Citrus Breeding

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History

• Early agriculturalists selected natural hybrids and mutants for seed propagation

• 1800’s- grafting and cuttings became popular to propagate best varieties

• 1900’s- artificial cross-pollination practiced

Breeding Goals

• Rootstock- tree size, stress tolerance

• Scion- fruit color, size, shape, flavor, yield

• Disease resistance- CTV, Phytophthora, CVC, Alternaria, Scab, Greening, etc.

Rootstock

• Dwarfing- Poncirus, some mandarins

• Compatibility- citrus better than Poncirus

• Seedling vigor and scion yield

• Fruit quality- size, shape, flavor, juice

Rootstock Hybrids

• ‘Carrizo,’ ‘Troyer’ Citrange- navel orange x Poncirus, very popular in FL, CA

• ‘Swingle’ Citrumelo- grapefruit x Poncirus, very popular in Florida, salt intolerant

• ‘Sunki’ x ‘Swingle’ tf- semi-dwarfing, salt-tolerant, possible replacement for SO in TX

Carrizo Citrange
Swingle Citrumelo

Rootstock Fruit

**Scion**
- Vigor, yield potential, cold tolerance
- Fruit type- mandarin grapefruit, orange
- Fruit quality- flavor, size, seediness, appearance, shelf-life

**Scion Hybrids**
- ‘Orlando,’ ‘Minneola’ tangelos- ‘Duncan’ grapefruit x ‘Dancy’ tangerine
- ‘Page’ mandarin- ‘Minneola’ x ‘Clementine’
- ‘Oro Blanco’ grapefruit triploid- tetraploid pummelo x grapefruit

**Disease Resistance**
- Viruses- CTV, Psorosis, Exocortis
- Bacteria- Citrus Variegated Chlorosis, Greening, Canker
- Fungi- Alternaria, Scab, Melanose, Phytophthora

**Breeding Techniques**
- Cross-pollination- combine genes from different parents in hybrid progeny
- Self-pollination- fix genes of interest in one line to stabilize phenotype (inbreeding)
- Mutation- natural or induced genotypic modification
Cross Pollination
- Combine desirable traits from different genotypes/species and exploit heterosis
- Swingle- one of earliest to make extensive crosses for rootstock improvement
- Many hybrid rootstocks between Poncirus and Citrus- citrange, citrumelo, citrandarin

Self-pollination
- Natural mechanism for species to maintain genetic uniformity- pummelo, mandarins
- Serious inbreeding depression in citrus overcome by apomixis- nucellar embryony
- Important for gene inheritance and function studies

Seed Structure
- Mono-Embryonic
- Poly-Embryonic

Mutation
- Natural mutations- ‘sports’ of buds or limbs: ‘Ruby Red,’ most orange varieties
- Gamma rays- chromosome breaks cause genotypic changes: ‘Star Ruby,’ ‘Rio Red’
- Chemical and t-DNA- interrupt single genes

Population Development
- Pedigree- all progeny from specific cross carefully evaluated, limited genetic base
- Recurrent selection- diverse populations improved by selection and intercrossed
- Mass selection- large population evaluated for a few outstanding individuals

Pedigree Method
- Most citrus varieties developed by this method- few crosses
- Relatively few parents (monoembryonic) as females; various males
- Each progeny evaluated from each family
Recurrent Selection

- Each population developed for important traits- good genetic diversity
- Crosses between individuals from improved populations evaluated for superior traits
- Most productive over long period

Mass Selection

- Characterized or heterogeneous populations from relatively few crosses screened
- Focus mainly on quantitative traits or genes with incomplete penetrance
- Labor intensive but rapid improvement

Biotechnology

- Protoplast fusion of different genotypes
- Gene mapping with molecular markers- gene cloning.
- Genetic transformation with novel genes to modify DNA- Agrobacterium, biolistics

Protoplast Fusion

- Isolate cell protoplasts from callus or leaf tissue and fuse in vitro to form hybrids
- Mostly polyploid plants regenerated from tissue culture- genetic hybrids
- Overcome barriers to sexual reproduction

Gene Cloning

- Mapping genes in DNA with molecular markers- RAPD, RFLP, AFLP, etc.
- Chromosome walking- locate DNA markers adjacent to gene of interest, clone gene inside bacterial plasmid
- cDNA cloning- isolate genes from mRNA

Map-based Cloning
Genetic Transformation

- Insertion of cloned gene sequence into DNA (genome) of desirable plant
- Modify single trait while maintaining good attributes of parent- SO with Ctv gene
- Insertion point in genome not targeted

Texas Priorities

- Salt and drought tolerance
- CTV and Phytophthora resistance
- Cold and heat tolerance
- Fresh market fruit- size, sugars, low acid

Past Achievements in Texas

- ‘Ruby Red Grapefruit’- bud sport of Thompson in LRGV, changed market
- ‘Star Ruby’- irradiated seedling of ‘Hudson,’ darkest red grapefruit
- ‘Rio Red’- irradiated budwood of ‘Ruby Red,’ most popular red grapefruit today

Past Achievements in California

- Hybrid mandarins- ‘Kinnow,’ ‘Pixie’
- Triploid seedless grapefruit- ‘Oroblanco’
- Hybrid red pummelo- ‘Chandler’
- Rootstocks- citranges, citrumelos

Past Achievements in Florida

- Tangelos- ‘Orlando,’ ‘Minneola,’ ‘Page,’
- Grapefruit- ‘Marsh seedless,’ ‘Duncan’
- Tangors- ‘Murrcott,’ ‘Temple,’ ‘Fallglo,’ ‘Ambersweet’

Current Variety Development

- New triploid, seedless mandarins- CA, FL
- New salt tolerant, dwarf rootstocks- CA, TX
- New low acid grapefruits- CA
- New fusion product rootstocks- FL
Current Molecular Research

- CTV resistance gene cloning- CA, TX, FL
- Low acid gene mapping- CA
- Fruit development gene mapping- CA, FL
- Chromosome Isolation and Fusion-TX

Future Goals

- CTV resistance gene in susceptible scions and rootstocks
- Phytophthora resistant, salt tolerant, high yielding rootstocks
- Fruit- sweeter, seedless, longer shelf life

Breeding Strategy for Texas

- Increase effort in transgenics development
- Increase emphasis on fruit quality and earliness for fresh market expansion
- Increase research into genetic cold tolerance