

UMCA Eastern Black Walnut Improvement

Seed orchard management

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Friday, October 11, 2024

Southern Regional Extension Forestry: Tree Improvement Webinar

Outline

- Background on UMCA black walnut improvement
  - Emphasize relevant aspects for a seed nut orchard
- Plant material selection
- Genetic mapping, spur bearin
- Spacing, fertility
- Seed handling and stratification

A short history of the Improvement Program

- **Began in 1998 to domesticate eastern black walnut (*Juglans nigra*) as an orchard tree**
- **Improved cultivars needed to standardize supply, enable growth, and increase value to growers**
- **Established with a collection of 54 cultivars based on kernel quality**
- Two generations of open-pollinated seedlings and controlled crosses during 2000s and 2010s
- Multi-year evaluation of 156 preliminary selections
- Recent Milestones:
    1. Nine candidate releases to on-farm trials
    2. Tech transfer approves first patented release in 2022
    3. Quantitative Trait Loci for phenological traits and bearing habit discovered and published

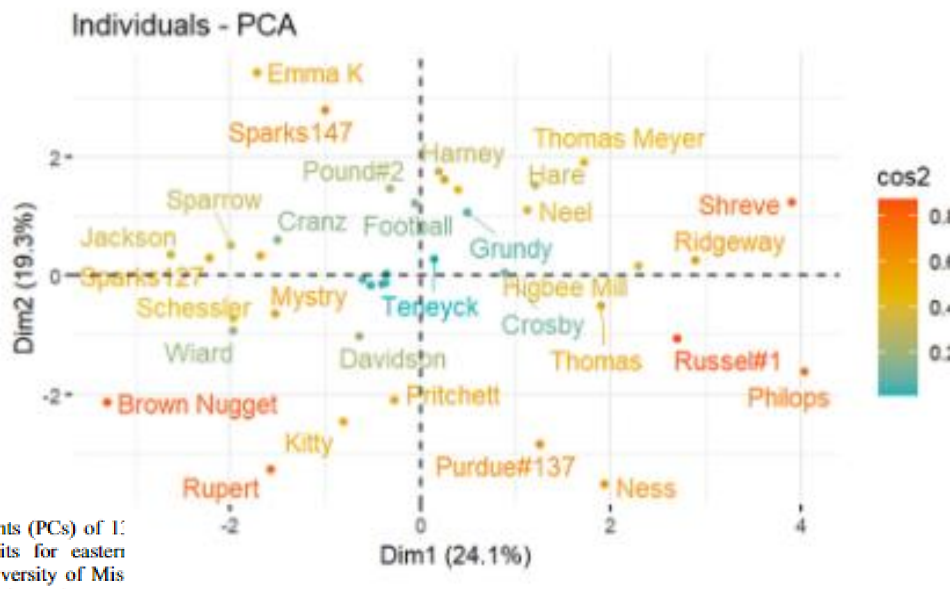
Germplasm Characterization

Diversity and trait relationships

- 54 cvs, chance seedlings curated by grower association members over the late 20th century.
- 20 traits were evaluated
- Phenology from ’01-08
- Nut and kernel quality data were collected in ‘07–10, ‘13, and ’15
- A lack of clustering in the PCA
- Kernel mass, percentage, and nut mass are do not share directionality
- Nut length may be a viable indirect selection criteria for increased kernel mass

Table 4. Eigenvector loadings in principal components (PCs) of 1[illegible] phenological, horticultural, and nut quality traits for easter[illegible] black walnut (*Juglans nigra*) cultivars in the University of Mis[illegible] souri Center for Agroforestry germplasm repository in Nev[illegible] Franklin, MO, USA.

Trait	PC1	PC2	PC3	PC4	PC5
Kernel percentage	−0.32	0.35	−0.17	−0.34	0.0
Kernel weight	0.21	0.42	−0.12	−0.05	0.1
Precocity	−0.28	0.19	−0.35	0.33	−0.0
Nut thickness	0.48	−0.01	0.16	0.28	0.1
Nut weight	0.51	0.01	0.07	0.29	0.1
Nut length	0.22	0.45	−0.03	0.00	−0.1
Kernel color	−0.07	0.35	−0.09	0.44	−0.2
Kernel venation	−0.06	0.45	0.05	0.12	0.2
Alternate bearing index	−0.08	0.22	0.38	0.07	−0.4
Budbreak	0.18	0.26	0.21	−0.48	0.2
Dichogamy habit	0.10	−0.02	−0.53	−0.02	0.4
Harvest date	0.36	0.06	−0.21	−0.41	−0.4
Season length	0.22	−0.12	−0.54	0.00	−0.4
Eigenvalue	3.14	2.51	1.84	1.41	1.1
Variance %	24.12	19.27	14.16	10.87	8.8
Cumulative variance %	24.12	43.39	57.55	68.42	77.2



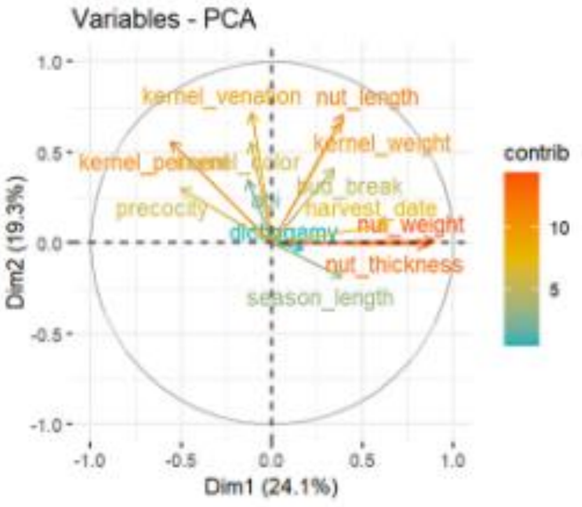


Fig. 1. Genetic variation for phenological and morphological characters of eastern black walnut (*Juglans nigra*) cultivars in the University of Missouri repository (New Franklin, MO, USA) as shown through the individual principal component analysis [PCA (top)] and variables PCA (bottom).

https://doi.org/10.21273/JASHS05242-22

Germplasm Characterization

Cultivar evaluation, recommendation

- Percentile based ranking of priority traits
- Great variation in early bearing

Table 3. Overall nut and precocity ranking for 54 eastern black walnut (*Juglans nigra*) cultivars from historic data collected between 20 and 2015.

	Kernel wt (g)		Kernel percentage (%)		Total nuts (no.)[i]		
Cultivar	Avg	Percentile	Avg	Percentile	Avg	Percentile	Total percen
Emma K	5.9	0.81	34.5	0.96	1473.0	0.98	2.75
Sparks 127	5.6	0.75	31.7	0.89	988.2	0.94	2.58
Daniel	6.9	0.98	30.5	0.81	482.6	0.72	2.51
Thomas Meyer	7.5	1.00	33.0	0.91	404.4	0.57	2.48
Sparks 147	5.6	0.74	35.0	1.00	412.5	0.58	2.32
Pound #2	6.3	0.91	34.5	0.98	258.0	0.42	2.31
Football	6.1	0.87	26.3	0.51	870.5	0.89	2.27
Kwik Krop	5.5	0.72	31.6	0.87	413.1	0.60	2.19
Jackson	4.8	0.25	34.1	0.94	1522	1.00	2.19
Neel	6.3	0.89	30.1	0.75	360.0	0.53	2.17
Surprise	6.0	0.83	28.3	0.64	454.6	0.70	2.17
Harc-Thomas	6.1	0.85	29.1	0.74	328.0	0.49	2.08
South Fork	5.4	0.64	26.6	0.57	870.0	0.87	2.08
Sparrow	5.1	0.51	28.0	0.62	761.5	0.83	1.96
Schessler	5.3	0.58	26.6	0.55	618.2	0.79	1.92
Bowser	5.0	0.47	31.2	0.85	373.3	0.55	1.87
Harney	6.6	0.94	33.1	0.92	16.0	0.00	1.86
Clermont(L)	5.7	0.77	24.8	0.45	435.0	0.64	1.86
Clermont(W)	5.7	0.79	23.1	0.32	453.0	0.68	1.79
Tomboy	4.9	0.40	23.2	0.36	1160.3	0.96	1.72
Brown Nugget	4.2	0.11	28.5	0.68	977.0	0.92	1.71

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Germplasm Characterization

Cultivar evaluation, recommendation

Table 1. Early phenological and reproductive characteristics of recommended black walnut nut cultivars for Missouri.

Cultivar	Season Length (days)	% Kernel	# Nuts/kg	Anthracnose Score* (1-5)	Alternate Bearing Index** (0-1)	Yield Efficiency*** (kg/cm2)
Bowser	125	31.7	66.4	4	0.81	0.028
Brown Nugget	128	28.4	67.7	5	0.51	0.074
Daniel	132	32.0	63.5	3	0.64	0.021
Emma K	133	33.7	57.8	3	0.86	0.091
Hay	132	31.6	45.9	2	0.36	0.076
Kwik Krop	135	30.3	56.4	3	0.47	0.032
Sparks 127	111	33.6	69.4	3	0.54	0.097
Sparks 147	127	37.2	63.7	3	0.55	0.036
Sparrow	112	28.9	53.4	1	0.41	0.080
Surprise	141	31.5	48.9	5	0.74	0.047
Tomboy	125	25.2	47.8	3	0.54	0.125

*Anthracnose Score: 1 = No defoliation due to anthracnose, 5 = complete defoliation
**ABI: 0 = No alternate bearing, 1.00 = Complete alternate bearing
***Yield efficiency: # nuts produced per cm^2 of stem over a five year period

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- **Multi-year evaluation of 156 preliminary selections**
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Historical Criteria for Selection

Rank	Code	Female	Male	Kernel Percentage	"Good" Percentage	Nut Weight	Trunk Diameter	Spur Bearing	Index Sum
1	A3	Sparks 147	Emma K	1.000	0.960	0.688	0.936	0.883	**4.467**
2	E24	Daniel	Tomboy	0.759	0.850	0.966	0.928	0.955	**4.458**
3	E29	Sparrow	Emma K	0.963	0.905	0.704	0.919	0.922	**4.413**
4	E6	Br. Nugget	Daniel	0.730	0.905	0.837	0.919	0.981	**4.372**
5	C19	Sauber #2	Emma K	0.794	0.835	1.000	0.852	0.890	**4.371**
6	C33	Sauber #2	Emma K	0.892	0.833	0.740	0.873	0.961	**4.299**
7	C7	Sparks 127	Football	0.992	0.940	0.551	0.775	1.000	**4.258**
8	D15	Sparks 127	Neel #1	0.778	0.960	0.726	0.805	0.935	**4.204**
9	D2	Sparks 127	Br. Nugget	0.860	0.936	0.535	0.631	0.968	**3.930**

Spur Bearing and Yield

- Terminal bearing – flower on branch tips only
  - Much lower yield
  - Undesirable for orchard production
- Spur bearing
  - Flowers on compact branches
  - Distributed throughout canopy
  - Significant yield increases
  - Similar to lateral bearing in *J. regia*

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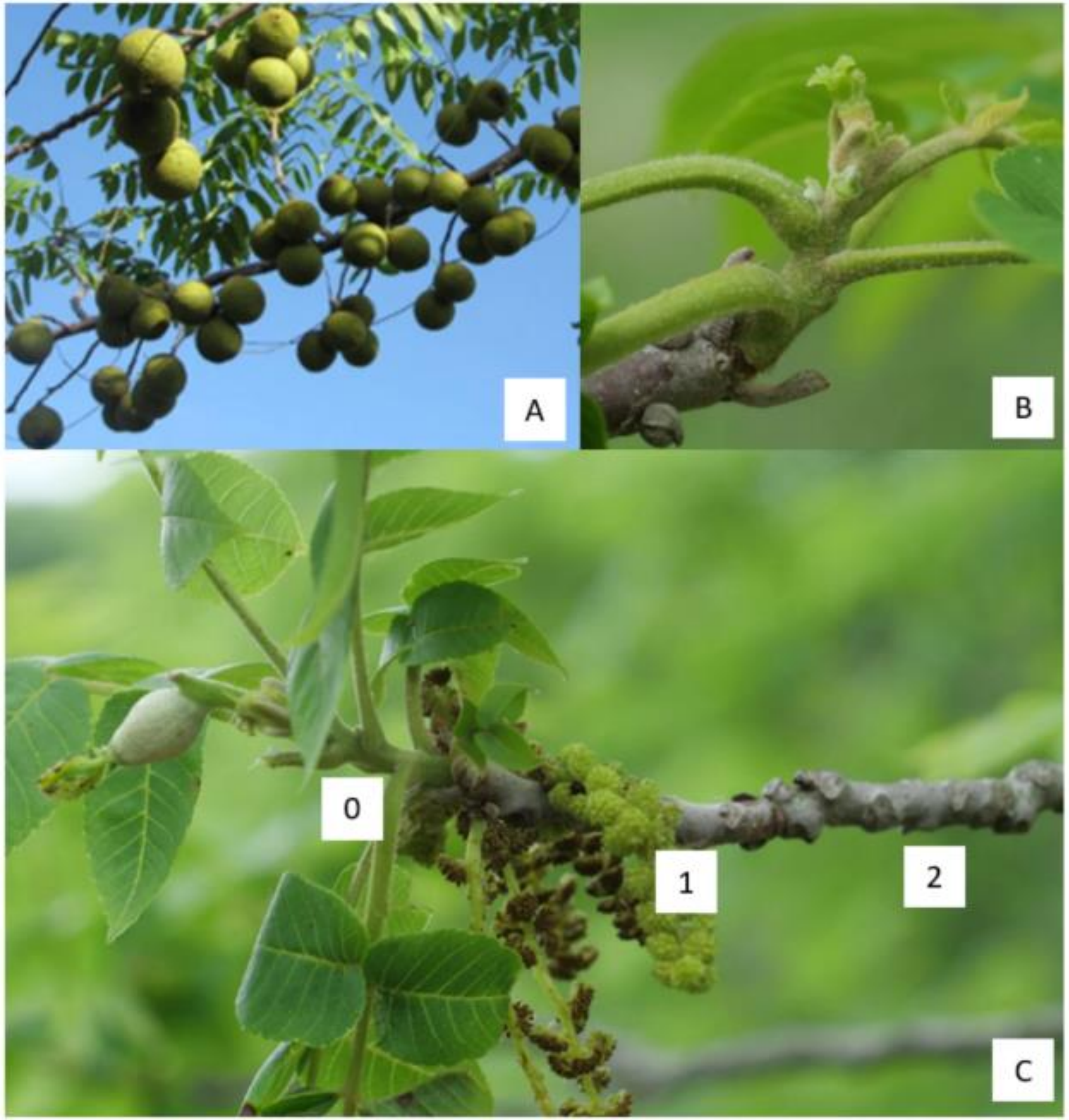
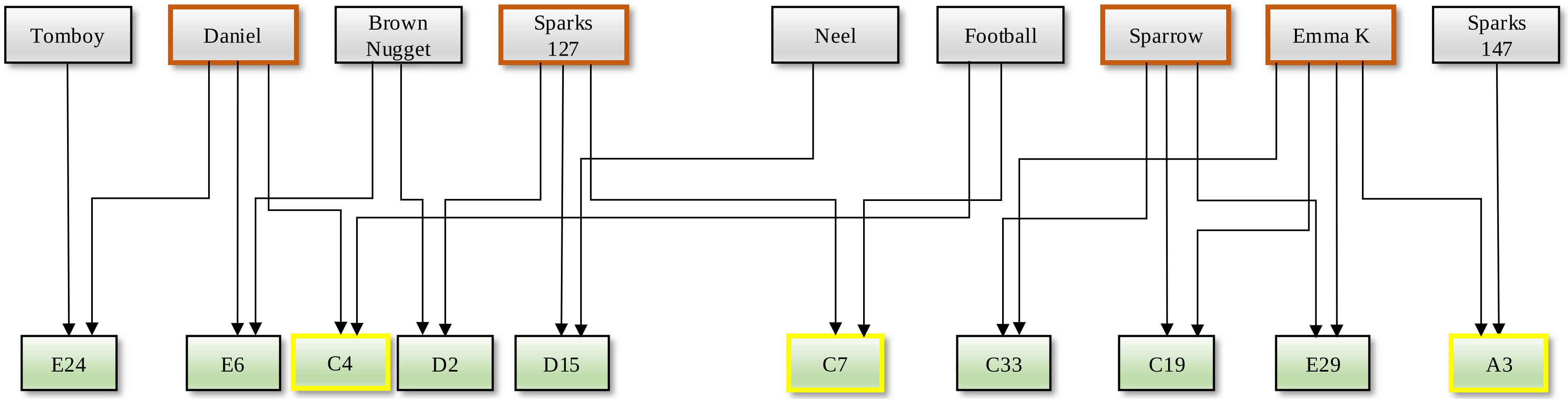


(**A**) Productive eastern black walnut tree showing a high degree of spur-bearing. Nuts are produced on short spurs that develop on main branches. (**B**) Fruiting spurs terminate in pistillate blooms after growing only a few leaves. (**C**) A fruiting spur with the current season's growth (**0**), last year's wood (**1**), and two-year old wood (**2**). Short, compressed internodes are typical characteristics of fruiting spurs

Coggeshall Selection Pedigrees



- 4 trials established 2022 (r = 8, n =1)
- Cultivar checks: Emma K, Neel, Daniel
- ~300 grafted trees remain in the HARC nursery

UMCA [redacted] – upcoming cultivar release

Replicated trials are ongoing (r =4, n =1) and newly established (r =8, n =1). Due to strong spur-bearing – a trait of genetic control, not environmental – this release will be made in advance of replicated trial completion to support early adopters – of which there are many .




UMCA [redacted]
(‘Sparks 127’ × ‘Football’)

- Spur-bearing: 1,295 nuts yrs 5-8
- Kernel percentage: 34-36%
- Nut defect rate: 10%

Quantitative Trait Loci Mapping

Chatwin, W., Shirley, D., Lopez, J., Sarro, J., Carlson, J., Devault, A., Pfrender, M., Revord, R., Coggeshall, M. and Romero-Severson, J., 2023. **Female flowers first: QTL mapping in eastern black walnut (*Juglans nigra* L.) identifies a dominant locus for heterodichogamy syntenic with that in Persian walnut (*J. regia* L.)**. *Tree Genetics & Genomes*, *19*(1), pp.1-15. https://doi.org/10.1007/s11295-022-01580-9

Objectives

- Develop genetic resources for eastern black walnut breeding
  - EST-SSR markers, genetic map, quantitative trait loci, trait-associated DNA markers
- Study phenological, nut quality and bearing habit genetic architecture
- Compare trait genetic architecture to that in Persian walnut

Spur Bearing and Yield

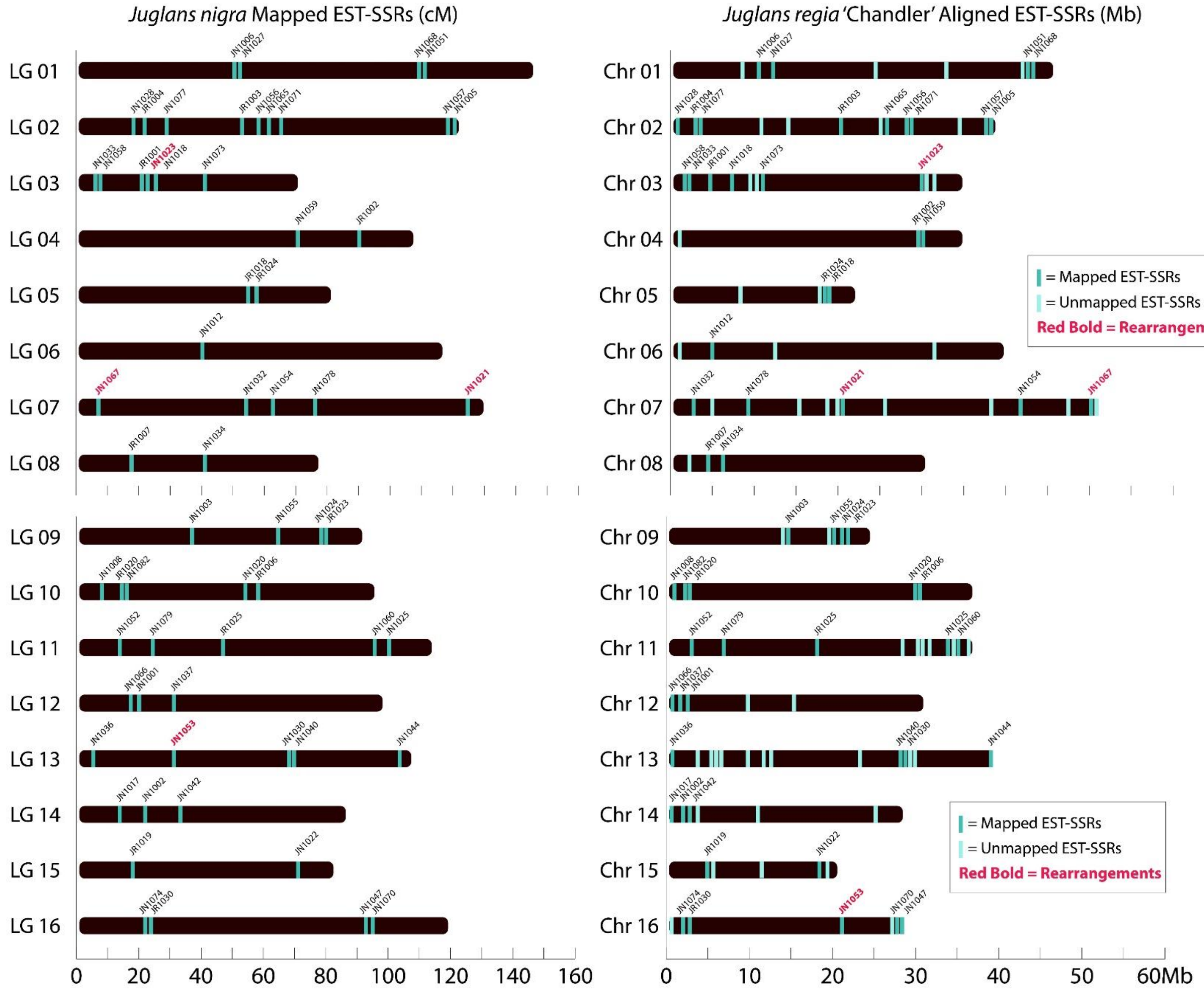
Phenotypic data collection

- 219 fruiting trees
- Total nuts borne on spurs counted for each tree
- Total yield (Kg) recorded for each tree
  - Hulled, pressure-washed, and dried

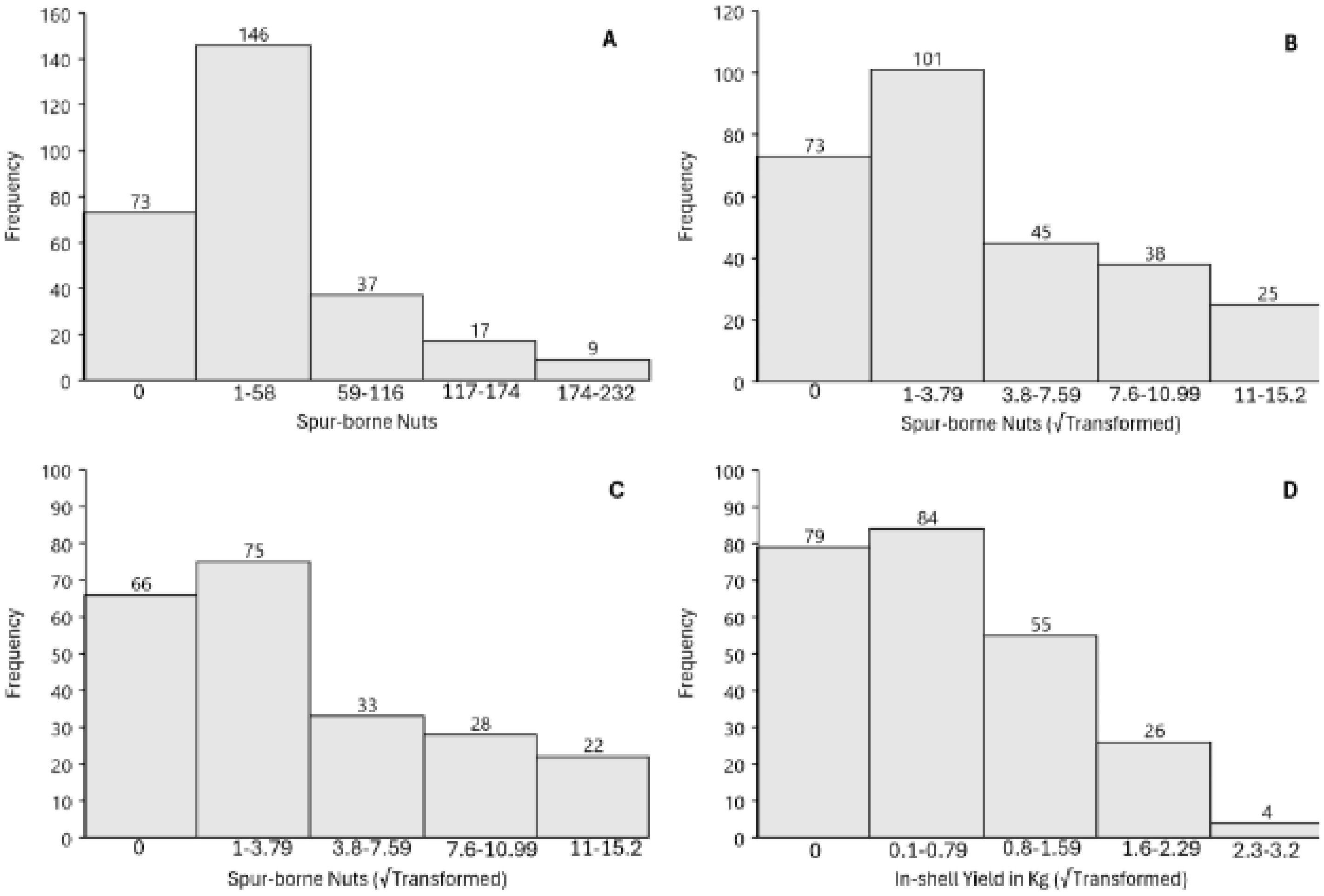
Genetic Map

- Linkage map:
  - 256 ‘Sparrow’ x ‘Schessler’ indiv.
  - 356 SNPs & 62 EST-SSRs
  - 16 linkage groups (LG)
  - 1646 cM in length

- EST-SSRs suggest collinearity between the Persian walnut and eastern black walnut, allowing comparative analysis.

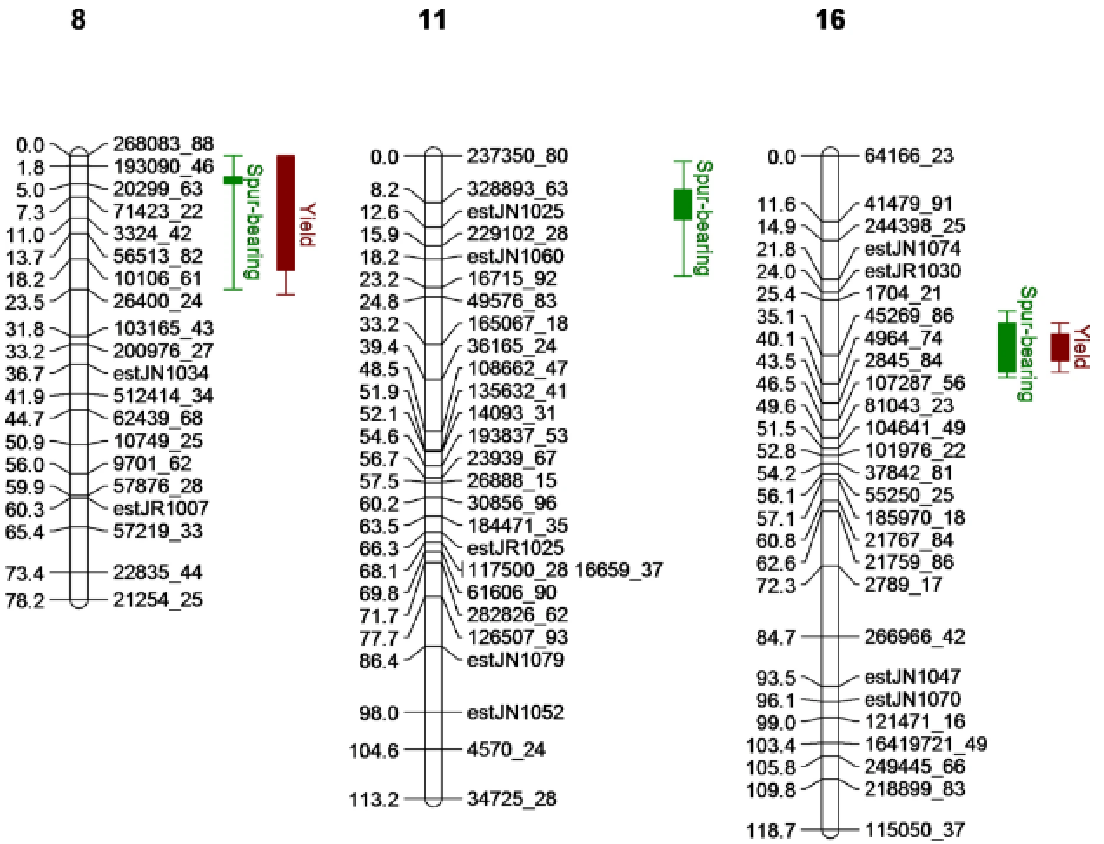


Spur bearing segregation

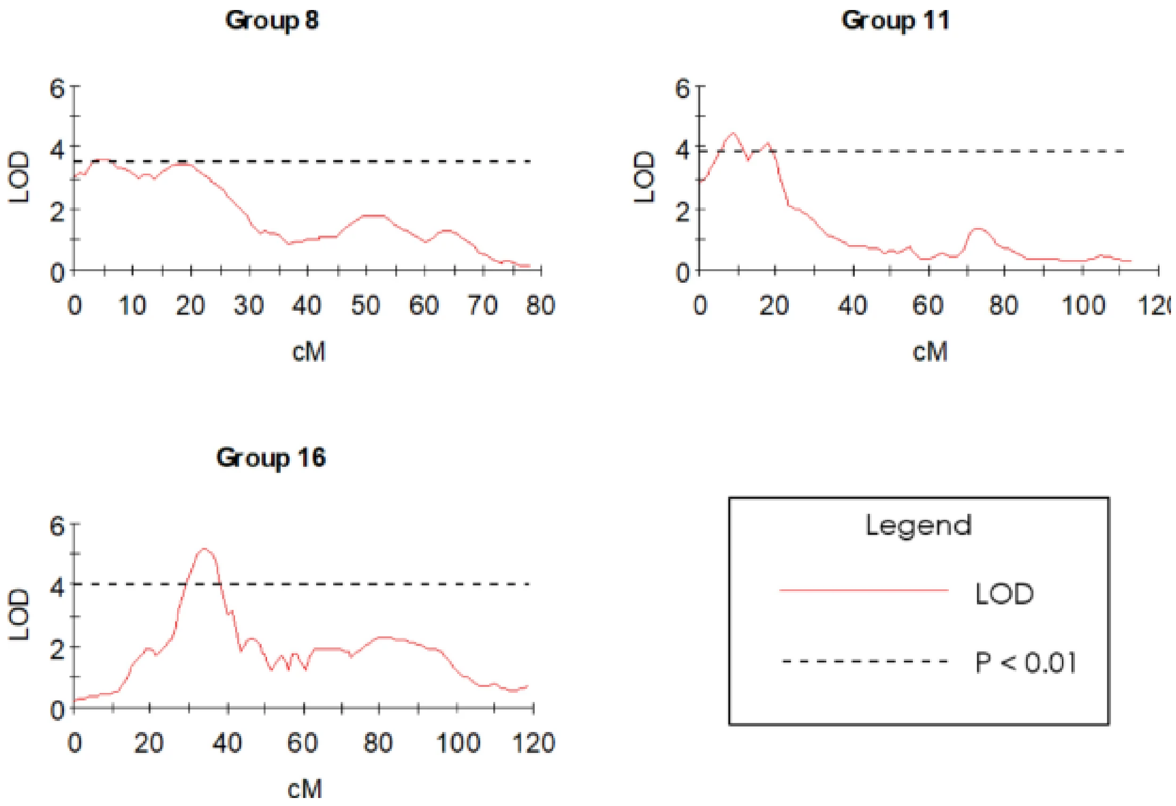


Histograms show the spur-borne nuts distribution and in-shell yield in the F_1 'Sparrow' × 'Schessler' population. All individuals (**A**), all individuals transformed (**B**), genotyped individuals included in QTL analysis (**C**), and In-shell Yield for all individuals transformed (**D**). Bins are divided by percentile

Spur bearing maps to 3 locations



Genetic linkage map of linkage groups 8, 11, and 16 showing QTLs associated with a high degree of spur-bearing and in-shell yield. Each marker shown on the right of linkage groups is labeled with its position in centimorgans on the left. Bars indicate the markers located within each QTL region at the $P < 0.05$ level and $P < 0.01$ level



LOD profiles for spur-bearing on linkage groups 8, 11, and 16 using the interval mapping function in MapQTL6. The $P < 0.01$ significance level was determined for each linkage group with a permutation test, represented by the dashed line. LOD values exceeding the threshold were detected, showing significant QTLs on linkage groups 8, 11, and 16

Relevance to seed orchard planning?

- Seedling populations segregate, with a low percentage of offspring carrying the trait even if they descend from spur bearing parents
- Clonal plant materials need to be utilized to leverage the benefit of spur bearing.
- Clonal material should have a data-support track record for spur bearing

Spacing

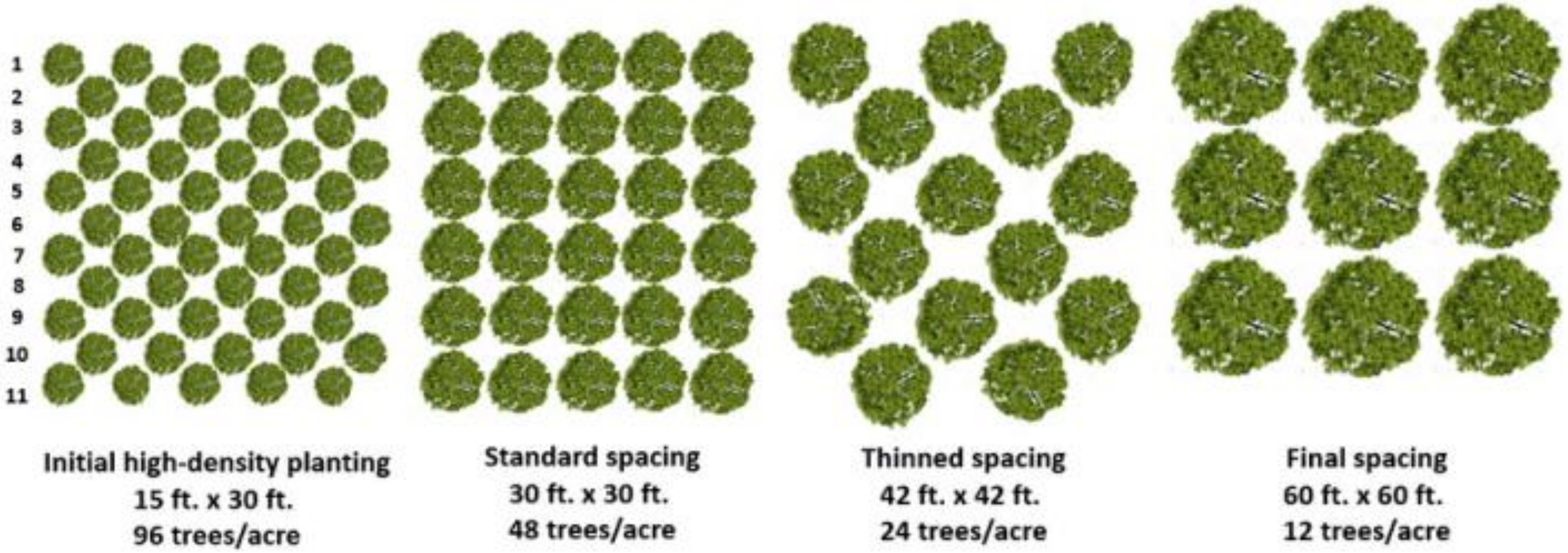


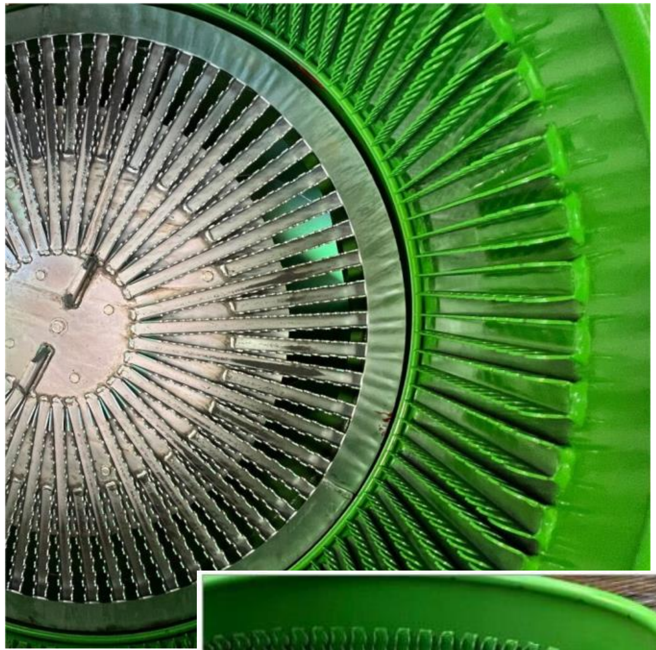
Figure 3. An orchard thinning process, planned around cultivar selection, should be a part of every walnut orchard. Initial high density should only be used when cultivating known, precocious cultivars with best management practices.

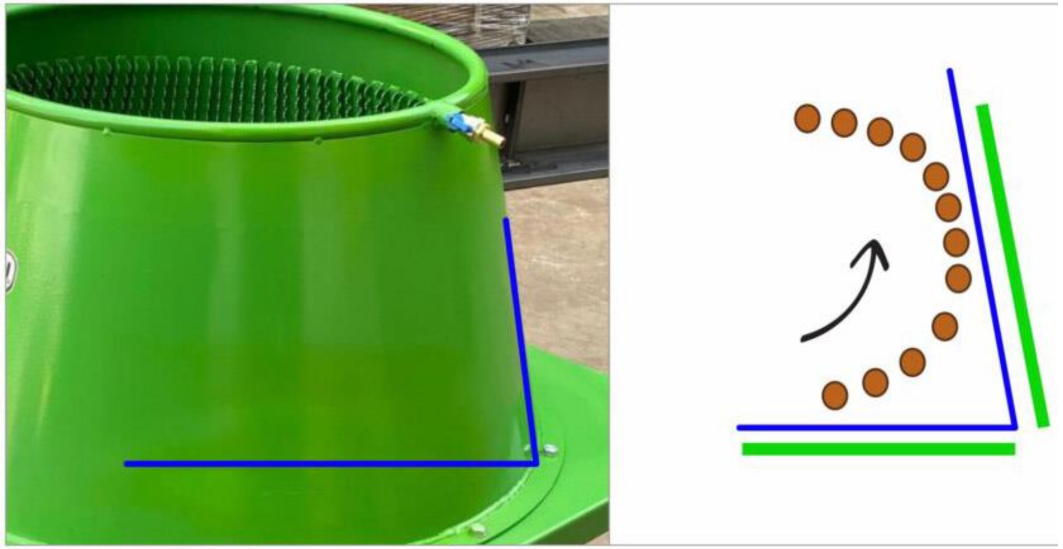
Fertility

- Once newly transplanted trees begin to make 8-10” of new growth by early-June, a half-cup of urea 46-0-0 nitrogen fertilizer around each tree over the entire weed-free area.
- Once established, 1-cup of urea per inch of stem diameter can be applied per tree in BOTH March and May.
- Mature orchards are generally given 100 lbs of actual N via urea with our research program; 60 lbs in March/April and 40 lbs in May/June.
  - Our second applications is sometimes deferred to Oct.
- Leaf nutrients guideline are found in our grower guide to help calibrate your fertility program: K, P, etc.

Seed handling post-harvest

Seed handling post-harvest





https://nutmec.com/en/walnut-equipment/walnut-hulling-equipment/kadioglu-cks80-walnut-huller-machine

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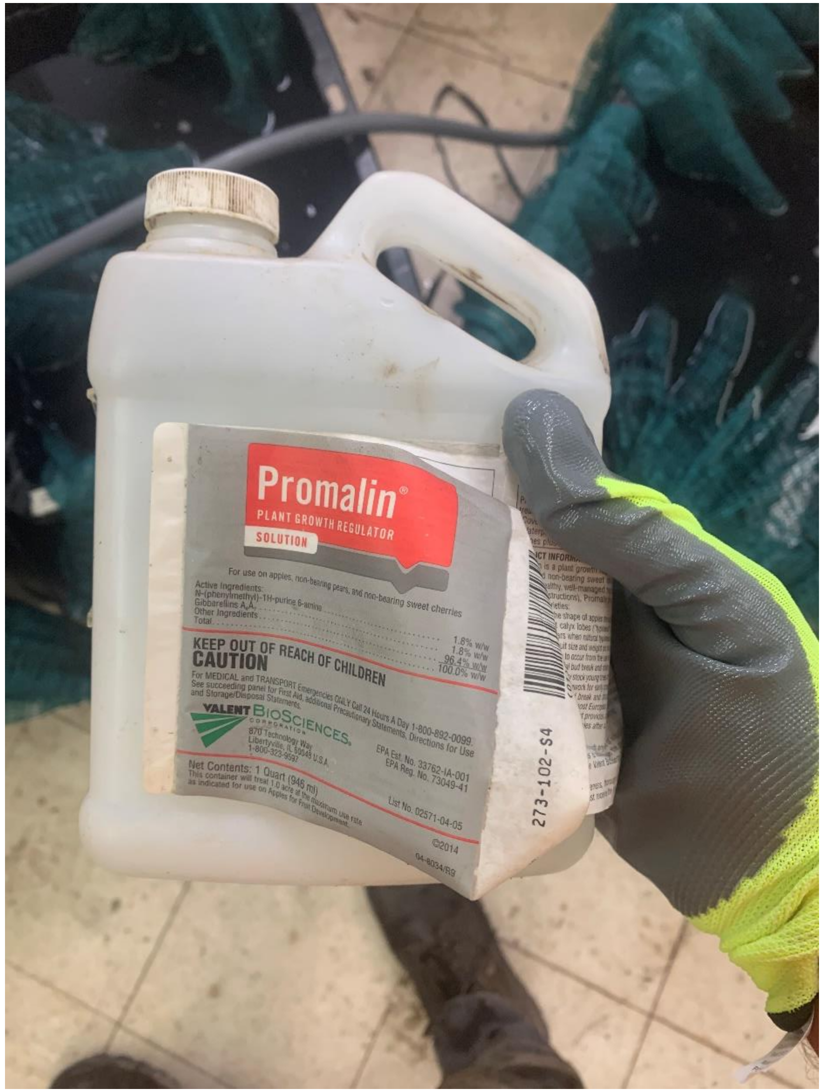

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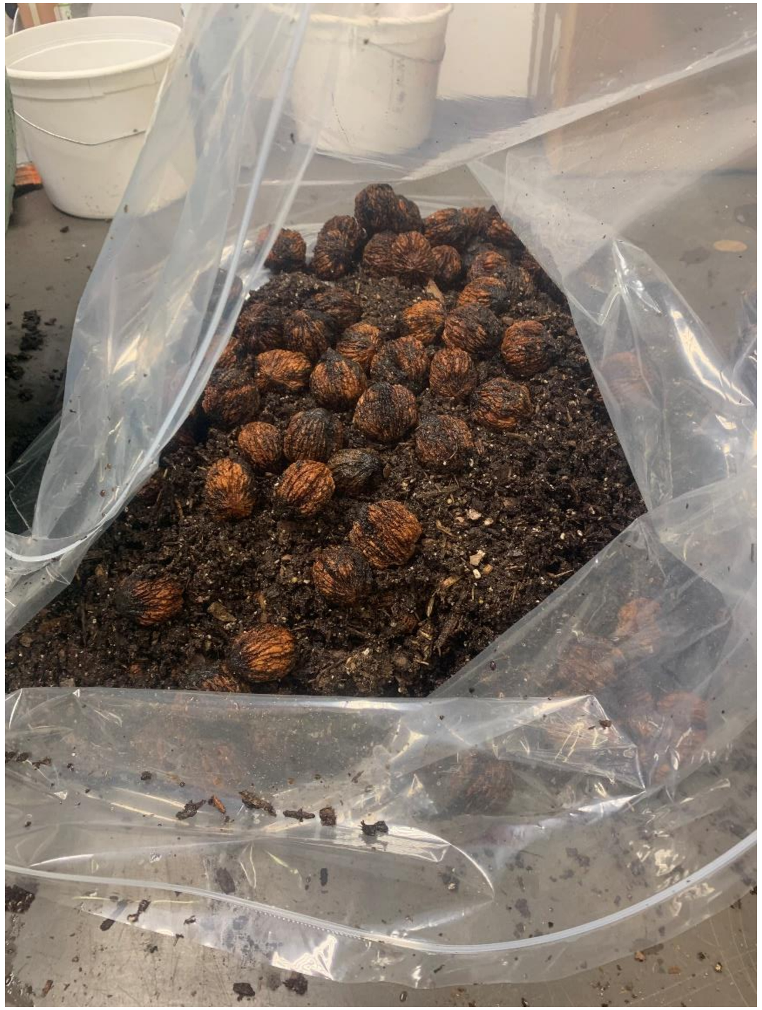
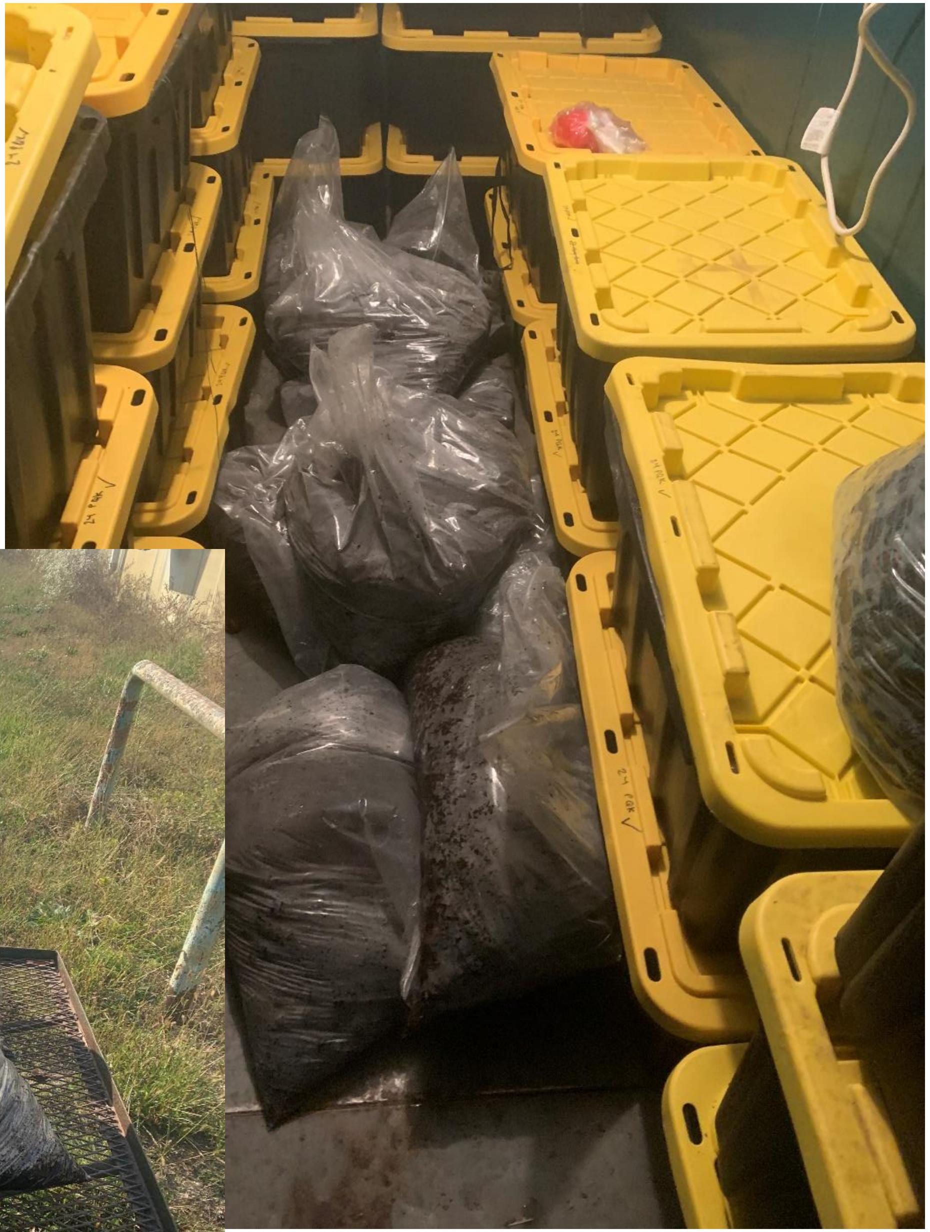


Seed handling post-harvest

- Monitor for moisture level, temperature, and possible mold
- Long periods of stratification are preferrable and influence germ. rate
- You should start to see radical emergence after 120-150 days. We stratify for 180 days often



Acknowledgement of Support

Center for Agroforestry
University of Missouri

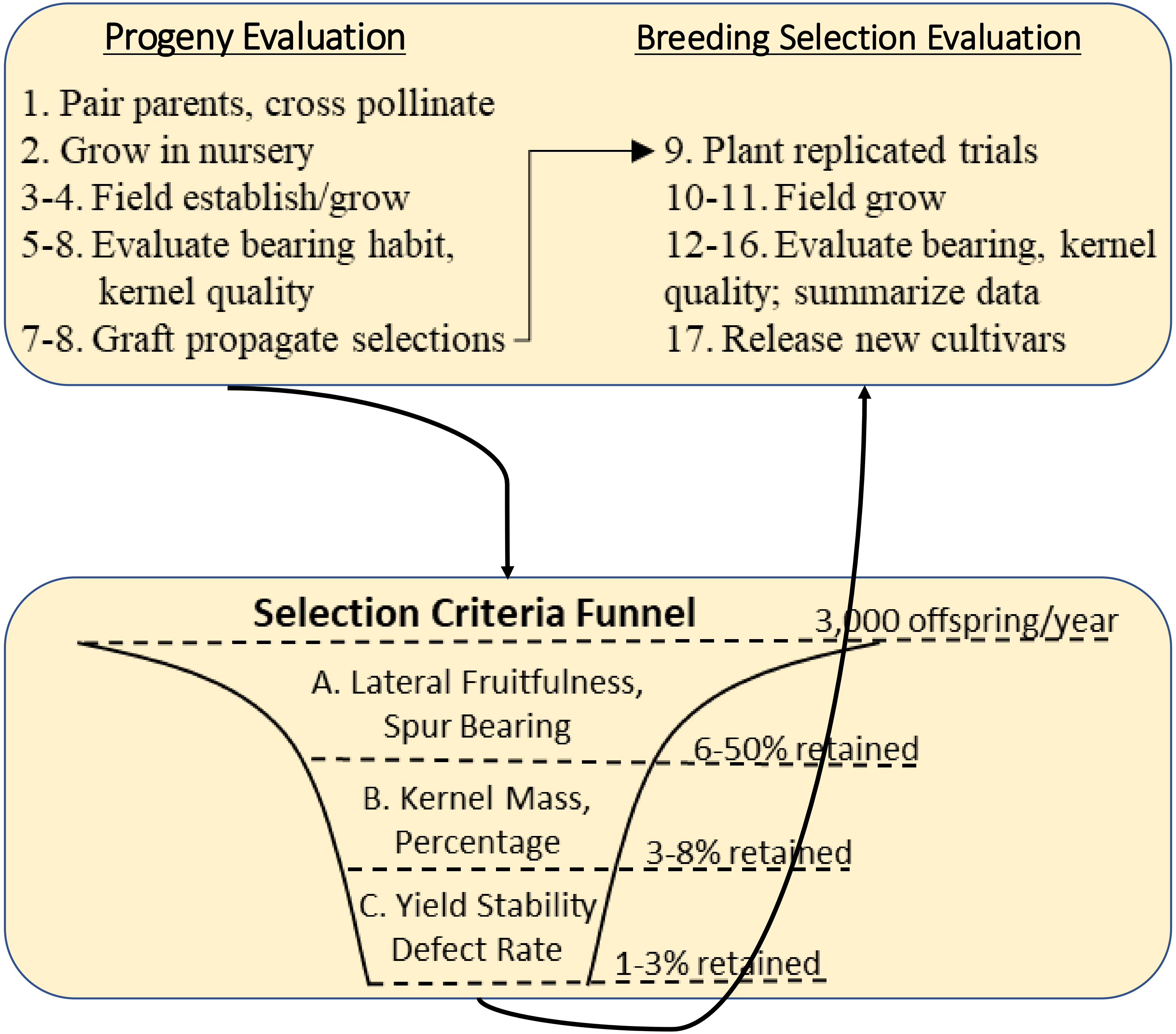
USDA ars
United States Department of Agriculture
Agricultural Research Service

MISSOURI DEPARTMENT of AGRICULTURE

This work is supported by the University of Missouri Center for Agroforestry and the USDA–ARS Dale Bumpers Small Farm Research Center, Agreement number 58-6020-0-007 from the USDA Agricultural Research Service.

Breeding Scheme & Selection Funnel

- Breeding Scheme (top)
  - 8 years/generation
  - 17 years to release
  - Incorporate genetic markers to accelerate timeline
- Selection Funnel (bottom)
  - Establish a workflow to generate 1,000 offspring/year
  - Progeny are first culled for spur bearing
  - Next, kernel mass/percentage
  - Finally, defect rate and yield stability



An Example of Application

- Heterodichogamy is an important source of flowering time variation – prospectively useful in pollinizer development for early female bloom cultivars or cultivars with reciprocal bloom compatibility