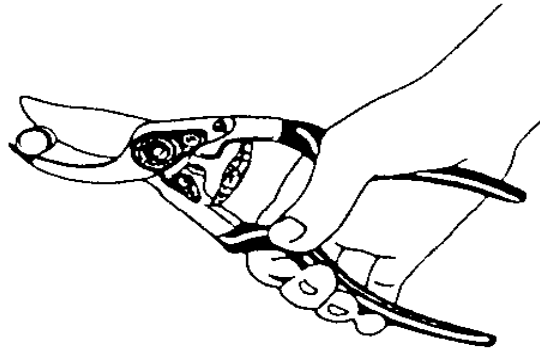
Tree Support Influences Growth and Fruiting

Reduced movement

- Less secondary trunk thickening.
- Fewer carbohydrates used in wood development.
- More available for fruit production.



Staking Modifies Tree Growth



- Un-staked trees require more pruning.
- Movement causes minute damage to cells and trunk tissue.

Stress → Ethylene → Lateral Cell Growth

SITE SELECTION/PREPARATION

CHOOSING YOUR NURSERY STOCK

Selecting Rootstocks for High Density Systems

- Must be dwarfing rootstocks
- With vigorous scion cultivars
 - dwarfing clone of M.9 or B.9 rootstock and/or greater planting distances.
- With weak scion cultivars
 - vigorous clone of M.9 rootstock should be used and/or closer planting distances.

Whip vs. Feathered

- Tall spindle system
 - Requires use of highly feathered trees (8-15 laterals)
 - Economic benefits are based on fruiting in year 2 and 3
 - If fruiting does not start until year 4 or 5 cost of maintenance overwhelms the benefit

TREE ESTABLISHMENT AND NUTRIENT MANAGEMENT

Irrigation

- Highly feather trees produce a lot more leaves in the first few years
 - Low root:shoot ratio
- Root systems are insufficient to meet tree demand
- Water stress can greatly reduce tree yield potential and jeopardize critical early yields

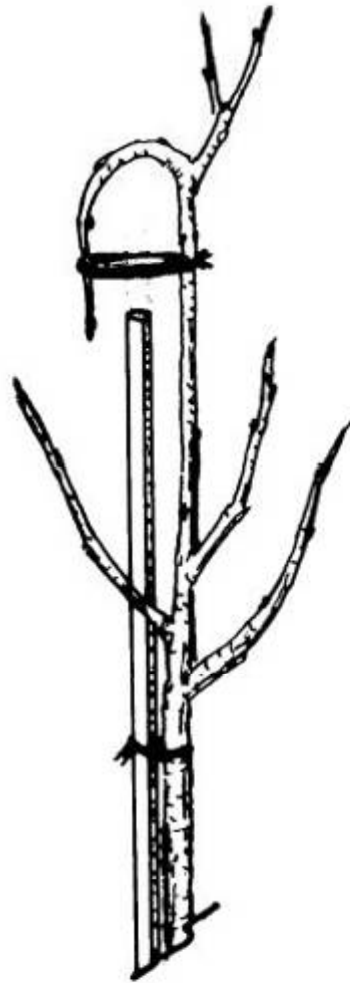
Irrigation

- Dry years can have dramatic impact on yield and disrupt the vegetative and fruiting balance
- Irrigation system should be installed **within 4 weeks of planting**

Leader Management

- Managing leader is necessary to maintain shape of tree and lateral branching
- Pruning invigorates tree growth and delays fruiting- not desirable in HD system
 - May be required if whips are used or if poor lateral development
 - Consider cost of delayed production with initial cost of highly feathered trees
- Other leader management techniques:
 - Weak leader renewal
 - Snaking
 - bagging

Top Management







Nutrient Management

- N is the most critical nutrient for vegetative growth
- Ca spray becomes critical
 - Greater demand, less supply

Fertilization Years 1-3

- Highly feather trees require supplemental fertilizer (N) to support early growth
 - Nurseries should apply urea foliar spray before leaf drop to provide reserve in the trees
 - Spoon feed through the irrigation system 2x\wk for 12 wks
- Forms of N readily available:
 - Calcium nitrate
 - Ammonium phosphate (?)

N Fertilization Year 3 +

- Low fertilizer requirements required to keep trees 'calm'
 - Minimal vegetative growth
- Consider soil fertility
 - 30-60 lbN/A
 - Can often be provided through mineralization
- Utilize soil and tissue analysis

Crop Load Management

- Do not over crop the trees during the establishment period
 - Poor vegetative growth
 - Increased stress
 - Biennial bearing
 - Trees do not fall into natural balance
- Tendency to over crop is high with:
 - Precocious root stocks
 - Highly feathered trees (no pruning)

Crop Load Recommendation During Establishment

- Annual cropping varieties (i.e. Gala)
 - 5 fruits/cm² TCA
- Biennial cropping/slow growing varieties (i.e. Honeycrisp)
 - 3-4 fruits/cm² TCA

(Robinson 2008)

Year	# Fruit /tree (annual bearer)
2	15-20
3	50-60
4	100

TRAINING SYSTEMS

Central Leader

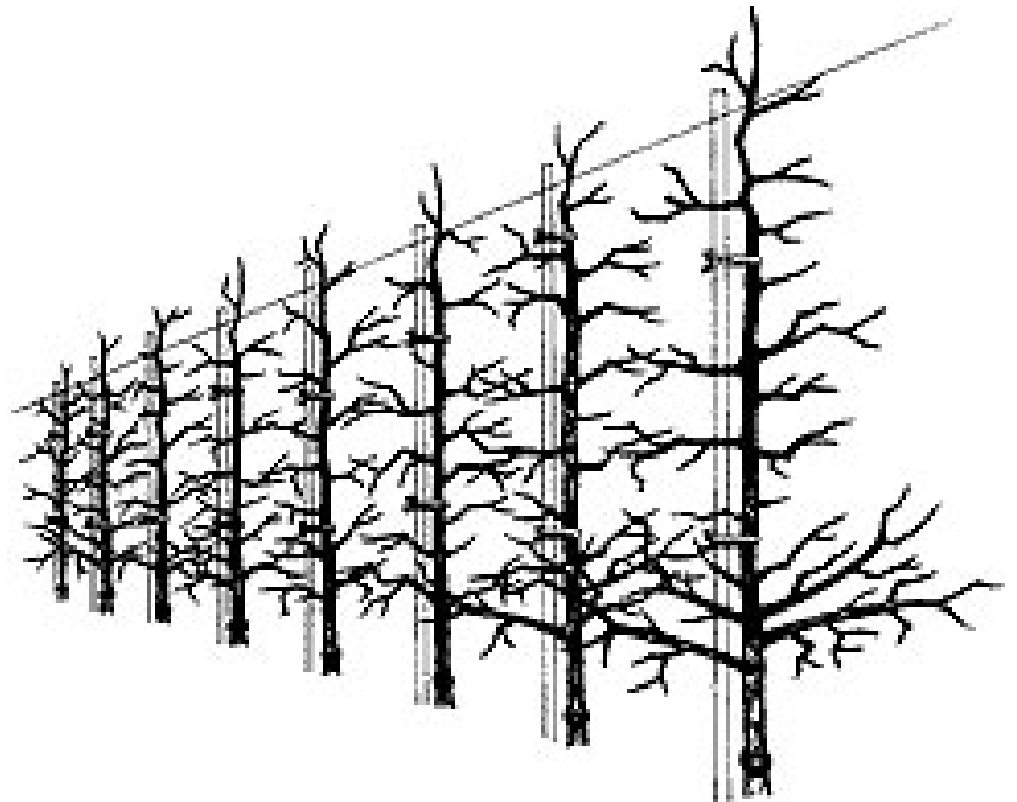
- 200-300 trees/acre
- Usually used with semi-dwarfing rootstock
- Leave only one trunk for the central leader.
- Remove branches with crotch angles less than 60 degrees.
- Remove all branches directly across from one another on the leader.
- Space lateral branches uniformly around the leader to prevent crowding as the limbs grow in diameter.

Slender Pyramid

- Hybrid of central leader and vertical axis (limb renewal)
- 300-500 trees/acre
- Tree height 14-16'
- Rootstocks: M.7, M.26, G.30, G.935, G.6210
- Trees are not headed at planting
- Bottom scaffolds are encouraged to fill in during first 2 year- other lateral removed
- Establish hierarchy of loose whorls around leader
- Renewal pruning of higher tier laterals

Vertical Axis

- 500-900 trees/acre
- Dwarfing rootstocks
- Narrow pyramid shape with dominant central leader
- Max height of about 12-14'



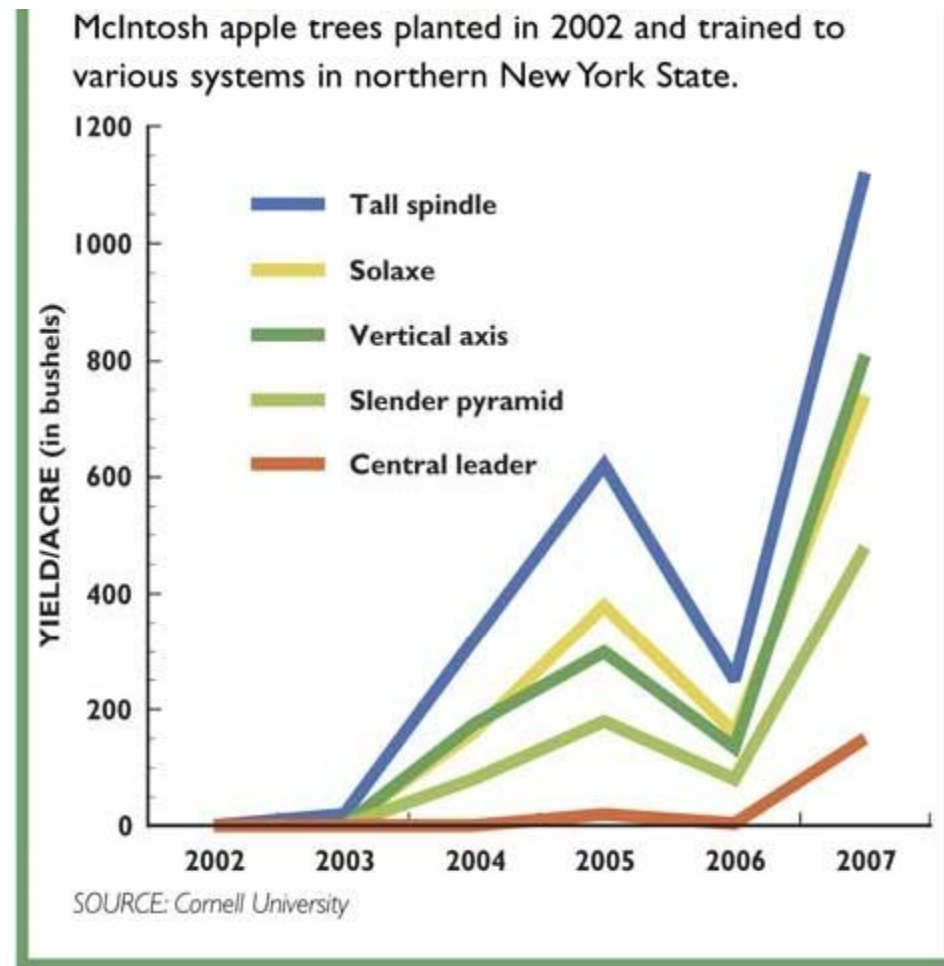
Tall Spindle

- 1000-1500 trees/acre
- Dwarfing root stock
- Highly feathered trees (10-15 feathers)
- Early fruiting- 2nd and 3rd leaf
- No permanent wood! All scaffolds are renewed by complete removal when they become too big
- Upper branches bent below horizontal to devigorate

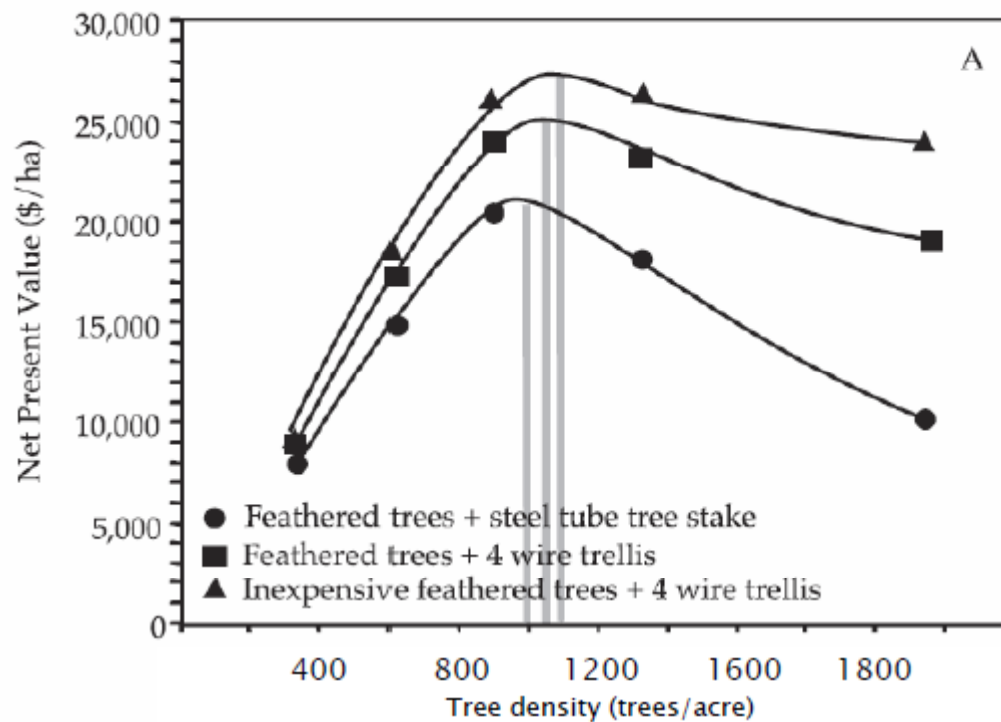
Yield Of 4 Different Training Systems (NY)

Variety	System	Tree Yield/Acre (bu.)				
		Den.	2nd	3rd	4th	Cum
McIntosh	Central Leader	218	0	1	24	25
	Slender Pyramid	444	0	37	113	150
	Vertical Axis	726	2	239	327	566
	Tall Spindle	1307	13	351	771	1135
Honeycrisp	Central Leader	218	0	1	27	28
	Slender Pyramid	444	0	33	117	150
	Vertical Axis	726	0.1	111	277	388
	Tall Spindle	1307	3	132	578	713

Yield of Training Systems (NY)



Optimal Tree Density



Economic studies show a 'sweet spot' for tree density ~ 1000 trees / acre

The Evolution Towards More Competitive Apple Orchard Systems in New York

Teresa Robinson¹, Stephen A. Hoving², Alton Gollman³, Kevin Jurgens⁴ and Mike Turkington⁵

Tree Density

- Optimal tree spacing depends on:
 - Rootstock vigor
 - Scion vigor
 - Soil fertility

John Clements (UMASS) has developed spacing calculator to assist

- <http://www.umass.edu/fruitadvisor/m/index.html>

SLENDER SPINDLE

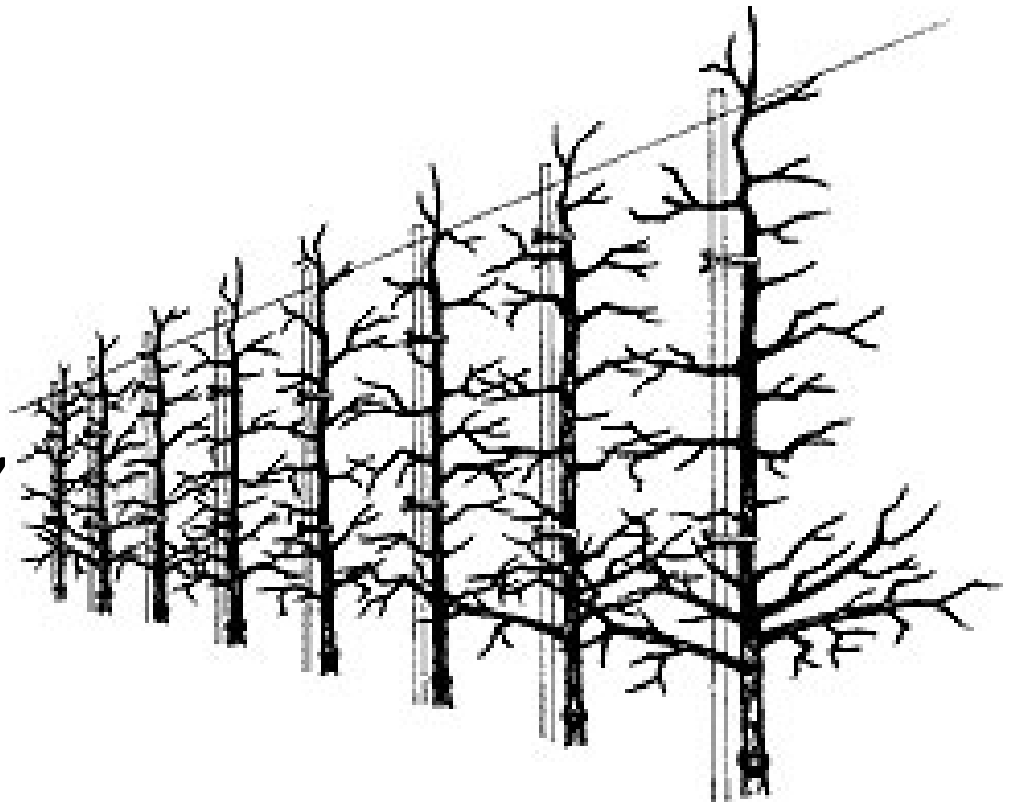
Slender Pyramid

- Density: medium (340 trees/A)
 - in-row spacing: 8'
 - Between row: 16'
- Tree Height: 14-16'
- Rootstock: semi-dwarf
 - M.7, M.26, M.30, G.30, G.935, G.6210

VERTICAL AXIS

Vertical Axis

- 500-1000 trees/acre
- Dwarfing rootstocks
- Narrow pyramid shape with dominant central leader
- Max height of about 10'
- Few cuts made during the first few years

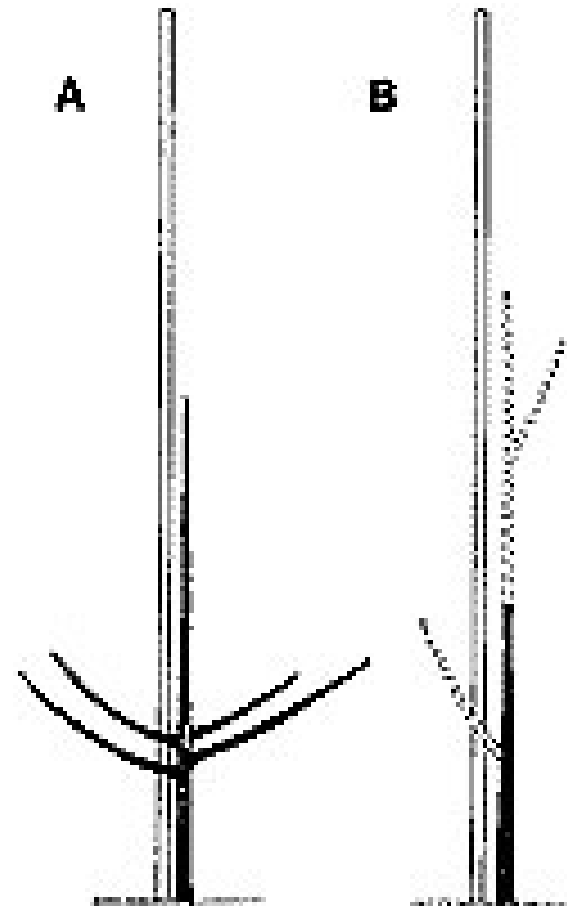


Tree Spacing and root stock

- Between row: 12-14'
- In row: 5-7'
- Tree height: 12-14'
- Rootstocks:
 - M.9, G.41, G.11, G.16
 - M.26- can be used but only with weaker scions

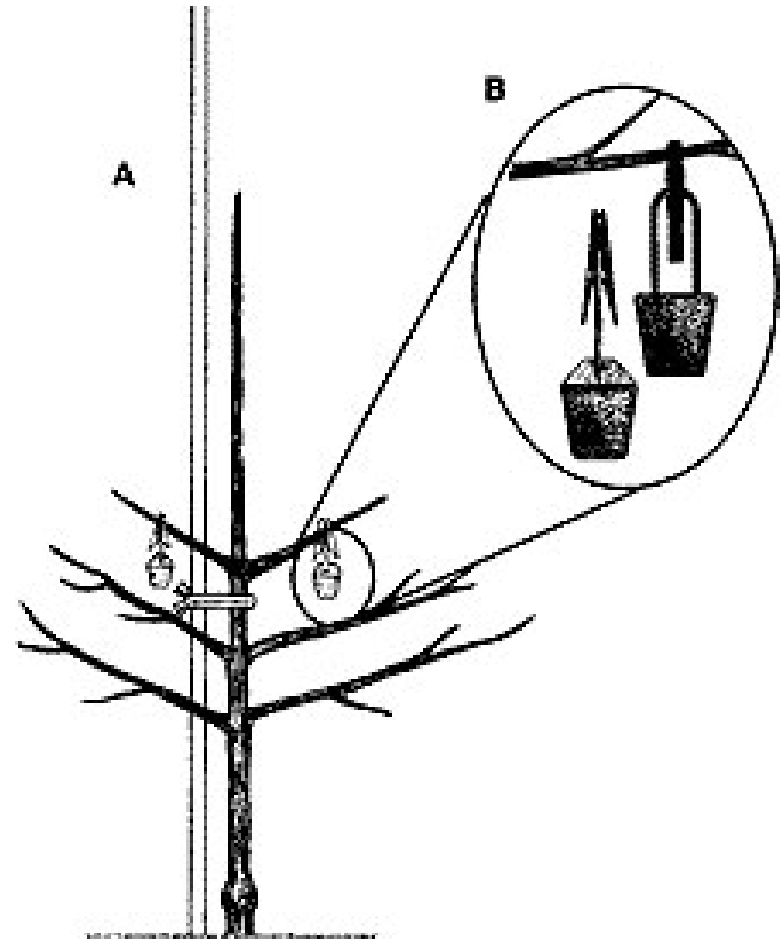
Vertical Axis: Planting Year

- Ideal tree has 4 branches evenly spaced and central leader
- Remove any branches within 18" of soil surface
- Remove branches that are at a narrow angle or unevenly spaced around the leader
- Poorly branched tree (B) head leader and remove branches



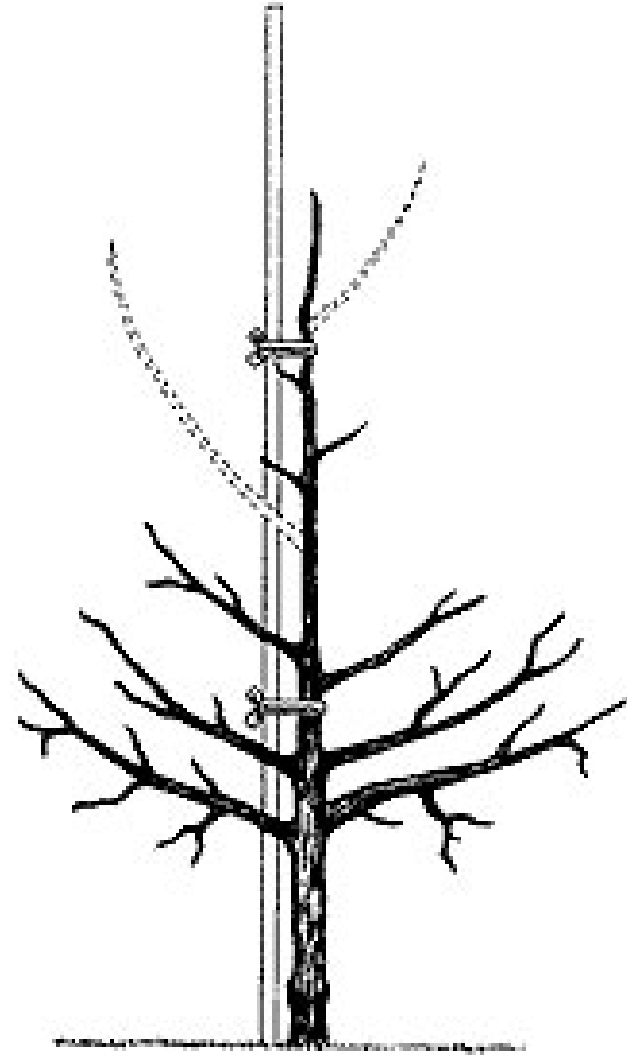
Vertical Axis: Summer Pruning

- July- Any branches less than 60° angle should be spread or tied down
 - Avoid excessive weights which will increase angle beyond 60°
- Sept- tree weights can be removed



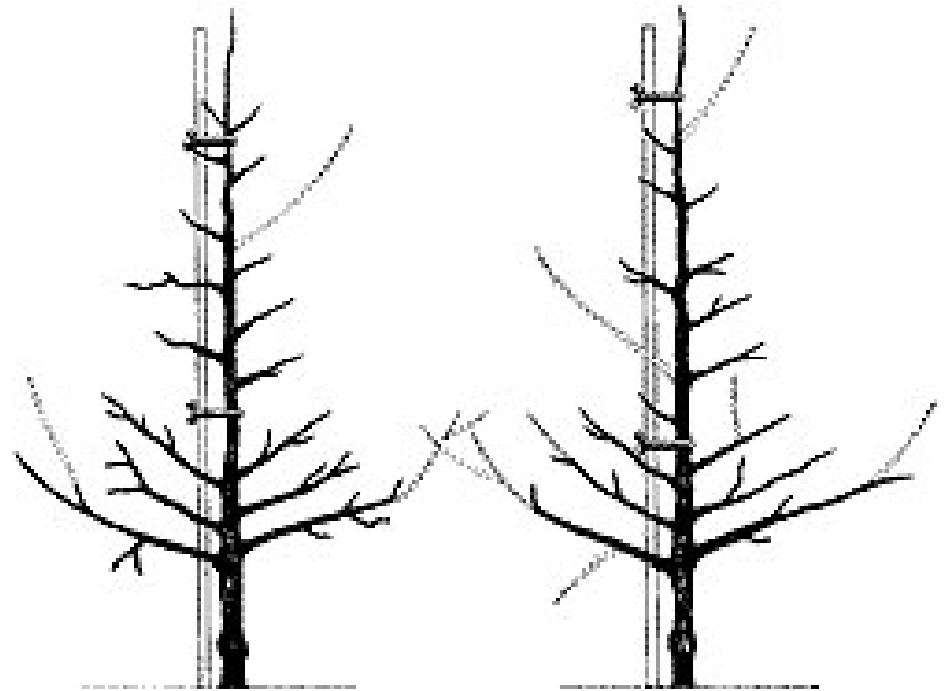
Vertical Axis: 2nd Year

- Spring- Remove vigorous shoots that compete with the central leader
- July- Weight limbs that are less than 60° angle



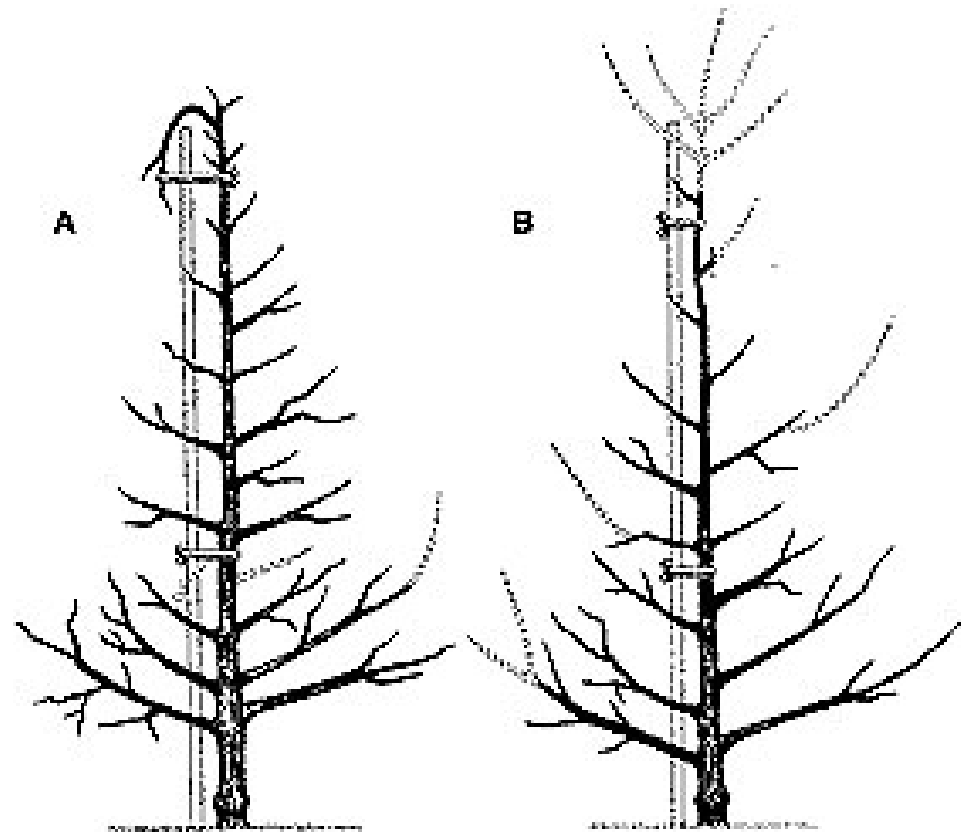
Vertical Axis: 3rd Year

- Spring- removed vigorous branches that compete with the central leader or shoots not trained to proper angle
- Prune lower branches that have grown into adjacent tree
 - Cut back to 2-year old wood or older to a less vigorous lateral branch



Vertical Axis: Mature Tree

- Manage height:
 - Bend over top
 - Head central leader back to less vigorous lateral branch on 2 year old wood or older
- Maintain pyramid shape
 - Bottom- cut back into 2 year old wood or older
 - Top- cuts should be made near the central axis
 - Buds at base of stub cuts will produce new branch



Vertical Axis: Mature Trees

- Remove:
 - dead/diseased branches
 - upright suckers
 - branches growing in toward tree
 - Branches with narrow angles
 - Branches directly above another branch to prevent shading
- Redeveloping Pyramid Shape
 - Cut back limbs to less vigorous laterals to the desired form

TALL SPINDLE

Tall Spindle

- 1000-1500 trees/acre
- Dwarfing root stock
- Early fruiting- 2nd and 3rd leaf
- No permanent wood! All scaffolds are renewed by complete removal when they become too big
- Upper branches bent below horizontal to devigorate

Tall Spindle: Planting

- Planting stock must be high caliper and highly feathered (8-15 Feathers)
- Very little growth is needed to fill the small space, so minimal pruning is needed
- Remove only larger branches that are out of balance with rest of tree
 - Greater than $\frac{2}{3}$ the diameter of the leader
 - Stub cut that leaves adventitious bud for renewal branch

Tall Spindle: Planting

- Large Caliper
 - Do not head the leader
 - Remove all feathers below 24"
 - Remove feathers larger than 2/3 dia. of leader
 - Do not tip the feathers
- Med Caliper poorly feathered trees or whips
 - Head leader at 60"
 - Remove feathers larger than 2/3 dia. of leader
 - Score above every other bud along leader from 24"-42" high

Tall Spindle: First Summer

- Pinch side shoots in upper $\frac{1}{4}$ of leader when shoots are 4-5" long
 - Re-pinch when regrowth is 4-5" long
- Tie leader to support system
- Train lower branches to below horizontal
 - Encourage flower production

Tall Spindle: 2nd Year

- Do not head leader
- Do not head feathers
- Remove:
 - Branches competing with leader
 - Narrow angled branches
 - Large scaffolds(2/3 dia. Of leader)
 - Large branches=large trees
 - Side branches longer than 2"

Early Cropping Is Essential

- Tall spindle requires reduced vegetative growth
- Recuperate establishment costs
- Cropping must begin in second year
- Cropping targets:

Year	# of fruit
1	1-5
2	20
3	40
4	70
5	90

Tall Spindle: Year 3-5

- Bend top
- Limit height by cutting back to weak fruitful side branch
- Remove:
 - Branches larger than $\frac{3}{4}$ " diameter
- Shorten older, pendant branches to a weak side branch or spur

Tall Spindle: Mature Trees

- Limit height by cutting to a weak fruitful side branch
- Annually remove 2 branches (limb renewal pruning)
 - Focus on middle tiers of branches first, then upper
- Remove low hanging branches
- Shorten pendant branches to point of bend
- Do not over prune!