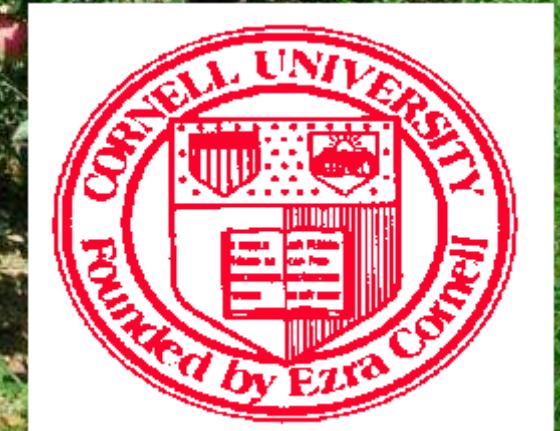


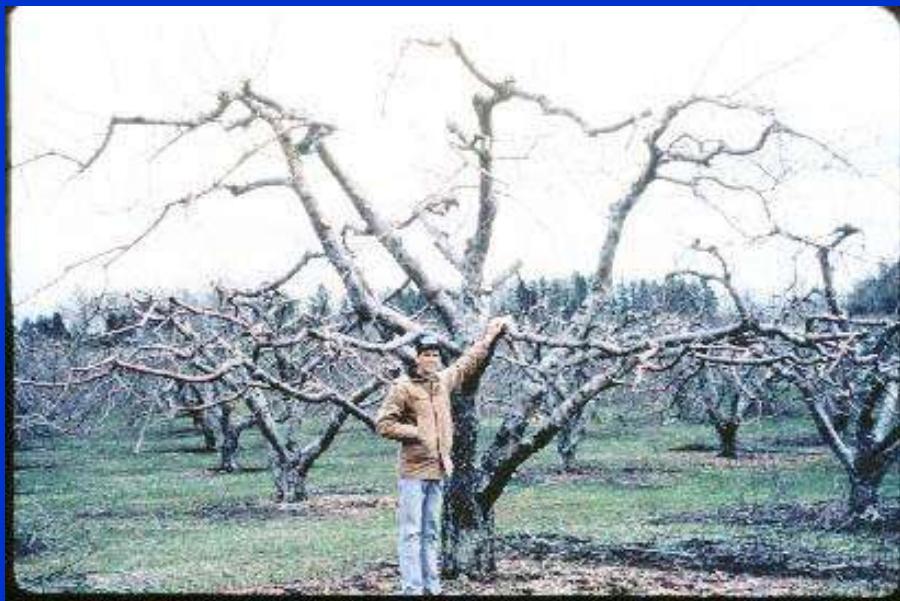
Apple Orchard Systems: Tree Density, Rootstocks and Pruning Systems



Terence Robinson and Steve Hoying
Dept. of Horticulture, Cornell University, Geneva, NY 14456



The evolution of orchard systems in the USA



Umbrella tree (100 trees / ha)

Central Leader (500 trees / ha)



Tall Spindle
(2,500 trees / ha)

Vertical Axis (1,200 trees / ha)

Slender Spindle (1,500 trees / ha)

Pedestrian Orchards -1980's



Multiple Rows using M.9



Moderate yields and moderate light interception

High yields but poor quality fruit in the middle row

High yields and high light interception



Geneva Y trellis/M.26

In the late 1980's tall orchards (again)



Precision V-trellis 2,000 trees/ha

Vertical Axis- 1,500 trees/ha

Mid -1990' s - Super High Densities (5,000 trees/ha)



Super Spindle / M.9

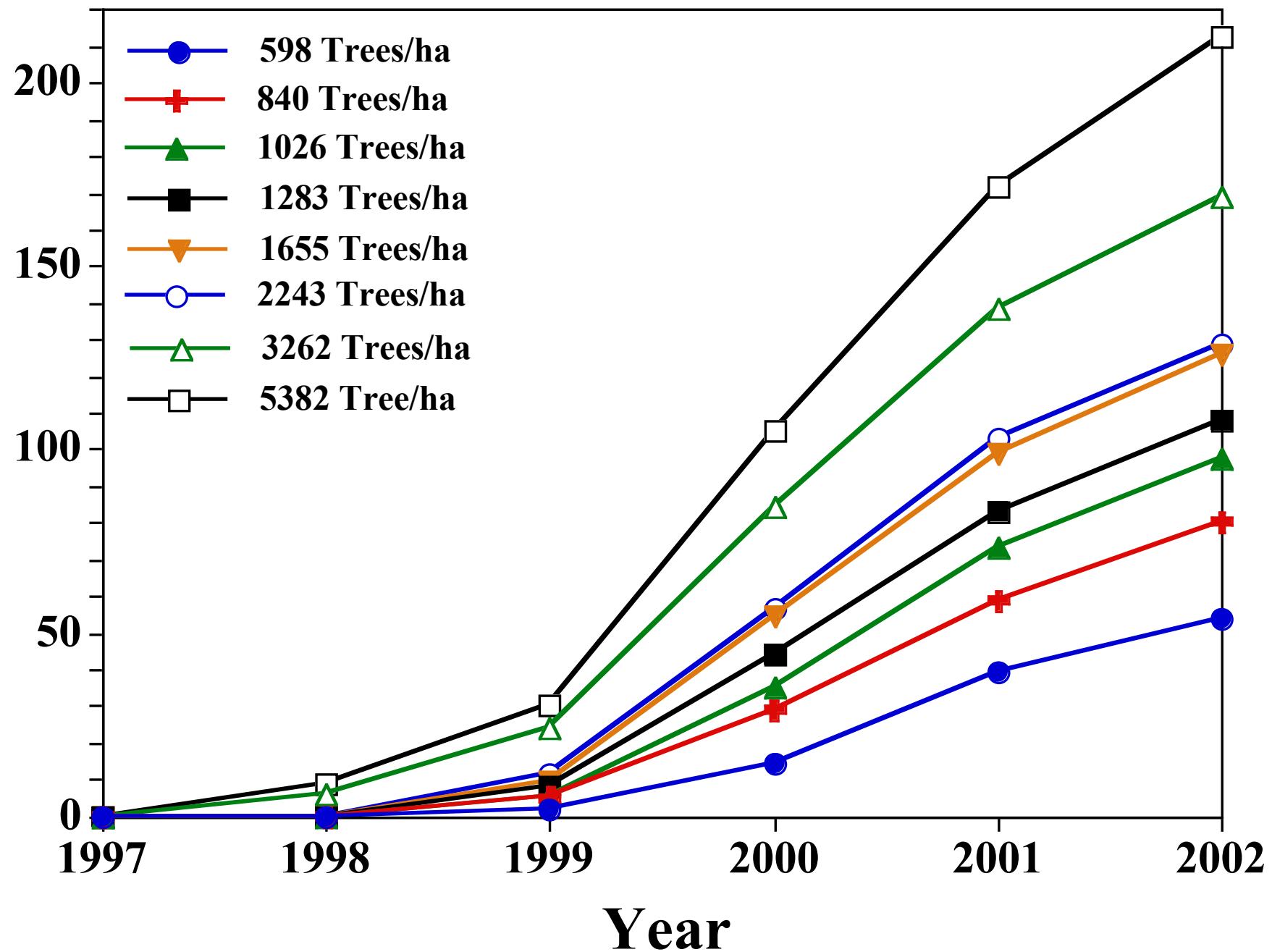
V Super Spindle/M.9

Late 1990's-

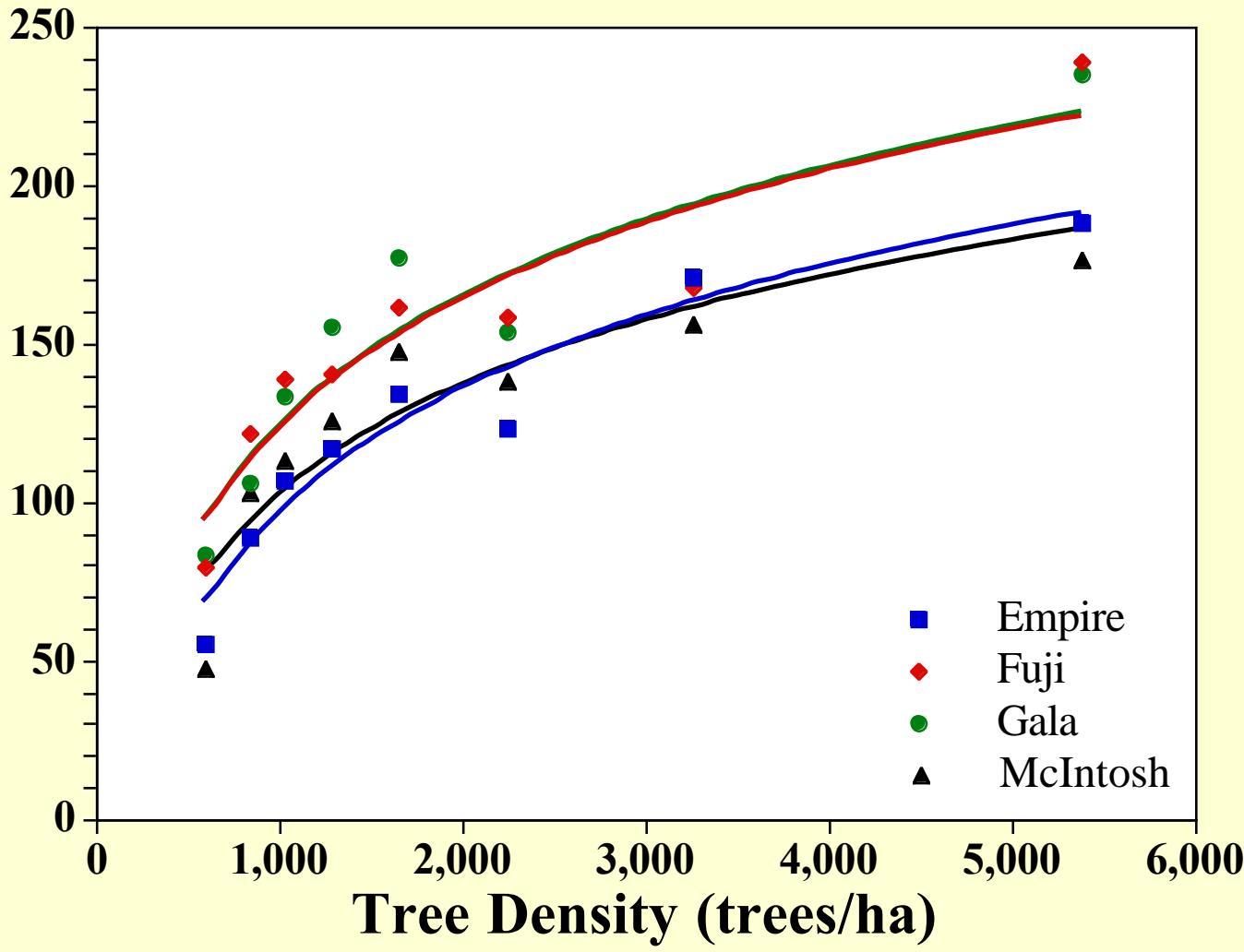
Tall Spindle/M.9



Effect of Tree Density on Cumulative Yield



Effect of Tree Density on 7 Yr. Cumulative Yield



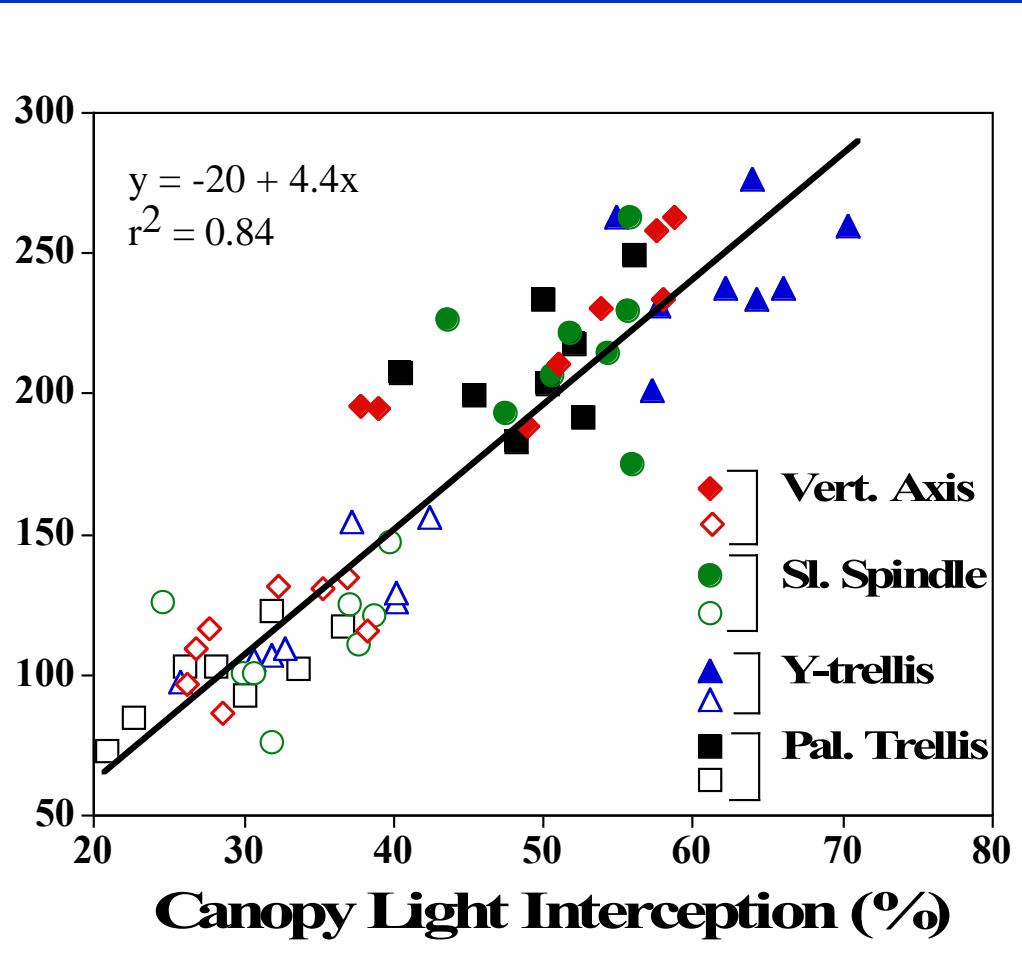
Tree density had a highly significant negative effect on cumulative yield per tree but a highly significant positive effect on yield per ha. The cumulative yield per ha of the highest tree density was 3X greater than the lowest density



Geneva Y-trellis/M.26



成熟的果园产量更高 (1,500–2,000蒲式耳/英亩)



70–75% 的采光量最佳

树高= 行间距 * 0.9 会达到 70–75% 的采光量

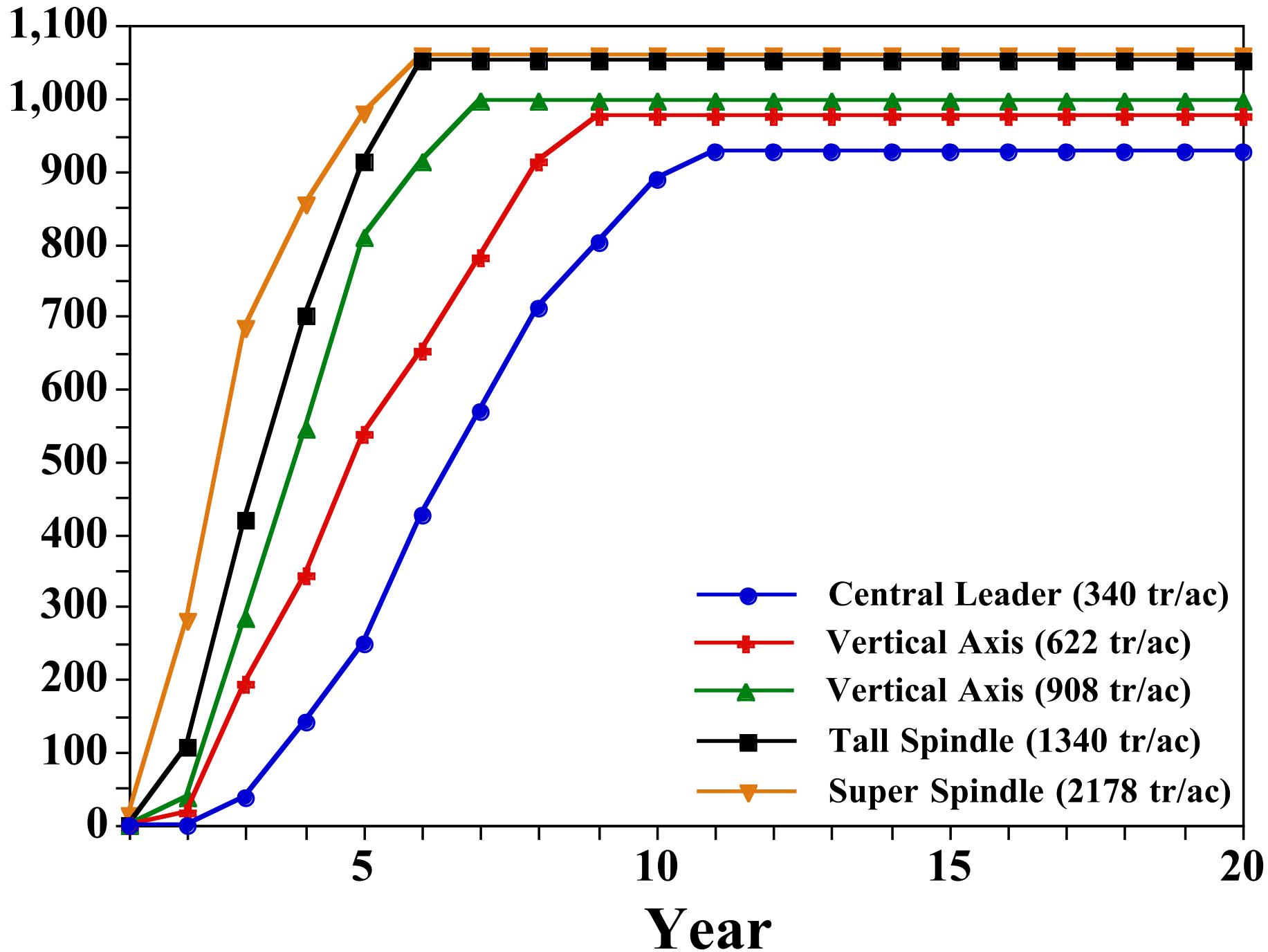


伸手即摘果园的采光量中等，产量也中等，除非行间距 7-8 英尺 (210-240 cm)

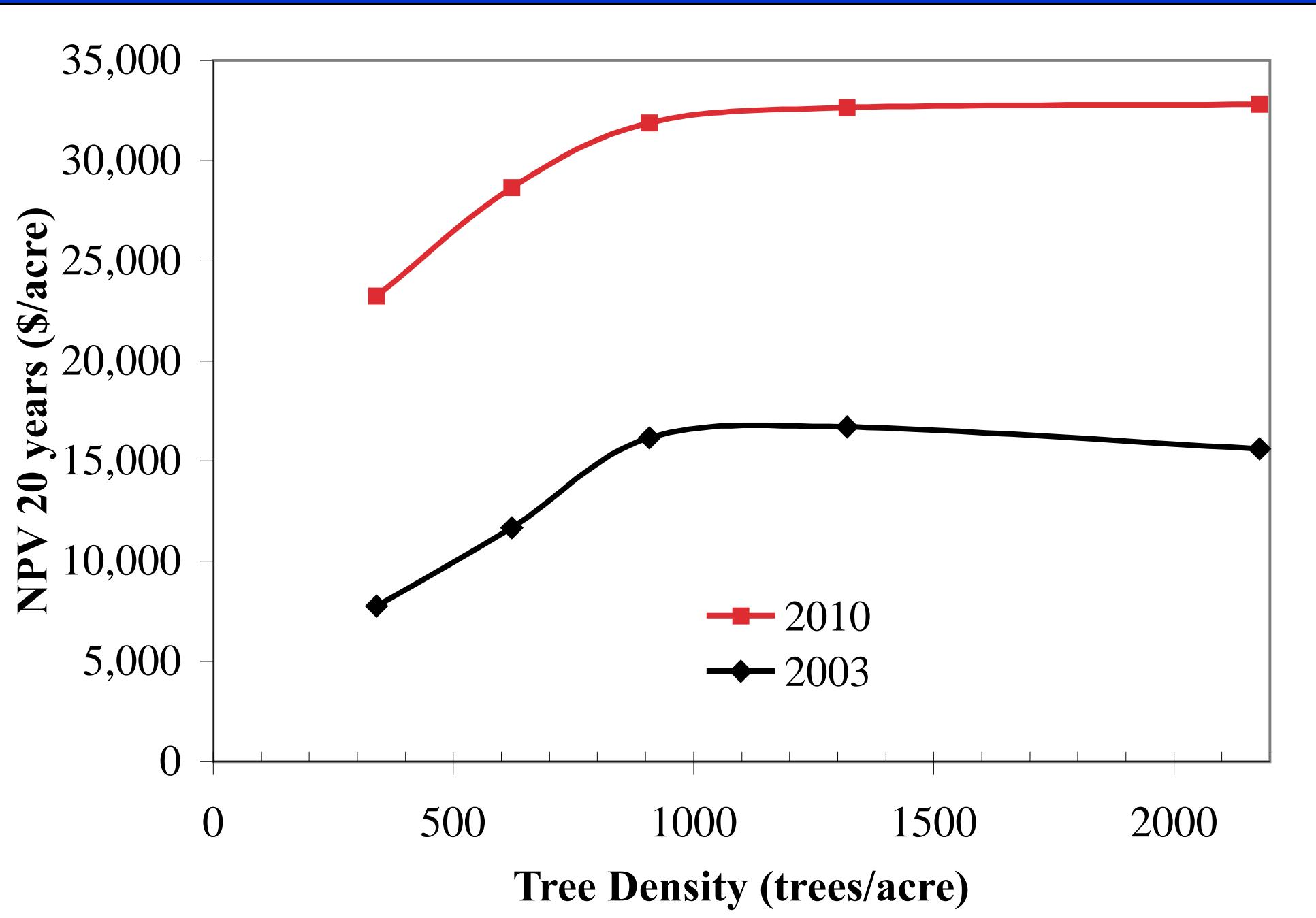


高树截光更多，
产量也更大

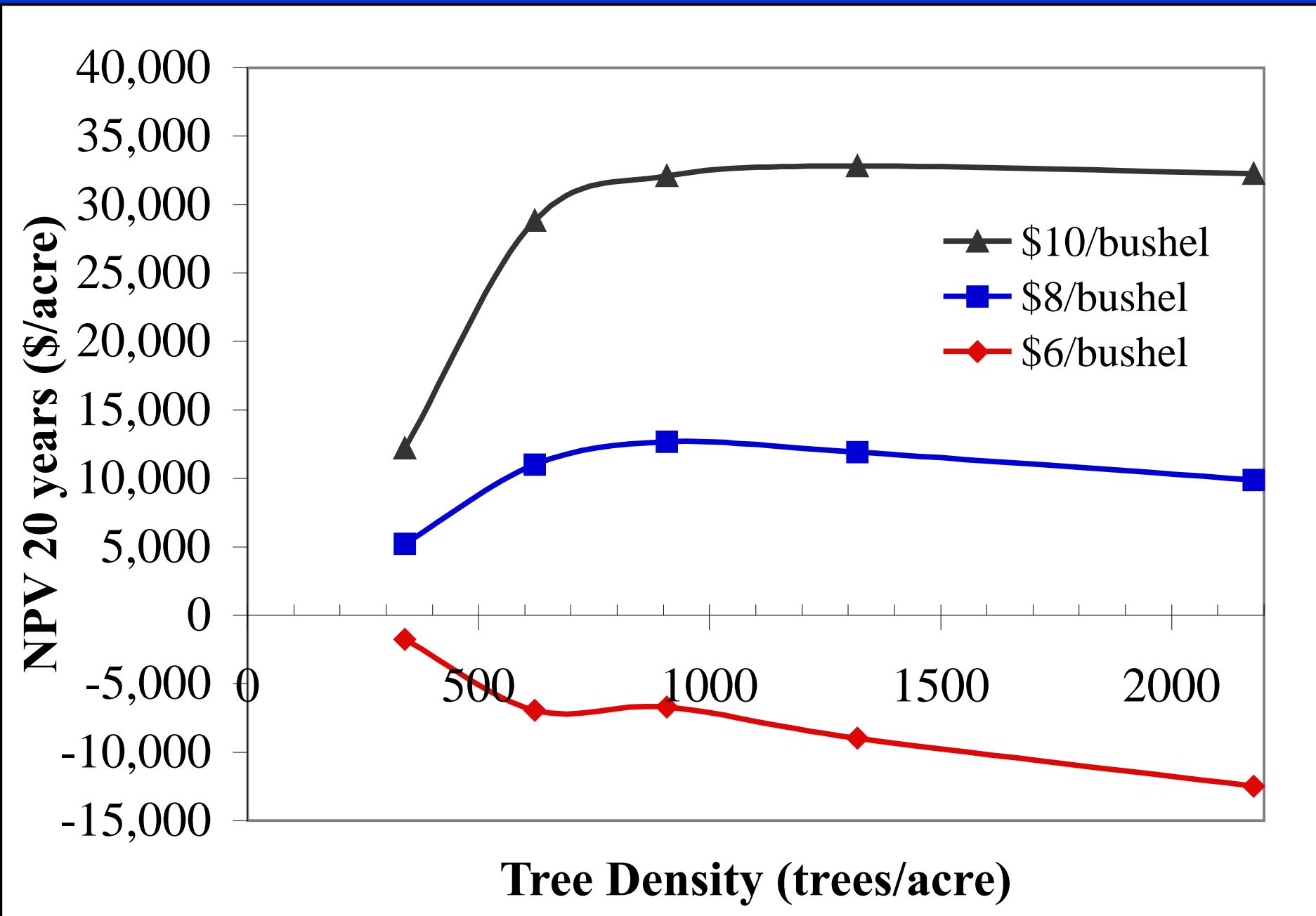
Annual Yield of 5 Systems



Profitability of Apple Orchards in NY over 20 Years



What is the optimum planting density?



The answer depends on price

Economic Summary

- Our results indicate that the New York growers should increase planting density from 1,500 trees/ha to 2,500-3,300 trees/ha in a system we call the “Tall Spindle”



Apple Rootstocks: The Foundation of High-Density Orchards

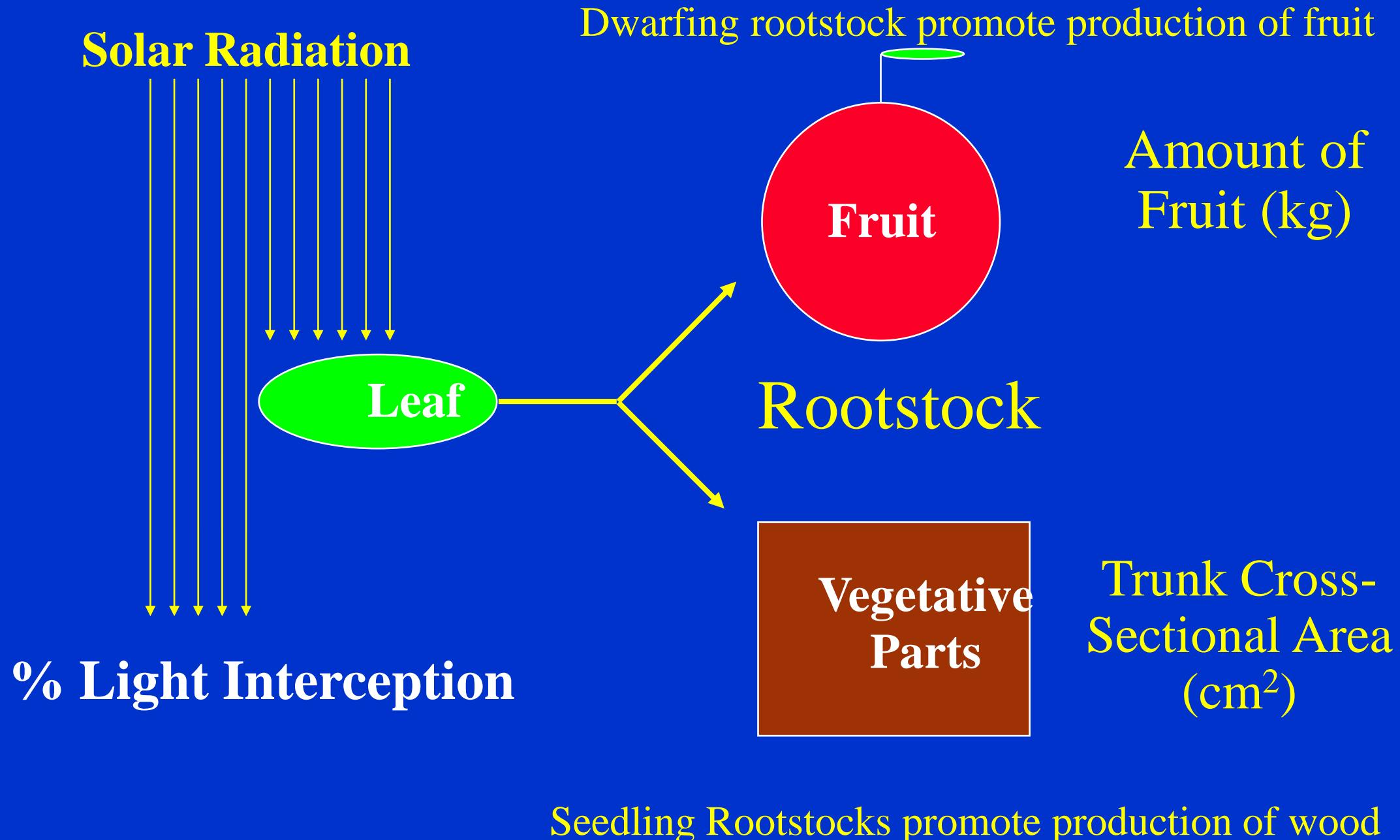




Benefits of Dwarfing Rootstocks

- Early of cropping (precocity)
 - Shorter time to payback initial investment
- Improved yield/unit land area (productivity)
 - Annual profitability
- Reduced tree size (dwarfing level)
 - Ease and cost of spraying
 - Ease and cost of picking
 - Ease and cost of pruning

The Apple Tree



Current Apple Rootstocks:

- Currently in the United States the most common apple rootstocks are M.9, M.26, B.9.
 - 60% of the rootstocks are M.9,
 - 20% are B.9,
 - 10% are M.26,
 - 4% are M.7,
 - 3% are MM.111
- In China most apple rootstocks are seedling

Challenges with Current Apple Rootstocks:

- Over the last 60 years, growers worldwide have used the Malling series of rootstocks from England. However their limitations are:
 - lack of winter hardiness,
 - lack of resistance to *Phytophthora* root rot,
 - susceptibility to fire blight bacterial disease,
 - burrknots,
 - poor anchorage,
 - root suckers,
 - sensitivity to apple replant disease,
 - brittle graft unions.
 - lack of precocity.

The Geneva Apple Rootstock Breeding and Development Program

Joint Program with USDA and Cornell University

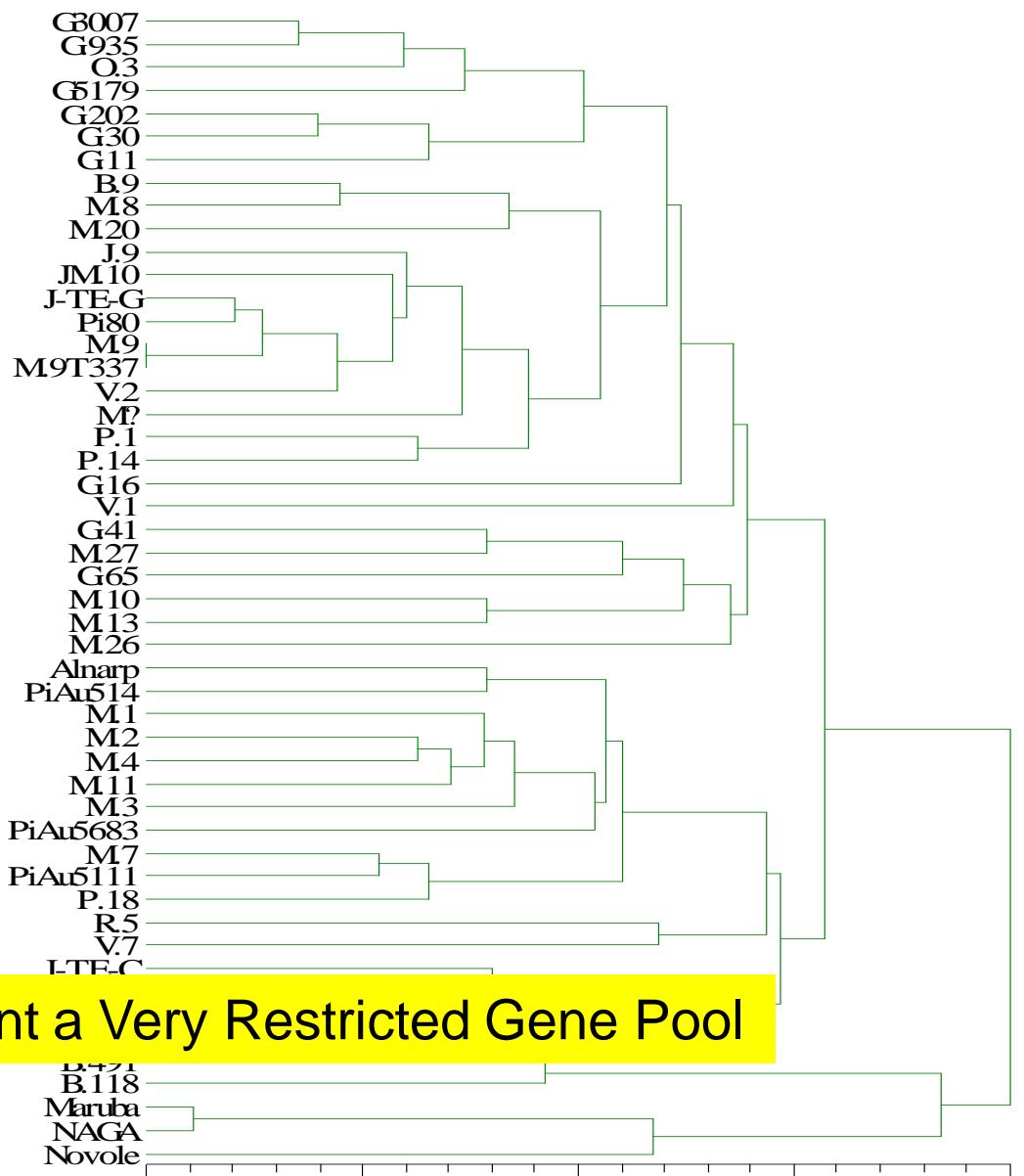
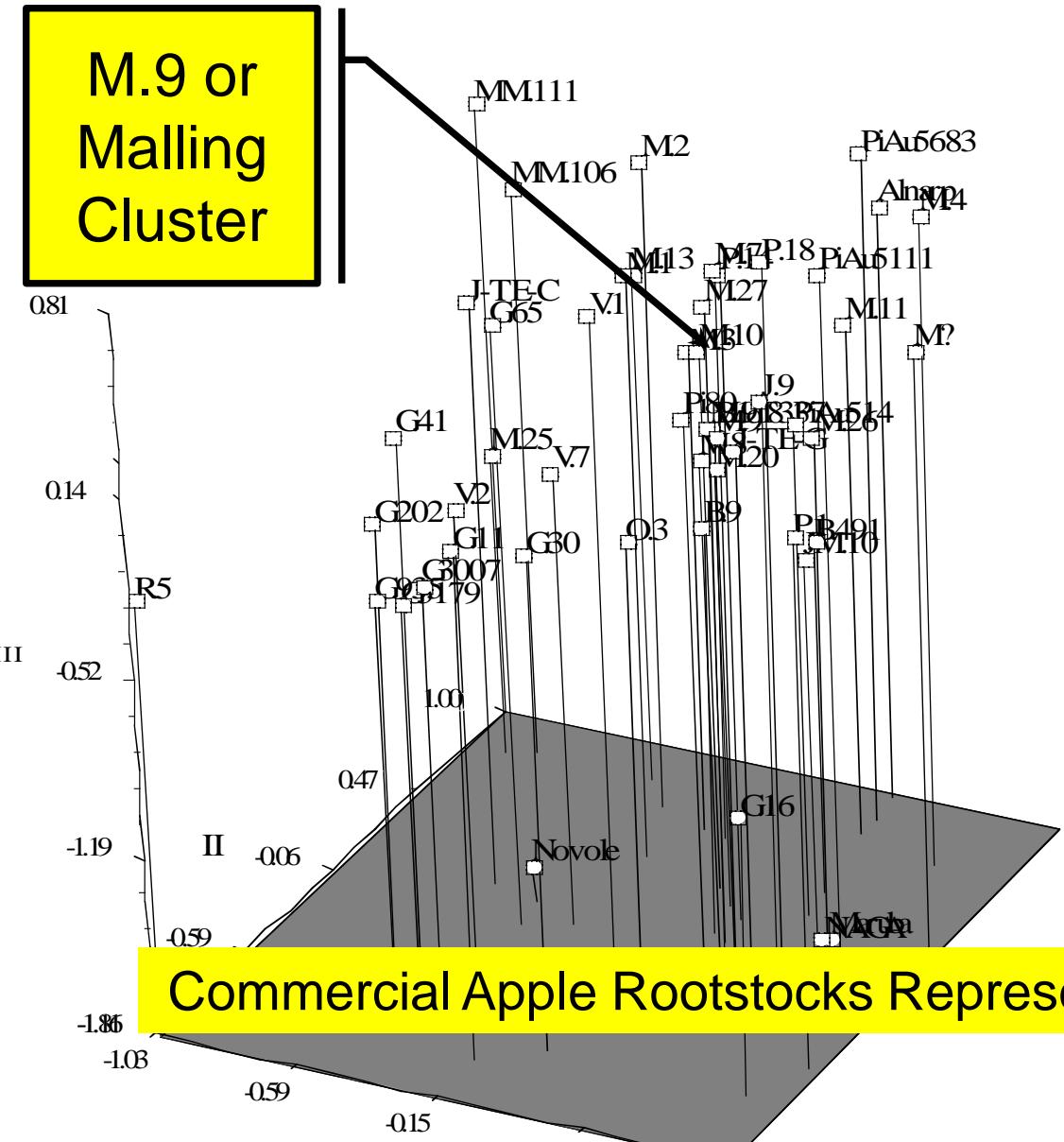
Dr. Gennaro Fazio, Herb Aldwinckle and Terence Robinson

Goal: Produce a series of rootstocks which are resistant to important rootstock diseases and insects that are dwarfing, productive and efficient.

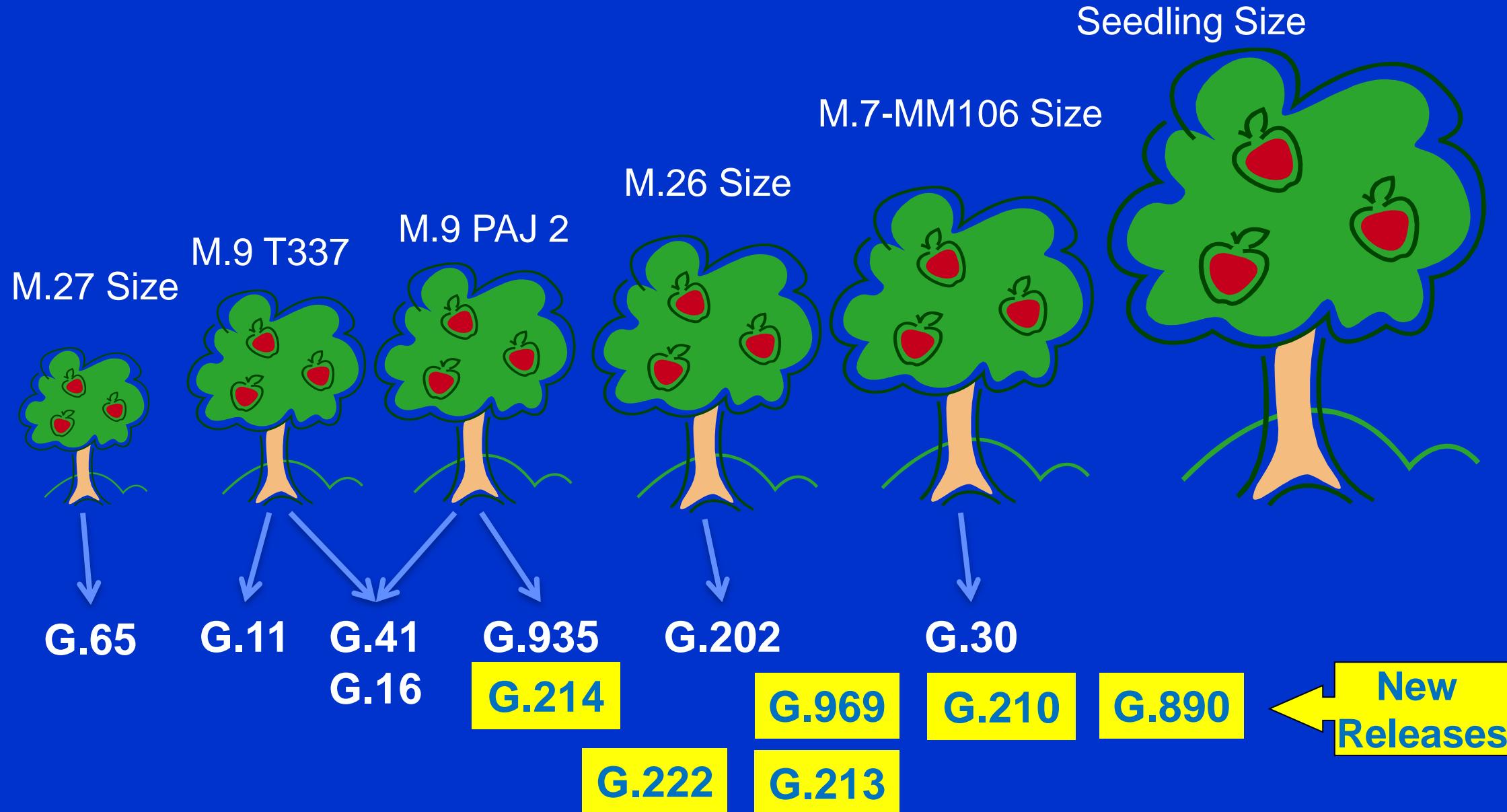
- Resistance to fire blight
- Resistance to *Phytophthora* root rot
- Resistance to woolly apple aphid
- Cold tolerant
- Resistant to apple replant disease.



The Geneva® rootstocks are a distinct genetic group from most commercial rootstocks



Released Geneva® Apple Rootstocks Arranged by Tree Size



Propagation of Geneva® Rootstocks

- Rootstocks are propagated in the USA by stoolbed.
- The Geneva rootstocks are started using Tissue Culture
 - Tissue Culture to induce greater juvenility in stoolbed
 - Tissue Culture plants as then planted in stoolbeds



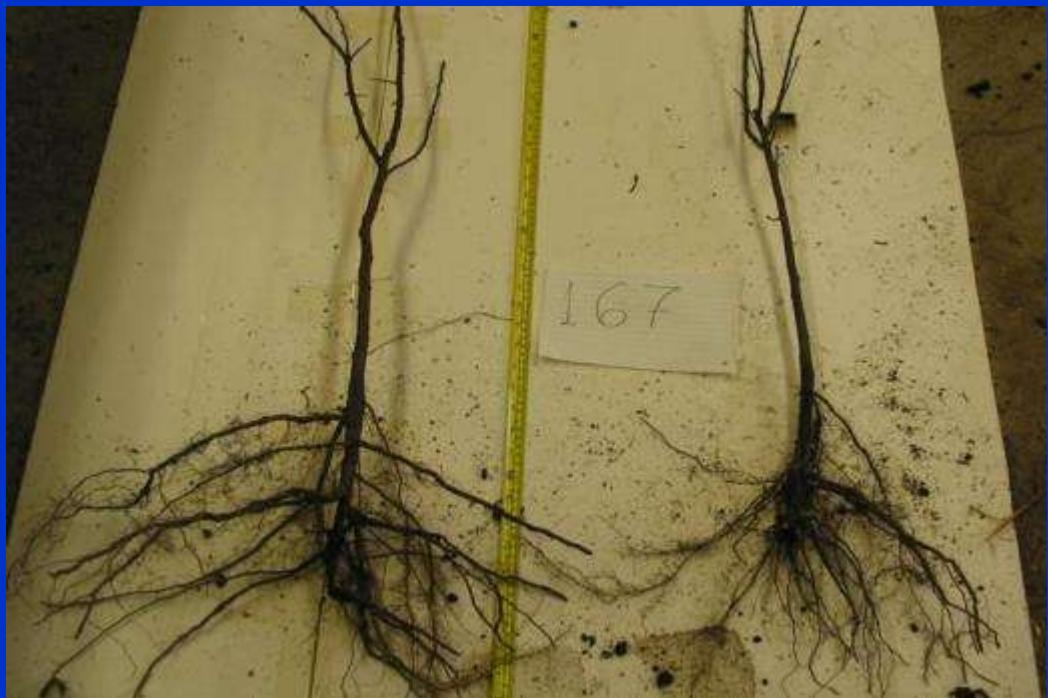
Rooting of G.41 Apple Rootstock from tissue culture plants



Rooting of G.41 Apple Rootstock in propagation beds



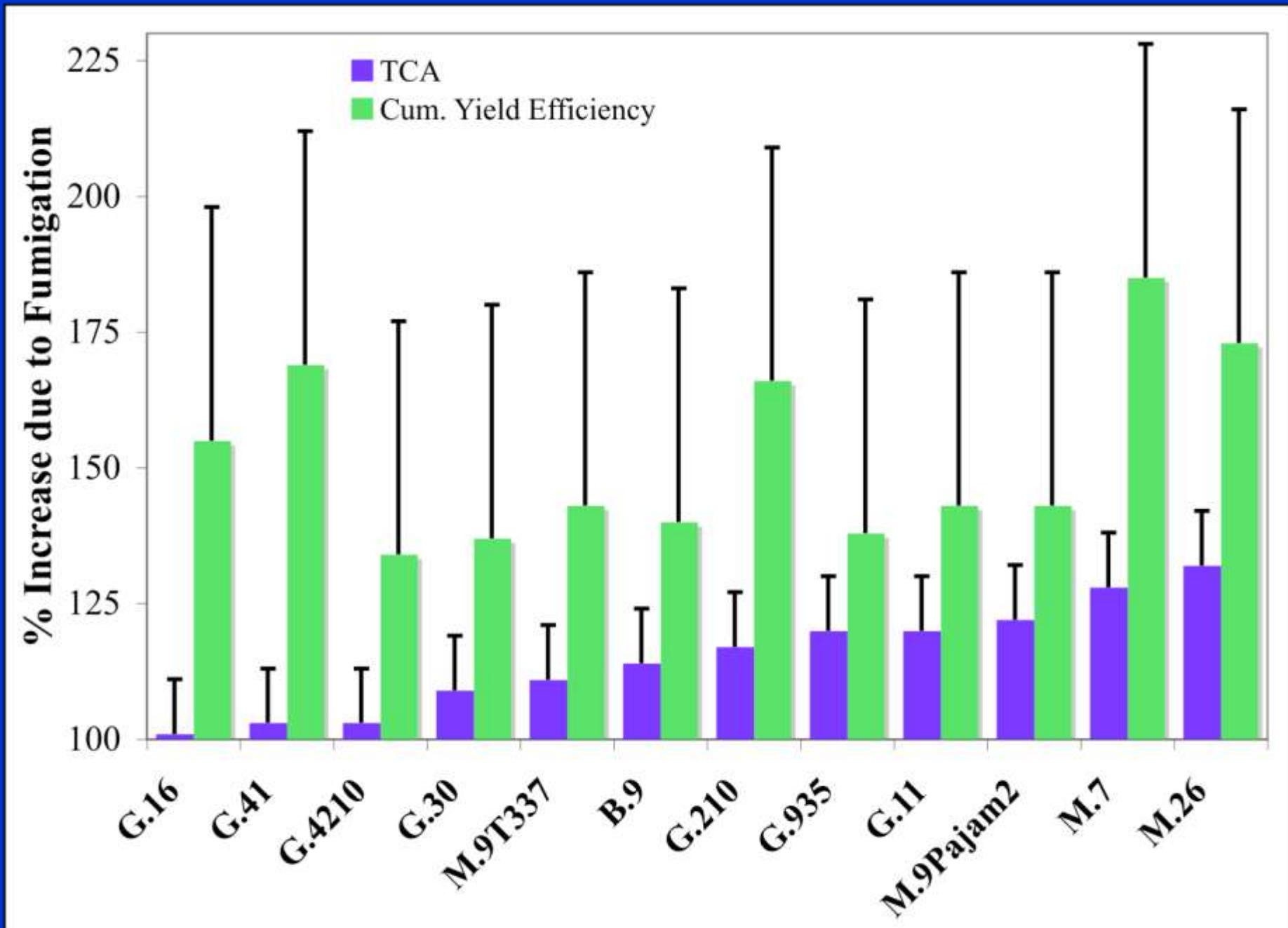
There is Variability in Root Architecture among Geneva Stocks



Drought Affects Root System Characteristics



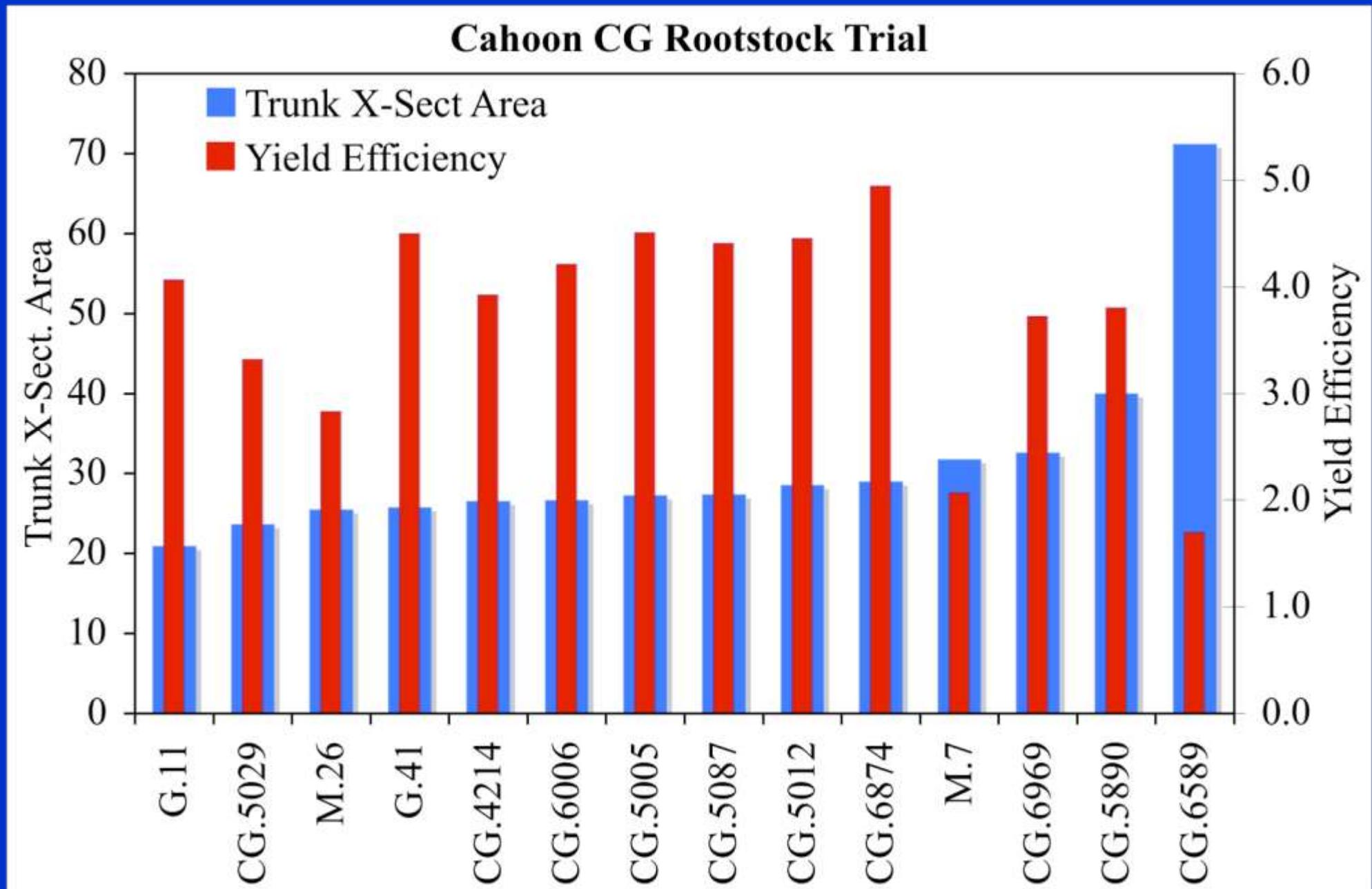
Many Geneva Rootstocks have Tolerance to Replant Disease



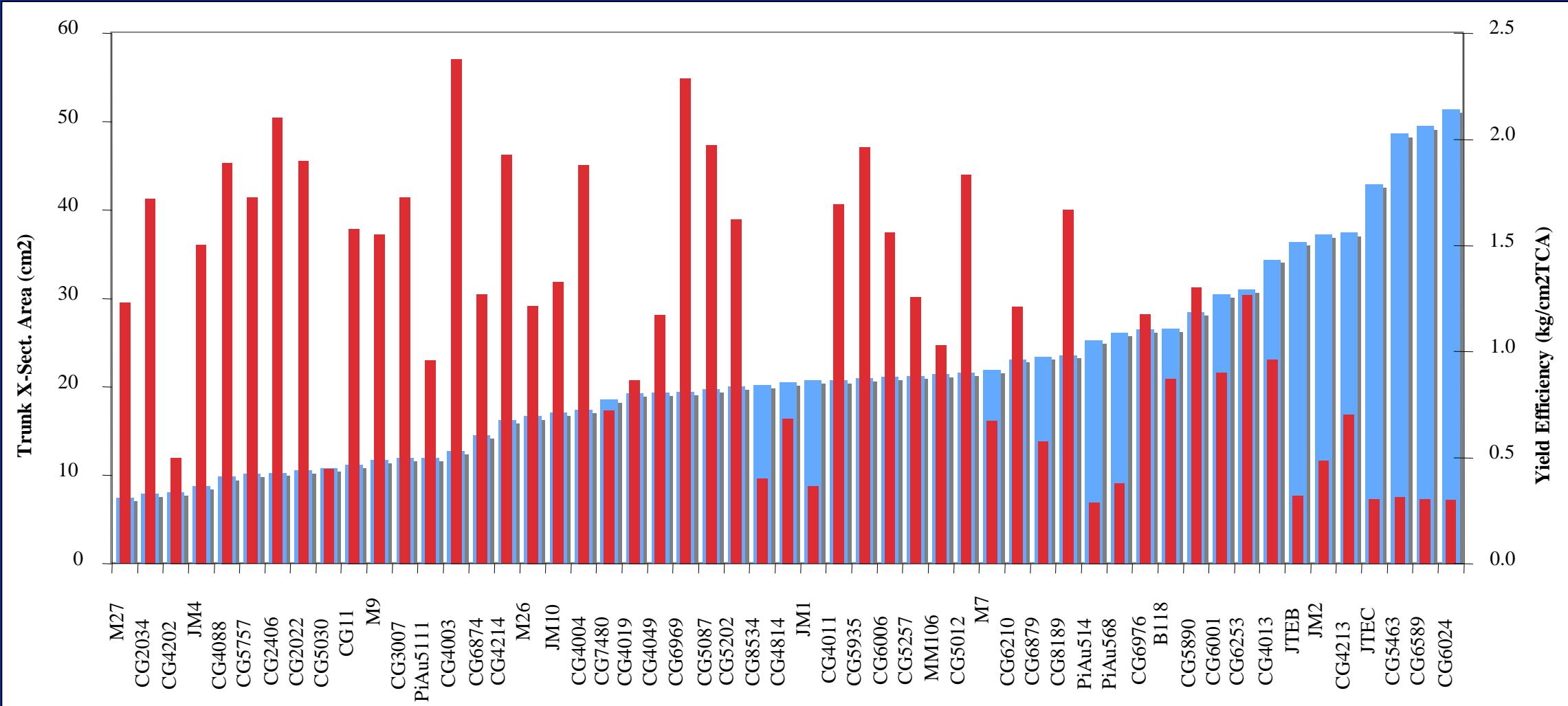
Fine Root Trait in Associated with Replant Disease Tolerance



Geneva Rootstocks have High Yield Efficiency



There are Many New Geneva Rootstock Selections to Test



在中国测试新砧木的可能性

我们计划和中国的大学合作，建立几个评估性果园



- G. 11 针对活力强的品种
- G. 41 针对活力较弱的品种或重茬
- G. 935 或 G. 202 针对活力很弱的品种

2013- Six Leading Production Systems in the World



Tall Spindle



Super Spindle



Precision V-Trellis



Bi-Axis



Solaxe



Mur Frutiere (Fruiting Wall)

Leading Apple Orchard Systems in the World

System	Tree Density (trees/ha)	In-Row (cm)	Between Row (m)
Tall Spindle (free)	2,500-3,300	90-120	3.3-3.6
Super Spindle (free)	5,000-6,000	50-60	3-3.3
Bi-Axis (free)	1,800-2,500	120	3.3-3.6
Solaxe (semi-organized)	1,500-2,500	120-180	3.6-4.5
Precision V-trellis (organized)	2,500-5,000	60-90	4-5
Fruiting Wall (free)	2,500-3,300	90-120	3.3-3.6

Principles of the Tall Spindle System

- Optimum Economic Tree Density
 - 2500-3,000 trees/ha
- High Early Production (Feathered trees+minimal pruning)
 - 150t/ha in first 5 years
- High Mature Yields (High light interception 70-75%)
 - Tree height=0.9*row width (~ 3-3.3m)
 - 65t/ha with Gala
 - 75t/ha with Fuji
- High Fruit Quality (Good light distribution in the canopy)
 - thin conical canopy
 - no permanent branches (limb renewal pruning = removal of limbs larger than 2 cm diameter.
 - columnarized (simplified) fruiting branches
 - balanced vigor and calm trees
- Improved Labor Efficiency
 - Simplified pruning recipe
 - Partial mechanization of dormant pruning and tree training (30-40% reduction in labor costs)
 - Summer side wall shearing for summer pruning.



Production potential in the second year

0 fruits



5 fruits



10-15 fruits



20-50 fruits



With the Tall Spindle we can achieve high early yields with highly feathered trees.



Brookfield Gala/G.41
New York State
10 branches at planting (2006)
40 fruits in the second leaf
(2007)



The Potential

Fuji/CG.007

85 fruits/tree in the
second leaf X 3374

trees/ha = 43 t/ha

Managing Feathered Trees

With the Tall Spindle we suggest removing 1-2 of the most vigorous feathers at planting and tying the rest below horizontal soon after planting.



Up to 3 feathers can be removed

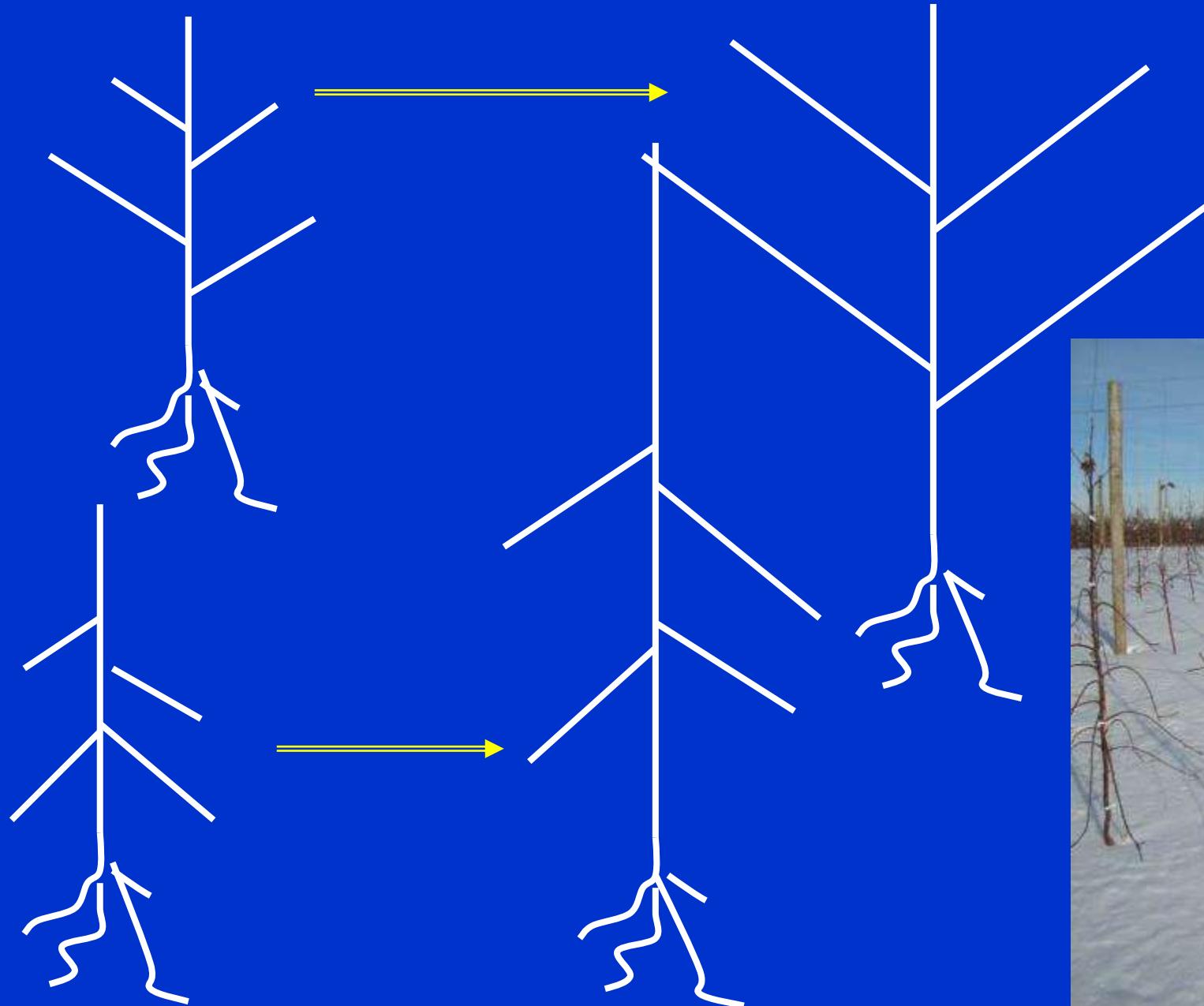


With Whips, tree should not be headed.



促进早产的策略

- 定植时不进行修剪 (除了去除过大的侧枝以外)
- 定植后尽快将侧枝压倒水平线以下





End of First Year
All Feathers tied down at planting



Tree at end of
second year
Feathers tied
down in year 1



Tree at end of
second year
Feathers left
erect in year 1



Grow the tree to the top wire (10 ft) by the end of the second year



Gala/M.9



Honeycrisp/M.9





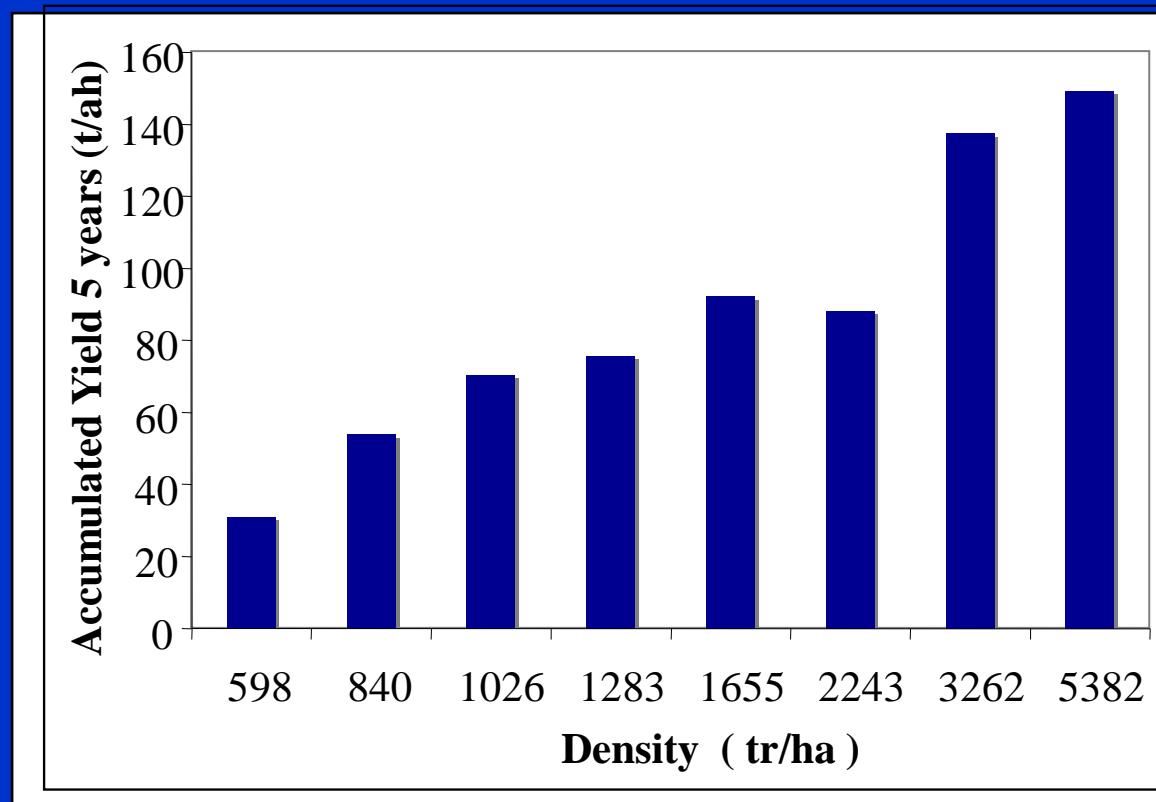
嘎拉/M.9 第五年, 80吨/公顷



New York targets for early yield:

- 10 t/ha in the second leaf
- 25 t/ha in the third leaf
- 45 t/ha in the fourth leaf
- 70 t/ha in the fifth leaf

A total of 150 t/ha over the first 5 years



Common Error: Excessive crop load in the 2-4th Years

We use a strict program of crop load management in the first 5 years.

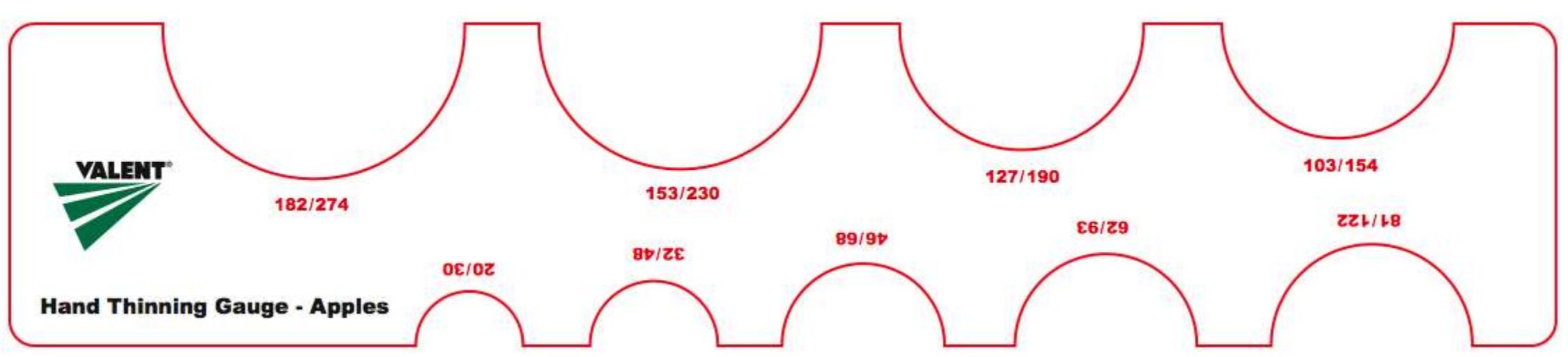
For non biennial bearing varieties we limit crop load to 5 fruits/cm² TCA

For biennial bearing varieties we limit crop load to 4 fruits/cm² TCA

Approximate number of fruits / tree

1 st Year	2 nd Year	3 rd Year	4 th Year
0	20	40	80

1st Year 2nd Year 3rd Year 4th Year



Concepts of Pruning – Limb Renewal Pruning



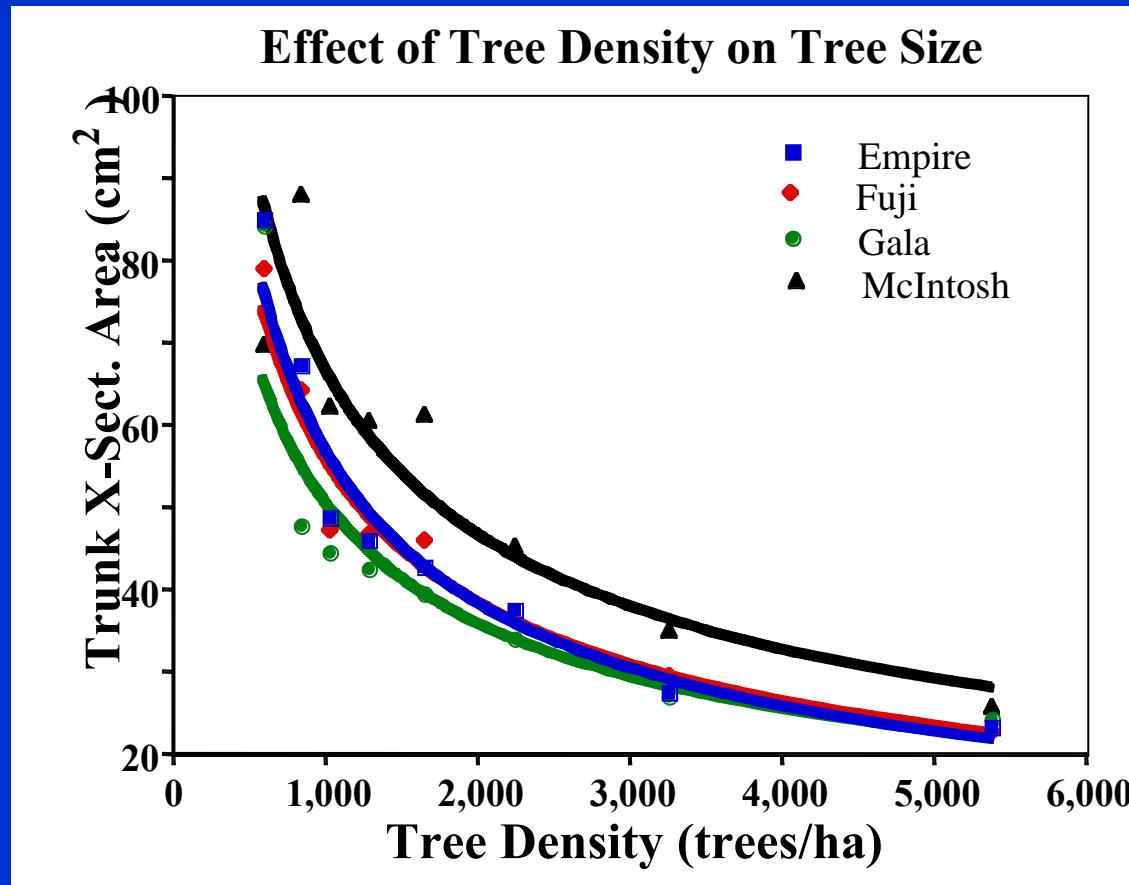
Common Error: Allowing large branches to remain in the tree



Large upper branches cause shade on lower canopy

Large branches export carbohydrates to trunk and root system.

“Large Branches Create Large Trees”





Simple Recipe for Pruning Mature Tall Spindle Trees

1. Limit height by cutting leader to a fruitful side branch at optimum tree height
2. Remove 2-3 branches per year larger than 2cm (2 cut rule)
 - Remember "large branches create large trees"
3. “Columnarize” or simplify each remaining branch so that it has a single axis and is left long and pendant



Pruning concepts of Large Fuji Trees

- High fruit quality requires good light distribution and calm trees.
- Limb renewal pruning is the single most important pruning concept for mature high density orchards.
- Large limbs lead to large root systems and greater tree vigor.



Removal of large limbs should be done over a 3 year period





Mature Tree Canopy Management

- "The best way of restricting vegetative growth is to produce apples."
- Use Nutrition to achieve calm tree growth.
- Use Pruning to open gaps in the canopy without stimulating vigor.
 - Remove 2-3 large branches (diam.~4cm) each year. Do not shorten other branches. Allow them to become pendant before shortening.
 - Modify summer pruning to allow replacement branches to develop on the trunk.

After Several Years of Renewal Pruning the tree has few large branches



Precision V-Trellis

Benefits - high tree densities, high mature yields, systematized pruning, adaptable to platforms, less expensive tree, adaptable to platforms, reduced sunburn.

Negatives points – Costly trellis, costly tree training and development, complicated management.



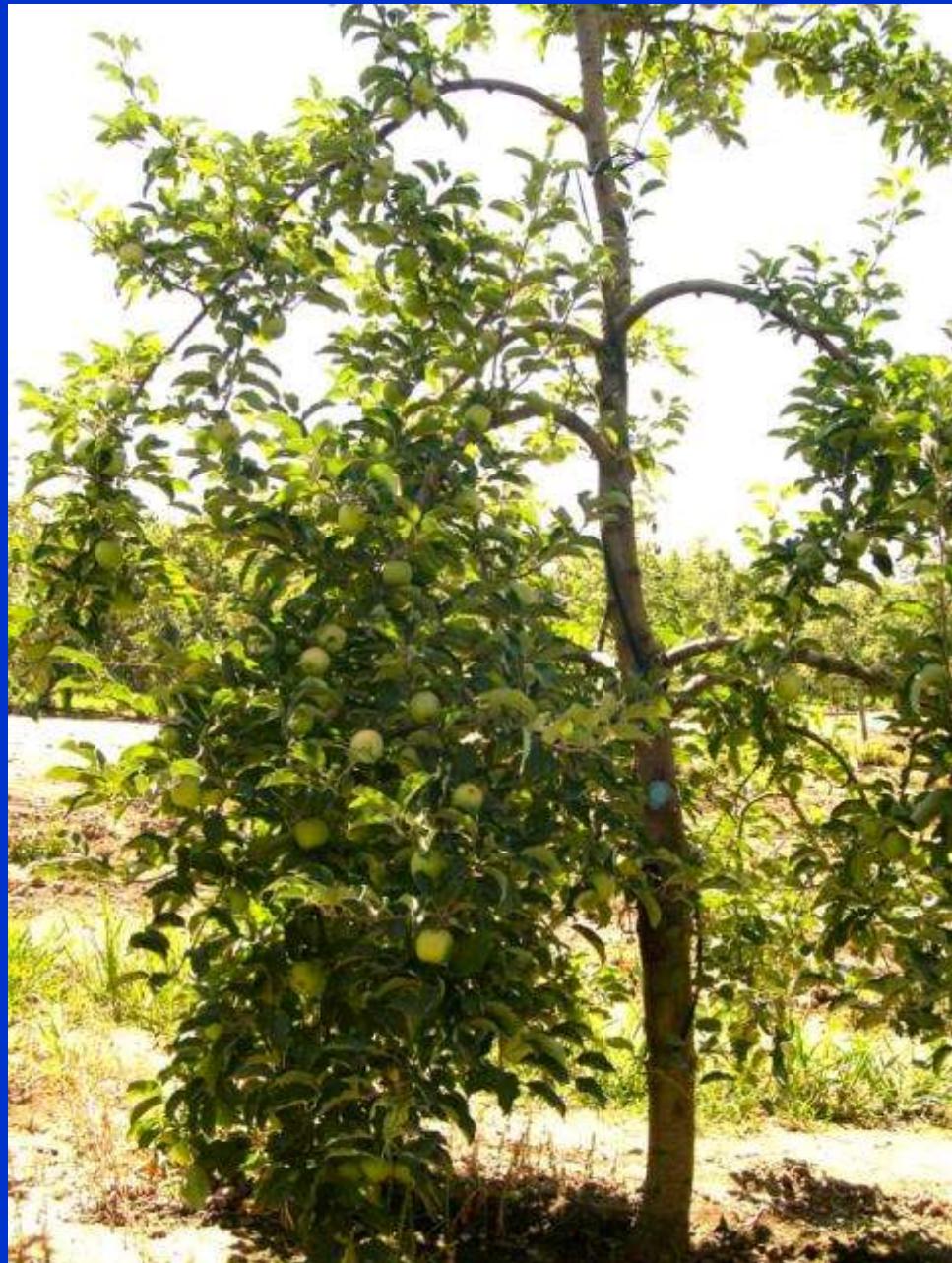
Super Spindle

Benefits - high tree densities, high early productions, simple pruning, high fruit quality, adaptable to platforms.

Negative Points – High investment, excessive vigor in the top, requires low tree costs, not more profitable than lower densities.



Solaxe



Solaxe

Benefits: Control of excessive vigor, high production, low alternate bearing.

Negative Points:

- At densities above 2000 tr/ha the large branches in the top create shading problems of the lower canopy.
- The chimney space is wasted.
- The chimney does not allow shoots for renewal shoots.
- High hand labor costs to do spur extinction and limb bending.
- It is useful for areas with excessive vigor or semi-dwarf rootstocks.



Vertical Axis





Bi-Axis

Benefits:- moderate densities but high number of leaders per acre, high yields, high fruit quality, reduced vigor in each leader, adaptable to platforms and mechanical pruning.



Negative points: Requires a 2 stem tree from the nursery.



Bi-Axis



Fruiting Wall, (Mur Frutiere)

Benefits include- mechanical pruning, reduction of costs, high yields high fruit quality.

Negative points – vigor can be excessive, fruits size can be smaller.

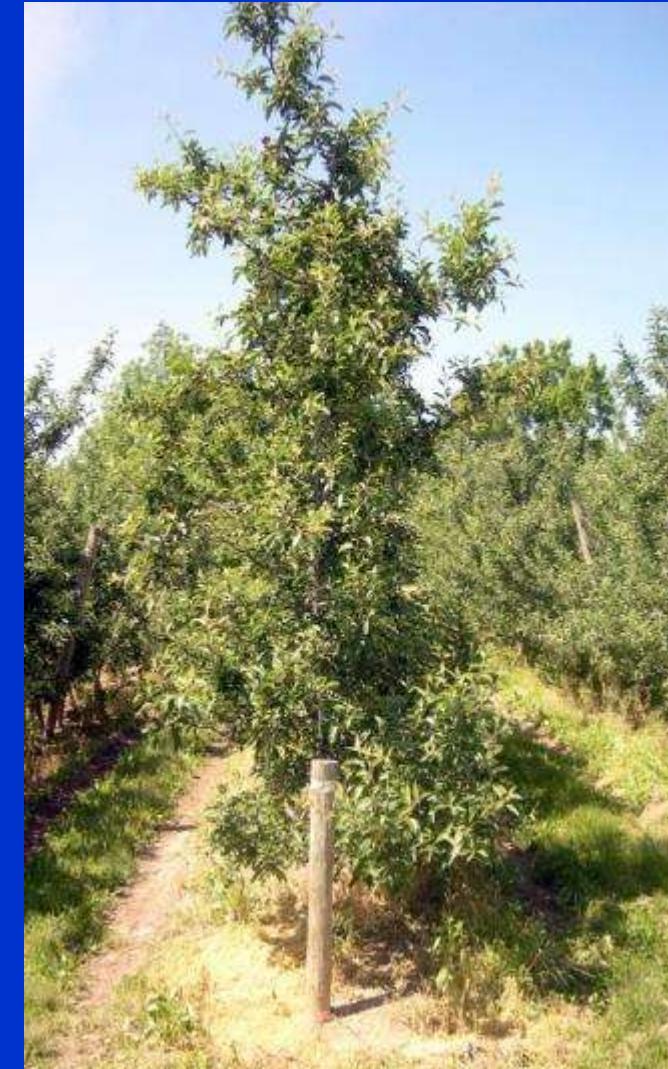


Fruiting Wall, (Mur Frutiere)



Which System is Best

- For most growers the Tall Spindle is the best.
 - Optimum Economic Tree Density 2,500-3,000 trees/ha
 - High early production 150 t/ha in first 5 years
 - High mature yields 75 t/ha with Fuji
 - High Fruit Quality thin conical canopy
 - Improved labor efficiency Simplified pruning recipe with partial mechanization of dormant pruning and tree training and summer side wall shearing for summer pruning.
- Where vigor is too high the Bi-Axis is an option
 - With pears and OHF rootstocks
- Where tree cost is low the Super Spindle is an option
- With spur or semi-spur type varieties the Fruiting Wall is very interesting.
- The Precision V- or Vertical Trellis have little potential where sunburn is a problem.



New Directions: Partial Mechanization of Dormant Pruning



The simple pruning recipe of the Tall Spindle is well adapted to the use of motorized platforms to reduce pruning costs

- The best fruit growers in NY have reported reductions in dormant pruning labor of 25-40% if the trees are grown in the Tall Spindle system.





Dormant Pruning with a 2-Row Platform



Partial Mechanization of Dormant Pruning and Hand Thinning can
Reduce Labor Costs by 25-50%

**New 2012 Kubota mounted Trimming
Platform with self-steering mechanism
(designed/built by Dan LaGasse, Lyons, NY)**



New Directions: Mechanical Summer Pruning with the Tall Spindle

Benefits include reduction of costs,
improved fruit quality.

Timing: June, July, August



Mechanization of Summer Pruning

Goal is to have a narrow fruiting wall with good light distribution but not create a vigor response in the tree and reduce pruning costs by 2/3.

With tall spindle the canopy should be an angled wall 1.5m wide at base and 75cm feet wide at top.

The pruning strategy is to use mechanized pruning for 2 years then a corrective dormant pruning to remove limbs that have become too large and open up the canopy.



Width 75cm

Width 1.5m

6th Lead Fuji with Mechanical Sidewall Shearing



6th Lead Gala with Mechanical Sidewall Shearing



Conclusions

- For most growers the Tall Spindle is a great system.
 - Optimum Economic Tree Density
 - High Early Production
 - High mature yields
 - High Fruit Quality
 - Partial Mechanization of Pruning for Improved Labor Efficiency.
- Biggest mistakes are:
 - Initial branches not tied down
 - Not growing the tree to 3m height fast enough
 - Excessive cropping in years 2-4
 - Too many large branches when trees are mature



Thank you for your attention

