Selecting rootstocks for your site: the foundation of a successful orchard IPM program

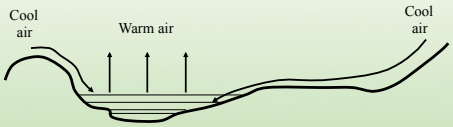
Ron Perry and Greg Lang
Professors of Horticulture
Dept. of Horticulture, MSU

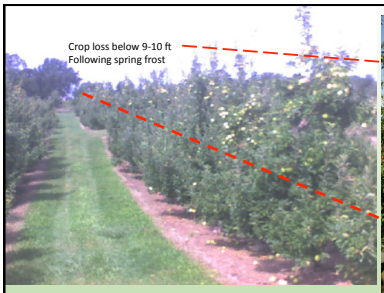
Factors used in determining best apple rootstock

- Selecting rootstocks based on:
  - Systems / spacing
    - Topographic characteristics of site
  - Abiotic and Biotic Challenges
    - Soil conditions; Physical limitations
    - Soil moisture and CEC Characteristics
    - Soil and aerial pests; diseases and insects
      - Dogwood Borer
      - Fireblight
      - Phytophthora crown rot
      - Wooly Apple Aphid

Systems and Spacing: Site Topography

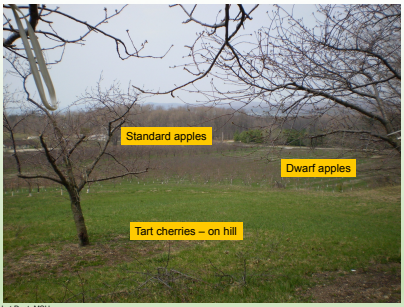
Elevation – Slope – Frost Pockets





Semi Vigorous Goldens / M.7, Central Leader, Flat site below hill

Tall Spindle Gala/B.9 10+ years

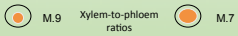


Systems / Spacing

1. The system you decide in which to grow fruit, will dictate spacing to a certain extent.
2. For example; if you chose the Tall Spindle system (high value fruit), the rootstock will be limited by the fact that trees are planted at 3-4 feet apart down row and 11-12 feet alleyway….. B.9, M.9 clones/equivalent (soil type).
   1. The alleyway width is critical if the plan is to use a mobile platform.
3. Less intense system; Vertical Axe or Central Leader, increased spacing = more options.
4. Trees on dwarfing rootstocks require support ….

Roots of dwarfing rootstocks are more brittle and concentrated in soil profiles

Support required for M.9, M.26, etc. due to precocity, brittle roots, function of ratio of xylem to phloem tissue, and change in yield efficiency and harvest index (more fruit per tree size as measured by trunk diameter or tree weight, respectively)



7

Cropping, especially on precocious rootstocks, eliminates dominance of Central Leader

Gravity

8

Rootstocks can dwarf and improve precocity; Honeycrisp rootstock trial TC

9

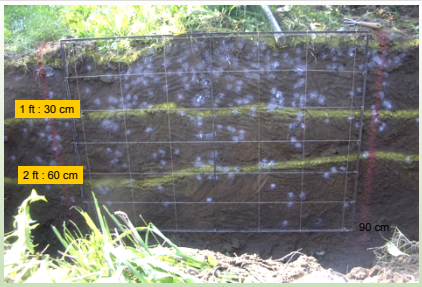
Tall Spindle calls for narrow canopies, narrow alleyways and $ investment

Factors used in determining best apple rootstock

- Selecting rootstocks based on:
  - Systems / spacing
    - Topographic characteristics of site
  - Abiotic and Biotic Challenges
    - Soil conditions; Physical limitations
      - Soil moisture and CEC Characteristics
      - Soil and aerial pests; diseases and insects
        - Dogwood Borer
        - Fireblight
        - Phytophthora crown rot
        - Wooly Apple Aphid
      - Ground floor management schemes
        - Conventional VS Organic

Soils

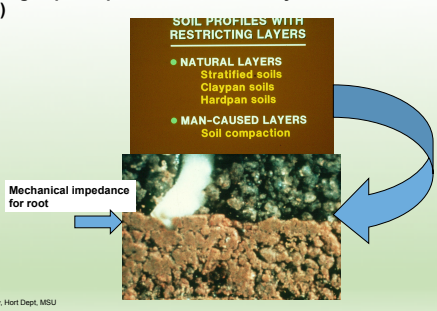
Weak Vigor	Medium Vigor	High Vigor
Sandy or gravelly soil	Loam soil	Clay loam
Low CEC	Medium CEC	High CEC
Low moisture retention	Medium moisture retention	High moisture retention
Phytophthora threat low	Phytophthora threat medium	Phythophthora threat high
Irrigation advised, especially with dwarf stocks	Irrigation advised, especially with dwarf stocks	Irrigation optional, but advised



Basically, most roots are found in the top 1.5 to 2 ft of the soil surface.

R.Perry, Hort Dept, MSU 13

Rooting depth important for fruit root systems: Need at least 3 ft (1 m)



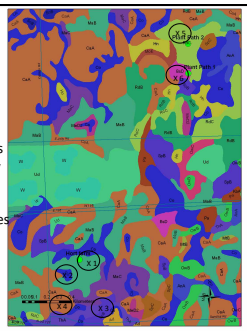
R.Perry, Hort Dept, MSU 14

Michigan Soils are variable

Glacial retreat deposition

Polygons here of a soil series map demonstrate variability in a field

Each color is a different series



Soils: Physical Limitations/Depth

Red Delicious / M.9

Red Delicious / M.7

1. Roots of M.9 and many dwarfing rootstocks are concentrated and less intensive compared to more vigorous rootstocks.

Fernandez, R. T., R.L. Perry and D.C. Ferree. 1995. Root distribution patterns of nine apple rootstocks in two contrasting soil types. J. Amer. Soc. Hort. Sci.120(1):6-13.

Factors used in determining best apple rootstock

- Selecting rootstocks based on:
  - Systems / spacing
    - Topographic characteristics of site
  - Abiotic and Biotic Challenges
    - Soil conditions; Physical limitations
    - Soil moisture and CEC Characteristics
    - Soil and aerial pests; diseases and insects
      - Dogwood Borer
      - Fireblight
      - Phytophthora crown rot
      - Wooly Apple Aphid
    - Ground floor management schemes
      - Conventional VS Organic

Soils: Physical Limitations/Depth

Red Delicious / M.9

Red Delicious / M.7

2. Roots of M.9 and mM.26 are less efficient in absorbing water/nutrients than MM.111.

Fernandez, R.T., R.L.Perry & J.A. Flore. 1997. Drought response of young apple trees on three rootstocks: Growth and development. J. Amer.Soc.Hort.Sci. 122:(1): 14-19.

Factors used in determining best apple rootstock

- Selecting rootstocks based on:
  - Systems / spacing
    - Topographic characteristics of site
  - Abiotic and Biotic Challenges
    - Soil conditions; Physical limitations
    - Soil moisture and CEC Characteristics
    - Soil and aerial pests; diseases and insects
      - Dogwood Borer
      - Firelight
      - Phytophthora crown rot
      - Wooly Apple Aphid
    - Ground floor management schemes
      - Conventional VS Organic

Mounding to control the Dogwood borer
Synanthedon scitula (Harris)

www.nysaes.cornell.edu

Peter McGhee, Larry Gut, Ron Perry

20

Emerging Dogwood borer (DWB)

Burr Knot

21

Soil berm (mound) on new apple planting

Sustainable approach to suppressing DWB

Also, pheromone confusion

Gut, L.J., P.H. McGhee and R. Perry. 2005. Soil Mounding as a Control for Dogwood Borer in Apple. HortScienc. 40(7):2066-2070

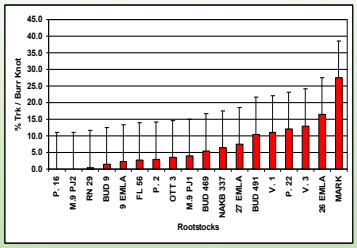
22

Remove mound > 3rd year Most soil will erode to below Union at end of year 3. If not wash away with high pressure water.

- **Burr Knots prevalent in M.9; adventitious rooting initials**
  - **Root initials extend when exposed to soil**

24

% Trunk Area (RS shank) covered by Burrknots



25

Gingergold / Bud.9 after 9 years; Exposed roots following mounding

26

Factors used in determining best apple rootstock

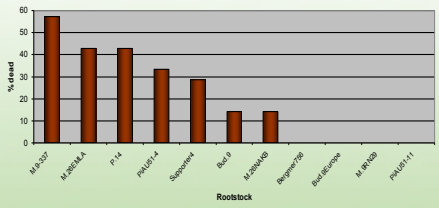
- Selecting rootstocks based on:
  - Systems / spacing
    - Topographic characteristics of site
  - Abiotic and Biotic Challenges
    - Soil conditions; Physical limitations
    - Soil moisture and CEC Characteristics
    - Soil and aerial pests; diseases and insects
      - Dogwood Borer
      - **Fireblight**
      - Phytophthora crown rot
      - Wooly Apple Aphid
    - Ground floor management schemes
      - Conventional VS Organic

Fireblight and Apple Rootstocks

- One of the major concerns for growing apples on clonal rootstocks in the Midwest and Eastern U.S.
- Most of the standard dwarfing rootstocks are highly susceptible.
- Canopy shoots can be infected and the bacteria spread and travel via the vascular system throughout the canopy and to the roots.
- Highly susceptible scion varieties such as Gingergold, Gala, Fuji, and Honeycrisp can become more susceptible on these rootstocks, especially M.26.
- Geneva rootstocks have been developed and released resistant to FB…. The problem: does not transfer resistance to scion. So you can lose scion but stock may remain alive!!
- Only Budagovsky 9 has shown an ability to suppress FB spread within vascular system of scion (Aldwinkle, et. Al.)

28

2002 NC-140 Buckeye Gala Scion, CHES. Percentage of dead trees (Fire blight) during 2004



29

Fireblight infections in canopy stop when Bud.9 is the rootstock

Gala / B.9

30

Fireblight Infection in 2004

31

Factors used in determining best apple rootstock

- Selecting rootstocks based on:
  - Systems / spacing
    - Topographic characteristics of site
  - Abiotic and Biotic Challenges
    - Soil conditions; Physical limitations
    - Soil moisture and CEC Characteristics
    - Soil and aerial pests; diseases and insects
      - Dogwood Borer
      - Fireblight
      - Phytophthora crown rot
      - Wooly Apple Aphid
    - Ground floor management schemes
      - Conventional VS Organic

Phytophthora root or crown rot

- M.9, B.9 and Geneva rooststocks are resistant
- M.26 and MM.106 are extremely susceptible

Wooly Aphid Aphids

- Most commercial dwarfing rootstocks including M.9, B.9, M.26, M.7, Ottawa 3
- Impact depends on climate/region.

Breeding and Developing New Apple Rootstocks

Dr. Jim Cummins
Cornell University

Established in 1968, Geneva, NY (NYAES)

Goals:
- Develop new cold-hardy rootstocks that are resistant to Fireblight, Phytophthora, Wooly Apple Aphids, Replant disease complex
- Retain productivity and precocity similar to Malling stocks

35

Cornell-Geneva Apple Rootstock Breeding Program

GENNARO FAZIO

- Research Geneticist, USDA–ARS, 2001
- Adjunct Professor
- Department of Horticultural Sciences
  New York State Ag. Exp. Sta.
- Cornell University
- Email: gfazio@pgru.ars.usda.gov
  Gf35@cornell.edu
- http://www.ars.usda.gov/pandp/people/people.htm?personid=24554

36

Apple tree spacing and rootstocks

- http://extension.umass.edu/fruitadvisor/fact-sheets/tree-spacing-calculator
- Developed for commercial fruit growers but helps students and hobbyists understand the factors in the decision making process.

Hopefully, the results will steer you in the right direction!

Semi-Dwarfing Apple Rootstocks

M.26 (EMLA.26)

- **Pros:**
- 40-50% of seedling vigor
- Precocious, good fruit size and quality
- Good production once established
- Cold-hardy
- Good vigor for Vertical Axe

- **Cons:**
- Incompatible with triploids and Northern Spy
- Needs well-drained, deep fertile soils
- Highly susceptible to Phytophthora and fireblight
- Burr knots
- Needs irrigation and support system

38

Dwarfing Apple Stocks; Higher Vigor M.9 clones

M.9 (RN.29 or Nic-29) (selected in Belgium by Rene Nicolai)

- 35-40% of seedling vigor
- + Adaptable to a wide range of soils
- + Precocious, large fruit, productive
- + Resistant to Phytophthora
- - Less brittle roots than lower-vigor M.9 clones
- - Highly susceptible to fireblight
- - Moderately cold sensitive
- - Requires irrigation and support
- - Burr knots

39

Dwarfing Apple Stocks: Low-Vigor M.9 Clones

M.9 NAKB 337 (Selected in Holland, virus-free)

- 30-35% of seedling vigor
- + Precocious, large fruit, productive
- + Tolerant of many soils, with the exception of light soils
- - In Michigan, tends to be inferior in performance to other M.9 clones
- - Transplants slowly, especially if poorly treated in shipment/storage
- - Highly susceptible to fireblight
- - Moderately cold sensitive
- - Requires irrigation and support

40

Other Commercial Dwarfing Stocks

Budagovsky 9 (B.9 or Bud.9) (developed in Russia)

- 25-35% of seedling vigor
- + Adapted to a wide range of soil types
- + Precocious and productive
- + Consistent cropping across varieties and years
- + Confers resistance to fireblight to the scion (even though the rootstock is susceptible)
- + Resistant to Phytophthora, mildew, and apple scab
- + Excellent cold hardiness
- + No license protection (not patented)
- - Fruiting too early may cause "runting" of tree
- - Requires irrigation and support

41

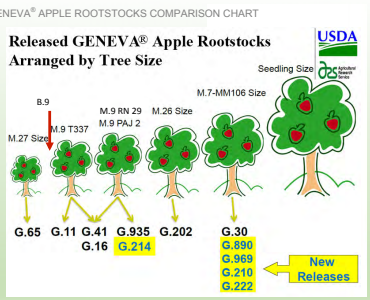
Gala / B.9 after 9 yrs

Gala / NAKB.337 after 9 yrs

42

GENEVA® APPLE ROOTSTOCKS COMPARISON CHART

Released GENEVA® Apple Rootstocks Arranged by Tree Size



43

CCTEC CORNELL CENTER FOR TECHNOLOGY ENTERPRISE AND COMMERCIALIZATION

GENEVA® APPLE ROOTSTOCKS COMPARISON CHART

NC-140

Traits	G.65	G.11	G.16	G.41	Sister G.214	G.935	G.202	Sister G.222	G.30	Sister G.210	Sister G.890	Sister G.969
Arranged in order by size (smallest to largest)	M.27	M.9-T337	M.9 T337	M.9 T337	M.9/M.26	M.26	M.26	M.9/M.26	M.7	M.7	M.7	M.7 and MM.106
Woolly Apple Aphid Resistance	No	High	No	High	High	No	High	High	No	High	High	High
Fire Blight Resistance	Very Resistant	Resistant	Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant	Very Resistant
Replant Disease Complex Resistance ✓	TBD	No	Partial	Tolerant	Tolerant	Tolerant	Tolerant	No	Tolerant	Tolerant	Tolerant	Tolerant
Crown and Root Rots (Phytophthora)	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant	Tolerant
Cold Hardiness ✓	Yes	Yes	Partial: Good Mid-winter, Bad early cold	Yes	TBD	Yes	Yes-Good, Mid-winter	Yes	Yes	TBD	TBD	TBD
Productivity/Yield Efficiency- as good or better than M.9	TBD	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	TBD	TBD	TBD
Low suckering and burr knots	TBD	TBD	Yes	Yes	Yes	Yes	Yes	TBD	Yes	Yes	Yes	Yes

Geneva NY Rootstocks ~ M.9

- **Geneva® 11** is similar in size to B.9 in some trials and similar to M.9T337 in others. Reduces biennality with Honeycrisp. It is fire blight resistant, Phytophthora root rot, but it is not resistant to wooly apple aphids or apple replant disease. Proving to be an excellent replacement for M.9 in North America and Europe.
- **Geneva® 214** is similar in size to M.9 in some trials and similar in size to the vigorous clones of M.9 in other trials. It is slightly less yield efficient than G.41. Resistant to fire blight, Phytophthora root rot, and woolly apple aphid. Shown tolerance to apple replant disease in field trials in New York and Washington.
- **Geneva® 41** is similar in size to vigorous clones on M.9 such as RN or Nic29. Reduced bienniality with Honeycrisp (T. Robinson). It is highly resistant to fire blight, Phytophthora and wooly apple aphids. Some tolerance to apple replant disease and has good winter hardiness. A good alternative to M.9 in high fire blight prone areas, in replant disease areas and in woolly aphid prone areas.

Geneva Stocks ~M.26

- **Geneva® 935** is similar in size to M.26 in some trials and similar to the vigorous clones of M.9 in other trials. It is highly precocious has very high yield efficiency.Resistant to fire blight, Phytophthora, and appears to have some tolerance to apple replant disease. It also appears to be very winter hardy, but it is not resistant to wooly apple aphid. Fruit size has been slightly smaller than with M.9. It is an excellent new rootstock for weak growing cultivars like spur-type 'Delicious', 'Honeycrisp', 'Sweet Tango' or 'Snapdragon'.
- **Geneva® 969** is similar in size to M.26 in some trials and similar to M.7 in others. It is highly yield efficient and was released in 2010 as a free standing semi-dwarf tree for processing orchards. It is resistant to fire blight, Phytophthora, and wooly apple aphid. It performs well in northern climates. It may be an excellent stock for weak growing cultivars in northern climates like Honeycrisp, Sweetango or Snapdragon when planted at high densities. Free standing in the orchard.
- **Geneva® 202** is similar tree size to or slightly larger than trees on M.26. It has high yield efficiency and is precocious. It is resistant to fire blight, Phytophthora, apple replant disease and to wooly apple aphid. It is a useful with weak growing cultivars and as an alternative to M.26 in climates that have problems with woolly apple aphid. It has become a popular dwarfing rootstock in New Zealand.

Robinson, T., Fazio, G., Aldwinckle, H. 2014. Acta Horticulturae. 1058:651-656.

Michigan State University AgBioResearch

Matching New Rootstock Traits (Dwarfing, Productivity, Disease Resistance) with 'Honeycrisp' Apple for Michigan

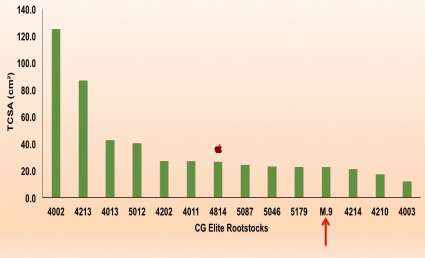
Greg Lang, Ron Perry, Tammy Wilkinson, Phil Schwallier, Denise Ruwersma, Nikki Rothwell, Bill Klein, and Gennaro Fazio

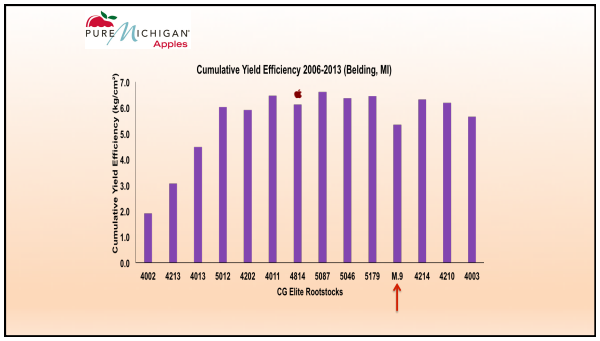
MICHIGAN APPLES

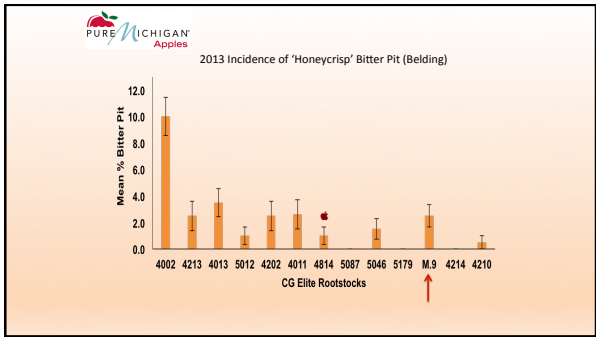
PURE MICHIGAN Apples

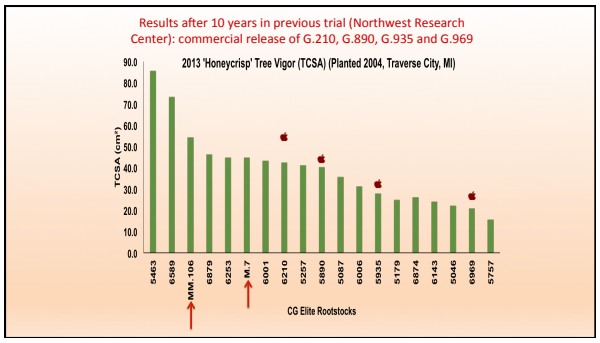
Results after 10 years in previous trial (Belding): commercial release of G.814 (tested as CG.4814)

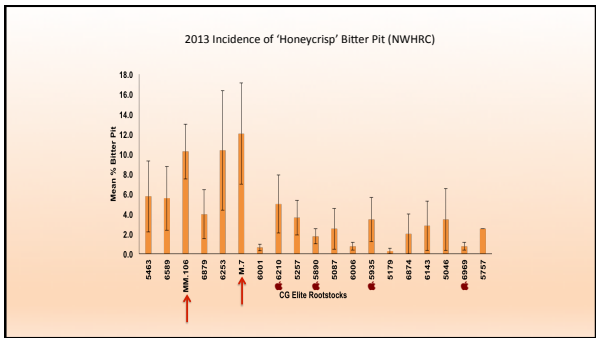
2013 'Honeycrisp' Tree Vigor (TCSA) (Planted 2004, Belding, MI)

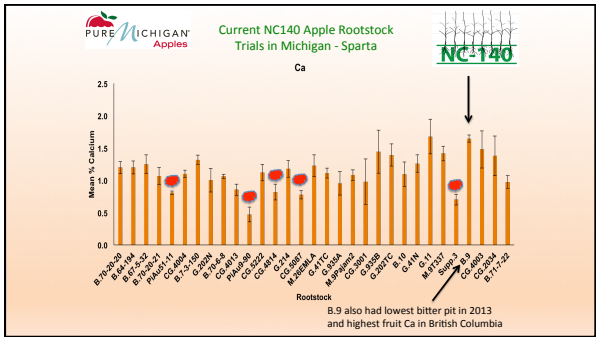


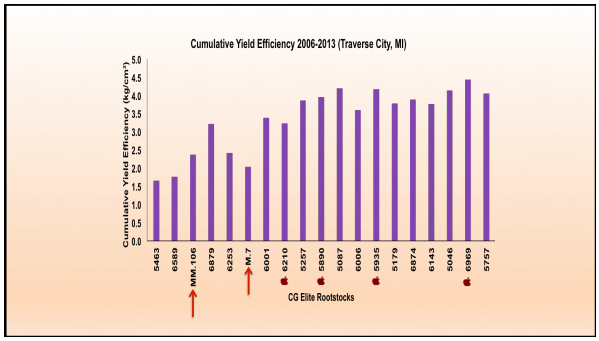

PURE MICHIGAN Apples
Cumulative Yield Efficiency 2006-2013 (Belding, MI)
Cumulative Yield Efficiency (kg/cm²)
4002 4213 4013 5012 4202 4011 4814 5087 5046 5179 M.9 4214 4210 4003
CG Elite Rootstocks


PURE MICHIGAN Apples
2013 Incidence of 'Honeycrisp' Bitter Pit (Belding)
Mean % Bitter Pit
4002 4213 4013 5012 4202 4011 4814 5087 5046 5179 M.9 4214 4210
CG Elite Rootstocks


Results after 10 years in previous trial (Northwest Research Center): commercial release of G.210, G.890, G.935 and G.969
2013 'Honeycrisp' Tree Vigor (TCSA) (Planted 2004, Traverse City, MI)
TCSA (cm²)
5463 6589 MM.106 6879 6253 M.7 6001 6210 5257 5890 5087 6006 5935 5179 6874 6143 5046 6969 5757
CG Elite Rootstocks


2013 Incidence of 'Honeycrisp' Bitter Pit (NWHRC)
Mean % Bitter Pit
5463 6589 MM.106 6879 6253 M.7 6001 6210 5257 5890 5087 6006 5935 5179 6874 6143 5046 6969 5757
CG Elite Rootstocks


PURE MICHIGAN Apples
Current NC140 Apple Rootstock Trials in Michigan - Sparta
NC-140
Ca
Mean % Calcium
Rootstock
B.9 also had lowest bitter pit in 2013 and highest fruit Ca in British Columbia


Cumulative Yield Efficiency 2006-2013 (Traverse City, MI)
Cumulative Yield Efficiency (kg/cm²)
5463 6589 MM.106 6879 6253 M.7 6001 6210 5257 5890 5087 6006 5935 5179 6874 6143 5046 6969 5757
CG Elite Rootstocks

Thanks !!!

Acclimation

- Three Stages of Acclimation
- "Acclimation" is the process leading to the development of freeze tolerance in woody plants.

- I. Stage I begins with short photoperiods, sensed by the leaves, triggers onset of the first stage of acclimation and plants will develop 10 to 15 degrees of cold tolerance as the days become shorter. Warm temperatures (60 to 70˚F) combined with short days promote maximum hardening. Following a period of warm temperature preconditioning, cold acclimation is continued by a period of cool nonfreezing temperatures (60˚ days and 40˚ nights).
- II. Stage II transitions when there is exposure to subfreezing temperatures (23 to 27˚). Increased hardiness is very rapid and trees may be as much as 10˚ hardier the day after a frost than they were the previous day.
- III. Stage III is the final stage of acclimation, results in maximum cold tolerance, is initiated by exposure to temperatures approaching zero degrees F.

**Often perceived in the spring as winter cold injury, much of damage is generated by sudden drops of temperatures during Stage II and transition in Stage III. Late November early December!!

Winter

- Hardiness continues as long as temperatures remain fairly cold.
- Fluctuations in hardiness occur with warm spells during winter = de-acclimation. And can re-acclimate when warm temperatures are followed by normally cold winter temperatures.
- Later in winter, once chilling requirement has been satisfied, trees begin to lose the ability to re-acclimate to hardiness levels obtained earlier in the winter, and may only partially re-acclimate.
- Chilling requirement/satisfaction most efficient at around 42-48 degrees F. Temperatures above and below do not contribute as much.