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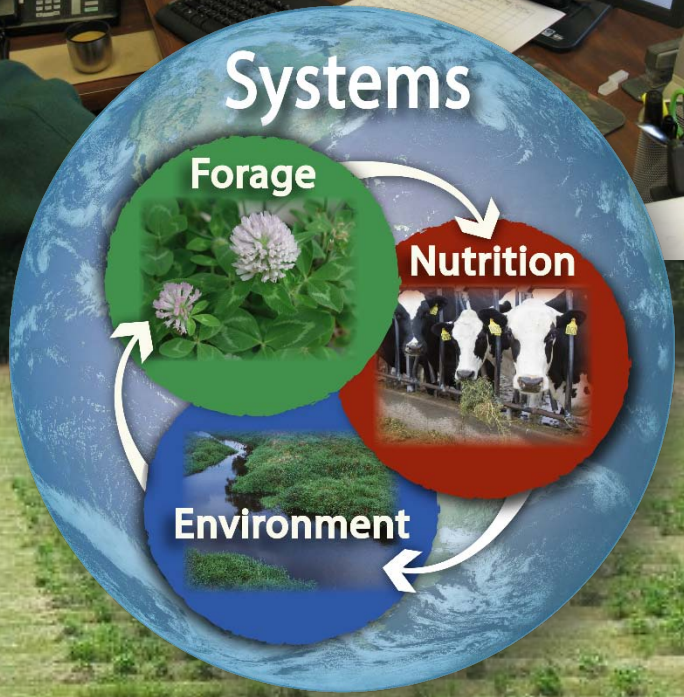
Rate of Forage Yield Breeding Gains in a Red Clover Breeding Program

Heathcliffe Riday



U.S. Dairy Forage Research Center
USDA Agricultural Research Service

Background

- Occasional breeding gain papers published
  - Usually compare varieties by release year
- Difficult studies to conduct

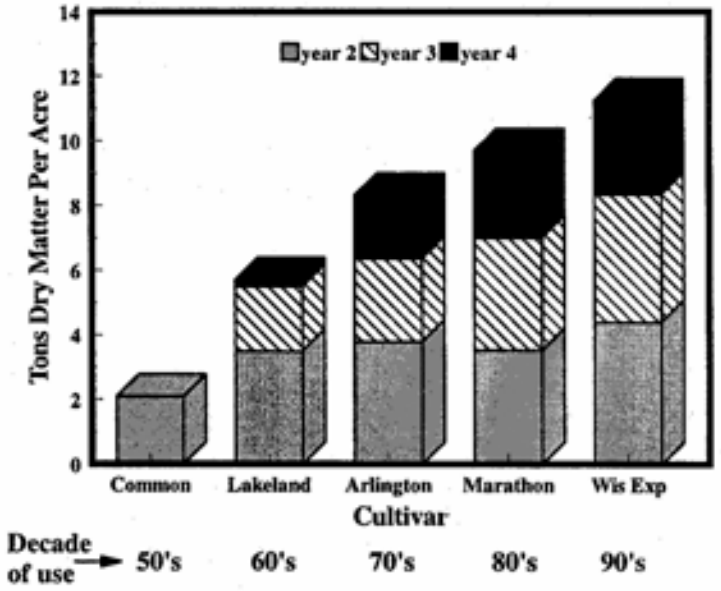


Figure 2. Forage production of red clover resulting from five decades of breeding for persistence and disease resistance.

(Smith, 2000)

Table 2 Estimates of genetic gain in red clover breeding. † Woodfield and Brummer (2001), ‡ Data from Six trials planted 1986 to 1991 in Wisconsin, USA. (Smith *et al*. 1987-1994; Riday and Krohn 2010a), § Data from 1 Rotational Grazed red clover – tall fescue mixture trial established 2004 in Wisconsin, USA (Riday *et al*. 2007), ¶ Unpublished results from (Riday *et al*. 2007), a – released 1953 (Hollowell 1961); b – released 1973 (Smith *et al*. 1973); c – released 1987 (Smith *et al*. 1994); and d – unreleased experimental first tested in 1992 (Smith 2000).

Trait	Benchmark variety	Improved varieties	Genetic gain (% yr^{-1})
DM yield†	G. Turoa	G. Hamua, Pawera	0.43
DM yield†	G. Hamua	G. Colenso	0.21
DM yield†	G. Pawera (4x)	G27 (4x)	1.39
1st post-seeding year DM yield‡	Lakeland[a]	Arlington[b], Marathon[c]	0.41
2nd post-seeding year DM yield‡	Lakeland	Arlington, Marathon	0.55
3rd post-seeding year DM yield‡	Lakeland	Arlington, Marathon	0.95
Trial DM yield‡	Lakeland	Arlington, Marathon	0.60
Establishment survival§	Lakeland	Arlington, Marathon, C328[d]	0.94
12-month survival§	Lakeland	Arlington, Marathon, C328	1.94
24-month survival§	Lakeland	Arlington, Marathon, C328	1.43
36-month survival¶	Lakeland	Arlington, Marathon, C328	2.78
48-month survival¶	Lakeland	Arlington, Marathon, C328	1.32

(Riday, 2010)

- Visual score for biomass plant^{-1}
  - 3 to 5 time per year
  - 4 summers and 3 winters
  - 12 to 18 total observations per plant
- Common check cultivar and halfsib families statistically bind nurseries together across locations and years
- Each nursery x scoring date “cohort” is standardized = 9 x (vig. score/99th percentile obs.)
  - Observed dead plants are given a zero vigor score

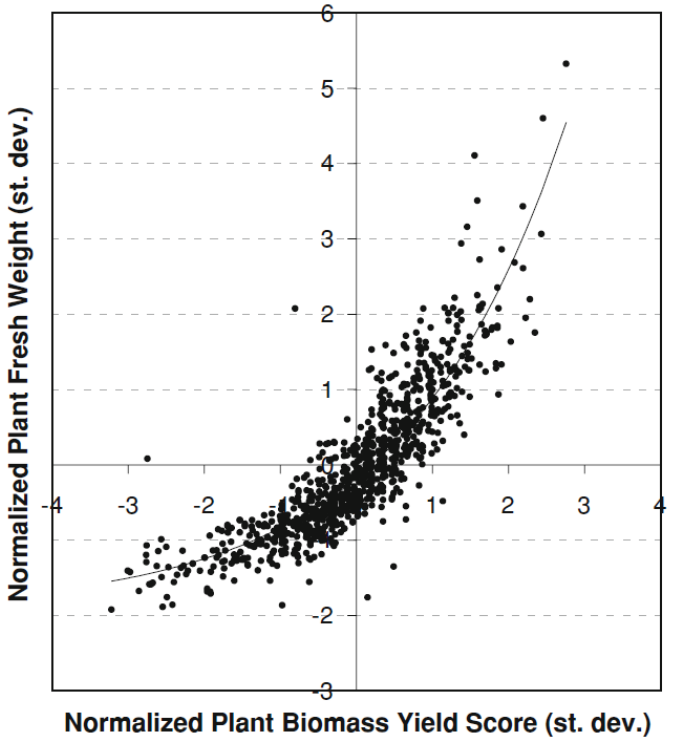
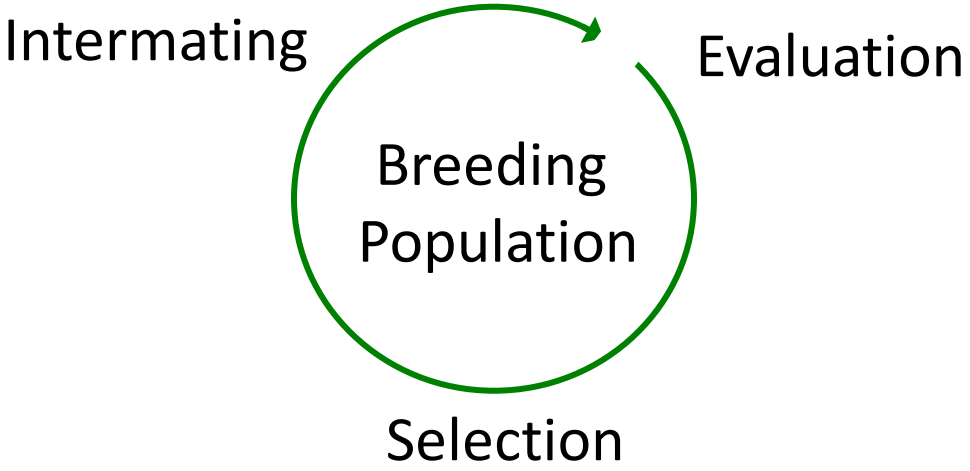


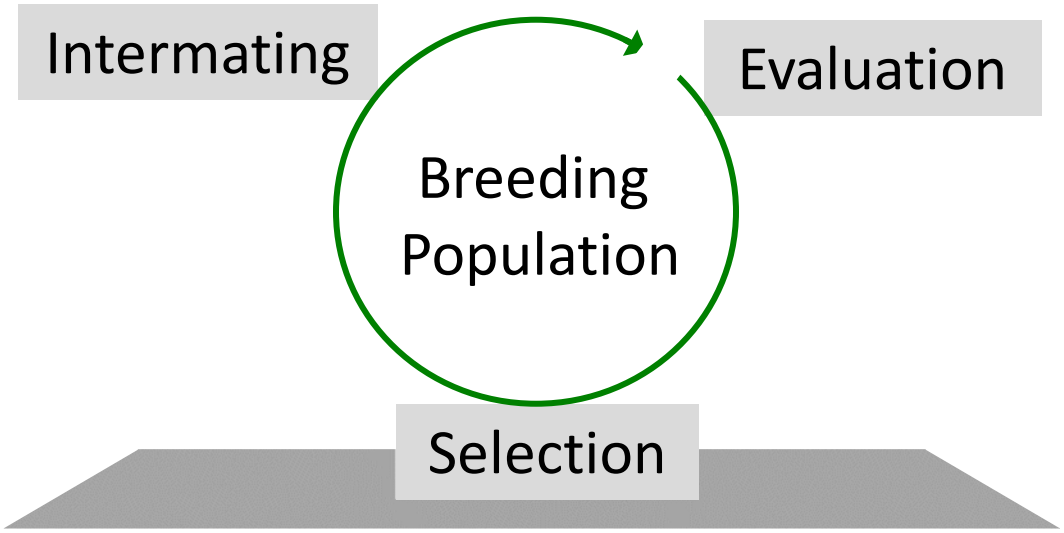
Fig. 1 Individual normalized plant fresh weights (standard deviations) plotted against the average of two normalized biomass yield scores (standard deviations) with fitted exponential function (fresh weight = $0.3784e^{0.475 \times \text{score}} + 1.923$) (pseudo-$R^2 = 0.79$)

(Riday, 2009)

Selection Program



A more complex perspective



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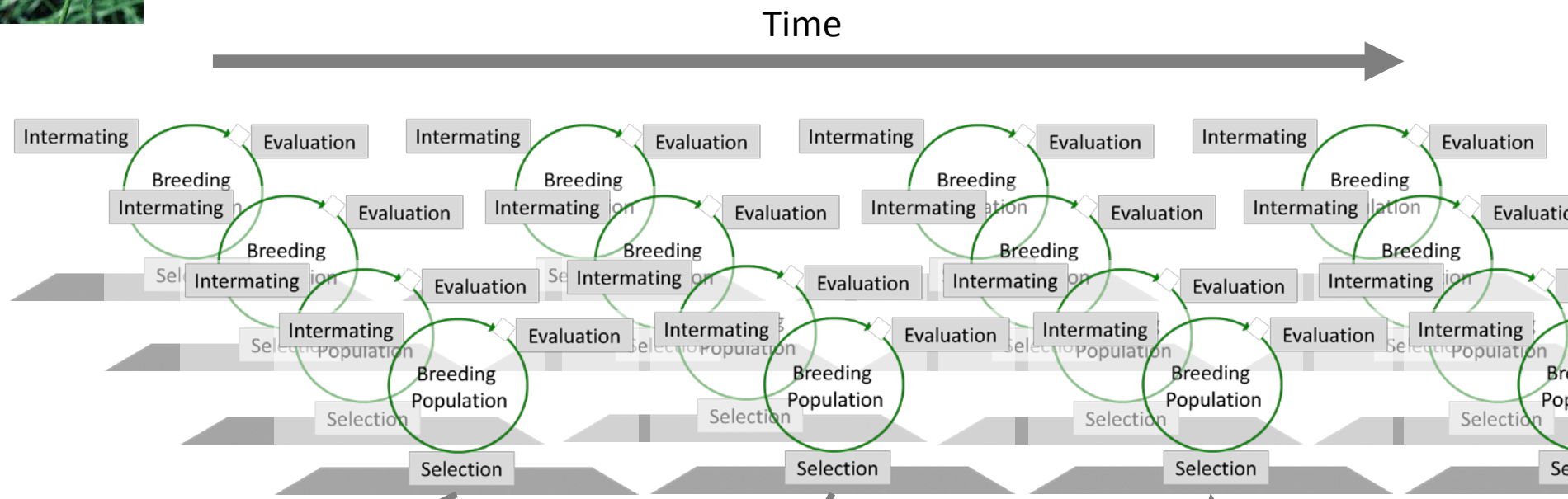


Individual plant observations database

Individual Plant Selections

Intermate groups of selected plants

"Phenotypic Selection"

Family means

"Genotypic Selection"

Grow individuals from remnant seed of best families and intermate

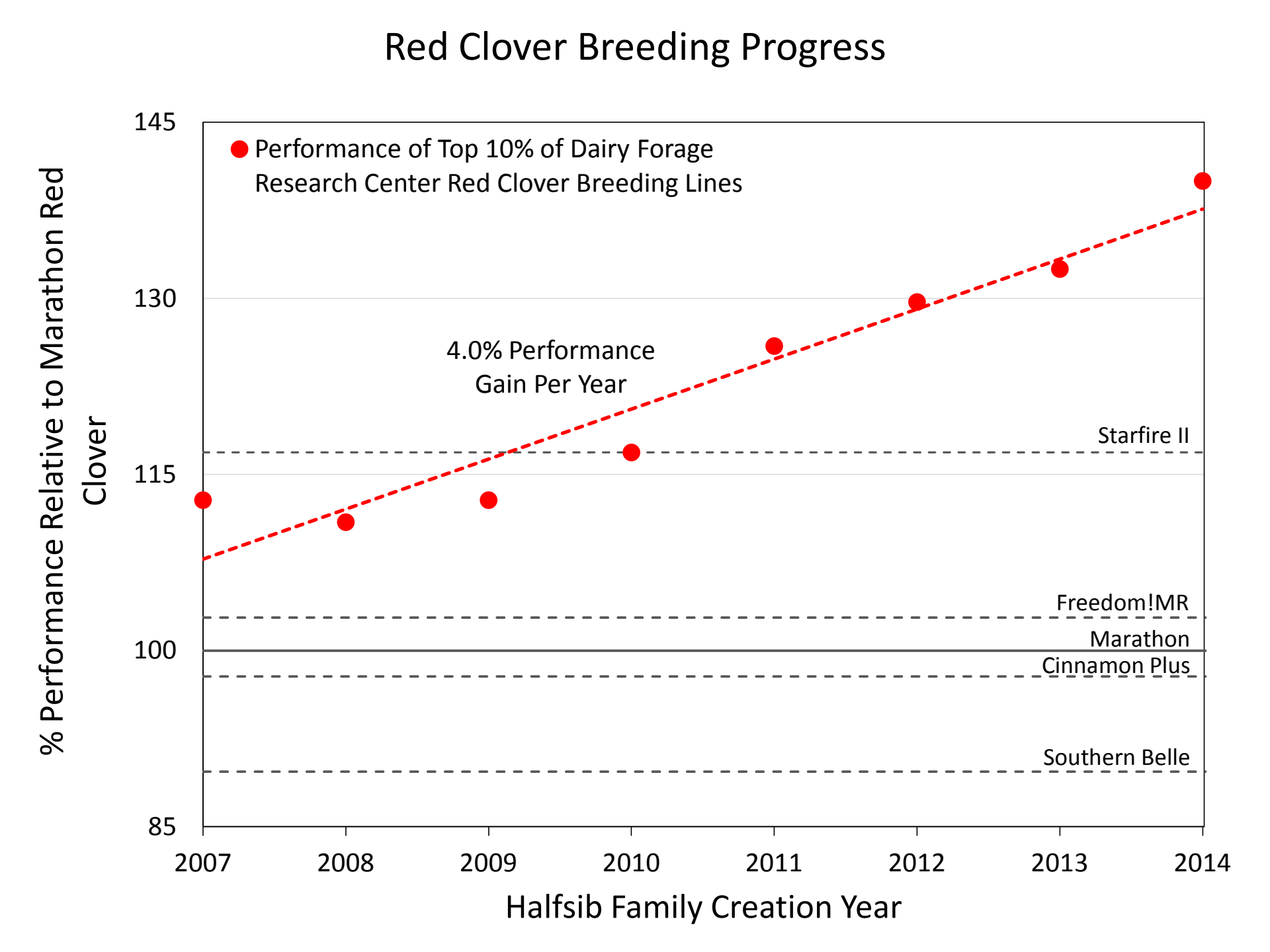
Experimental variety testing and initial seed increase

Large scale seed increase

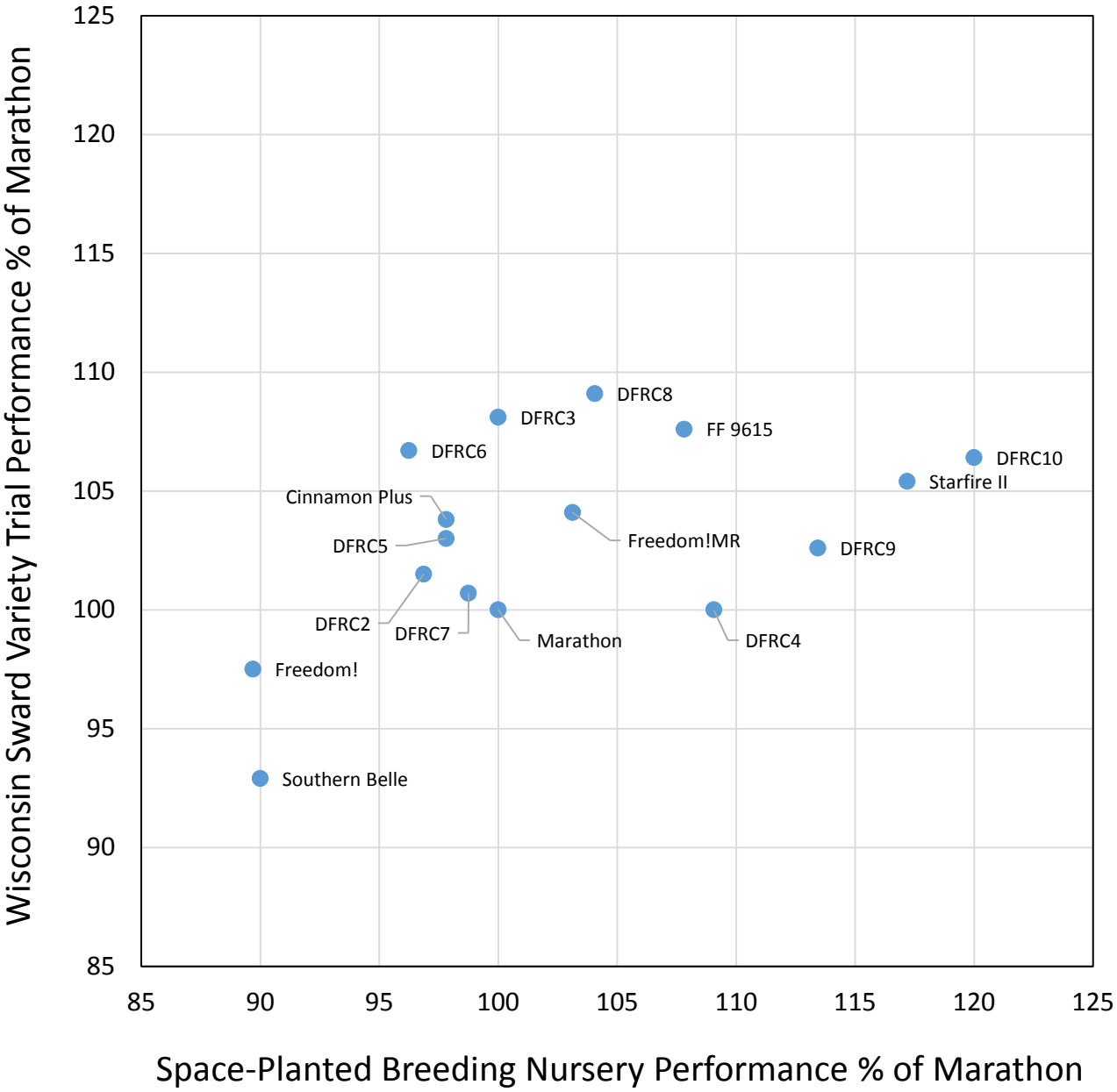
Data 2006-2015

- 694,134 repeated individual plant vigor observations
- Taken on 66,649 unique plants
  - Of these 9,065 paternity identified using DNA markers
- From 1,824 entries (halfsib families, populations, or varieties)
  - With halfsib families derived from 104 polycrosses
  - Minimum of 40 plants entry^{-1} to make selection decision
- Evaluated across 61 nurseries

→ Information used for Genotypic Selection

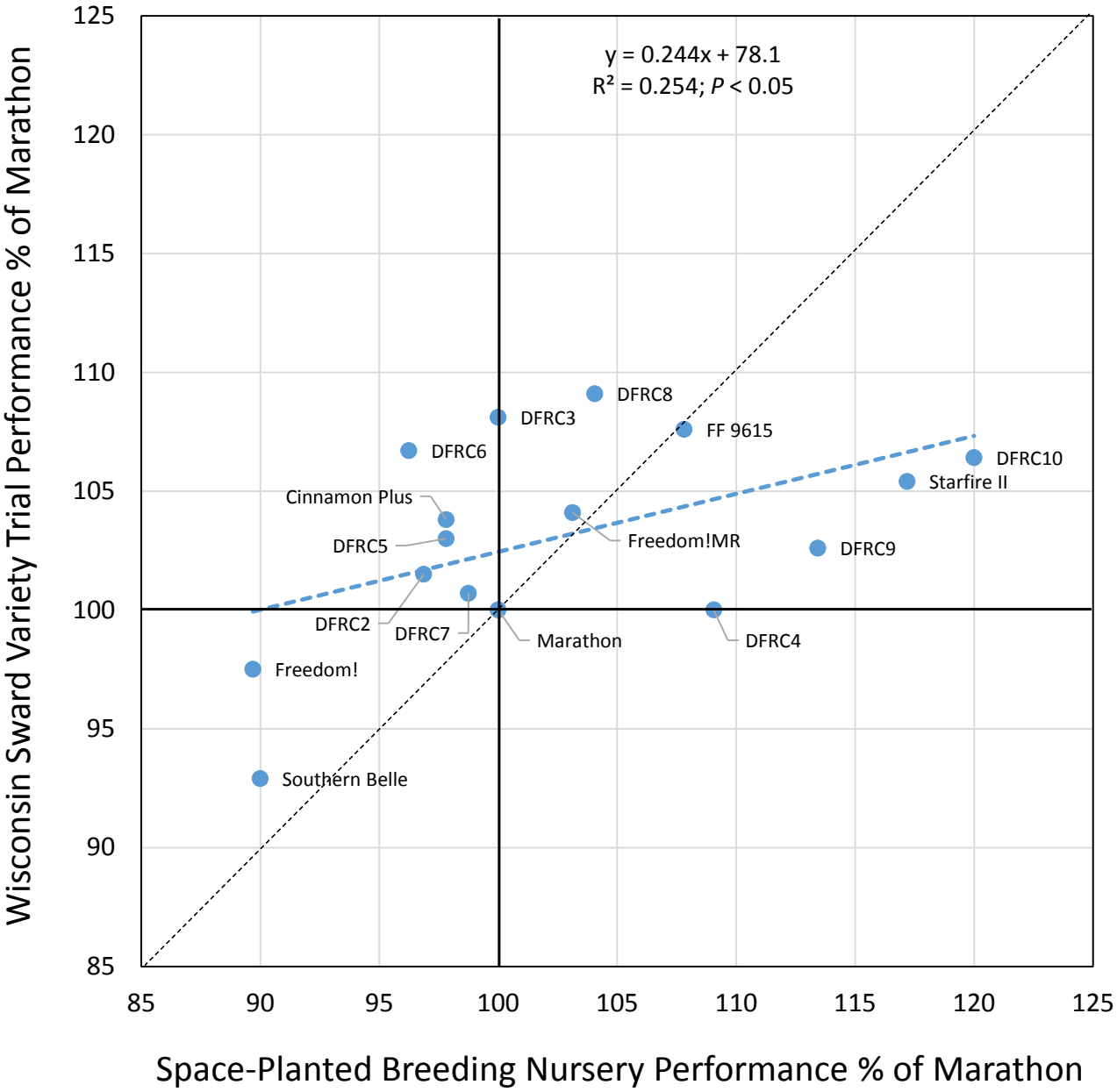

Red Clover Breeding Progress
145
130
115
100
85
% Performance Relative to Marathon Red Clover
Performance of Top 10% of Dairy Forage Research Center Red Clover Breeding Lines
4.0% Performance Gain Per Year
Starfire II
Freedom!MR
Marathon
Cinnamon Plus
Southern Belle
2007
2008
2009
2010
2011
2012
2013
2014
Halfsib Family Creation Year

Predicting Sward Performance from Visual Space-Plant Evaluations

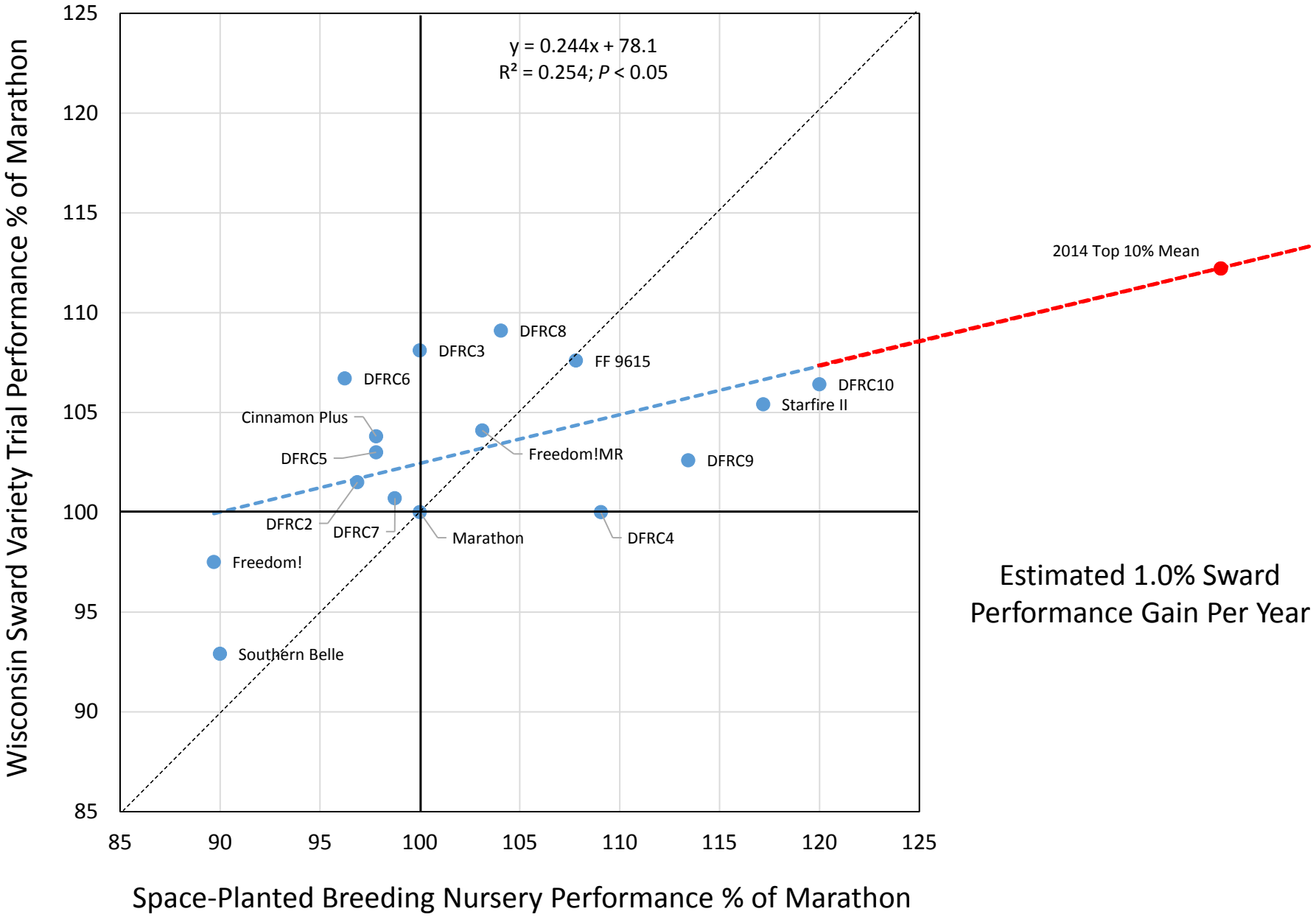


VS

Predicting Sward Performance from Visual Space-Plant Evaluations

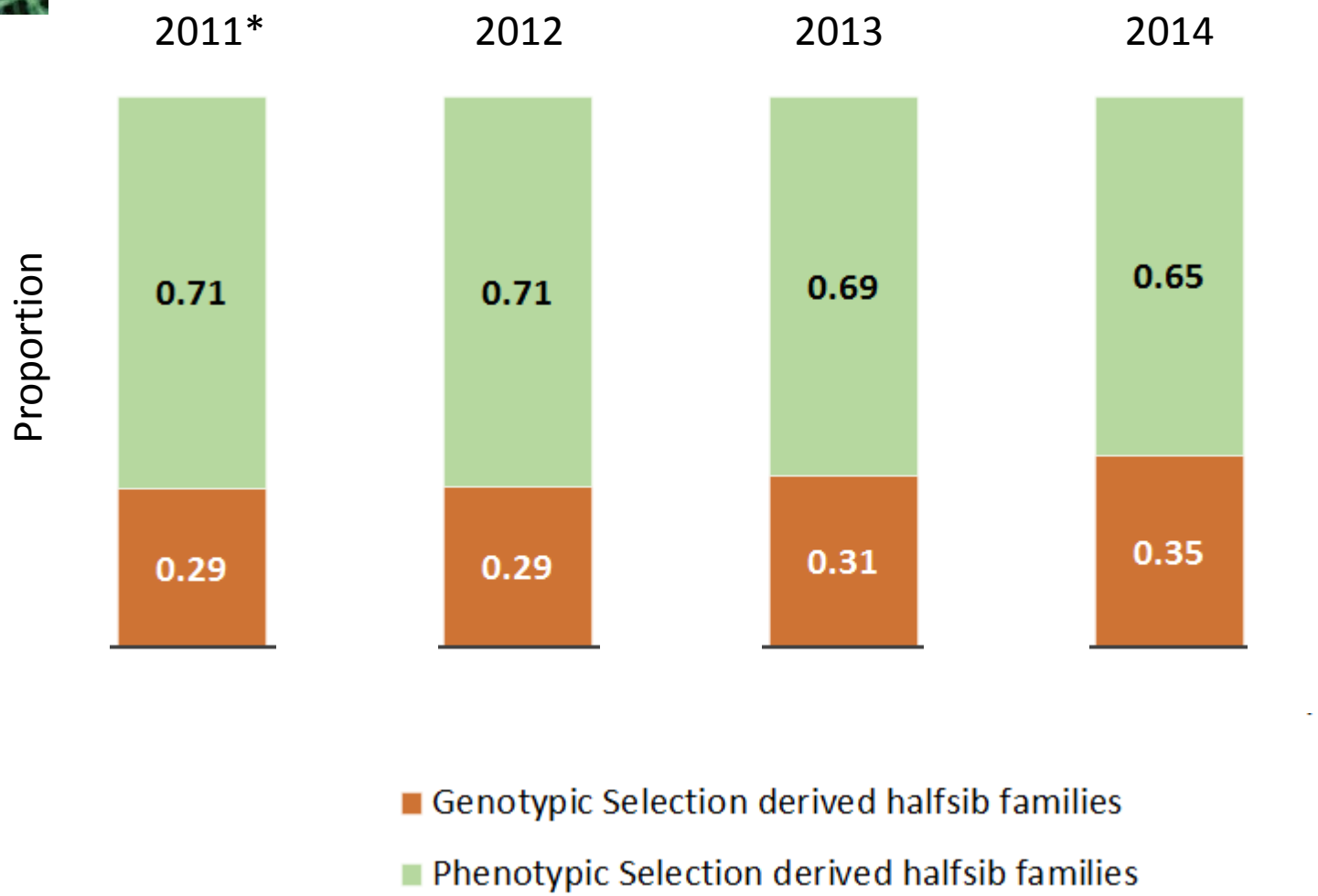


Predicting Sward Performance from Visual Space-Plant Evaluations



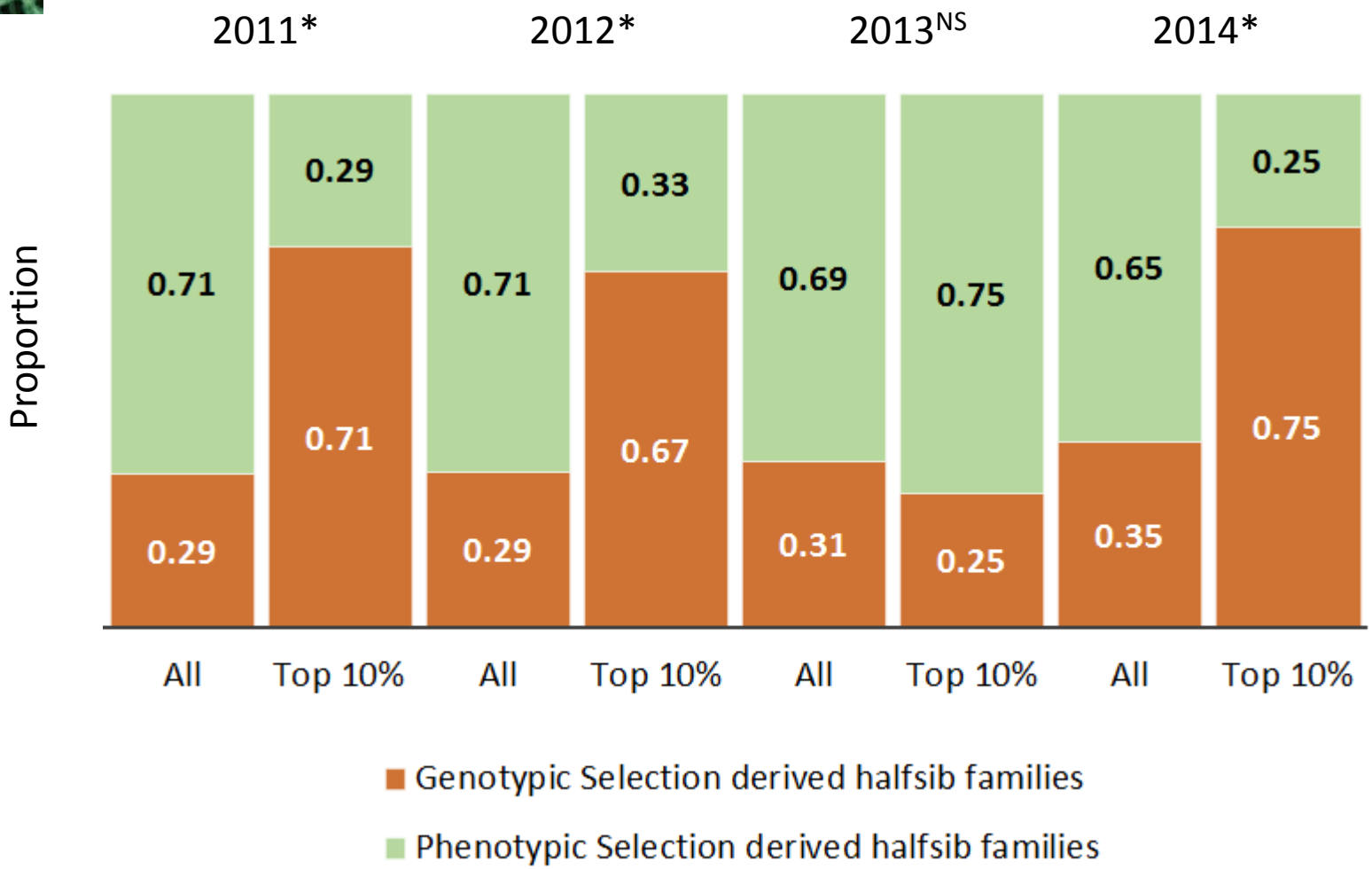
Estimated 1.0% Sward Performance Gain Per Year

Genotypic vs. Phenotypic Selection



* Year halfsib family was created

Genotypic vs. Phenotypic Selection



* χ^2-test significant at $P < 0.05$

Genotypic vs. Phenotypic Selection

	2011	2012	2013	2014	Mean
	x-times more genotypic selection derived halfsib families than equal expectation				
Genotypic Selection derived halfsib families in Top 10% of tested families	6.19	4.88	0.73	5.63	3.34*

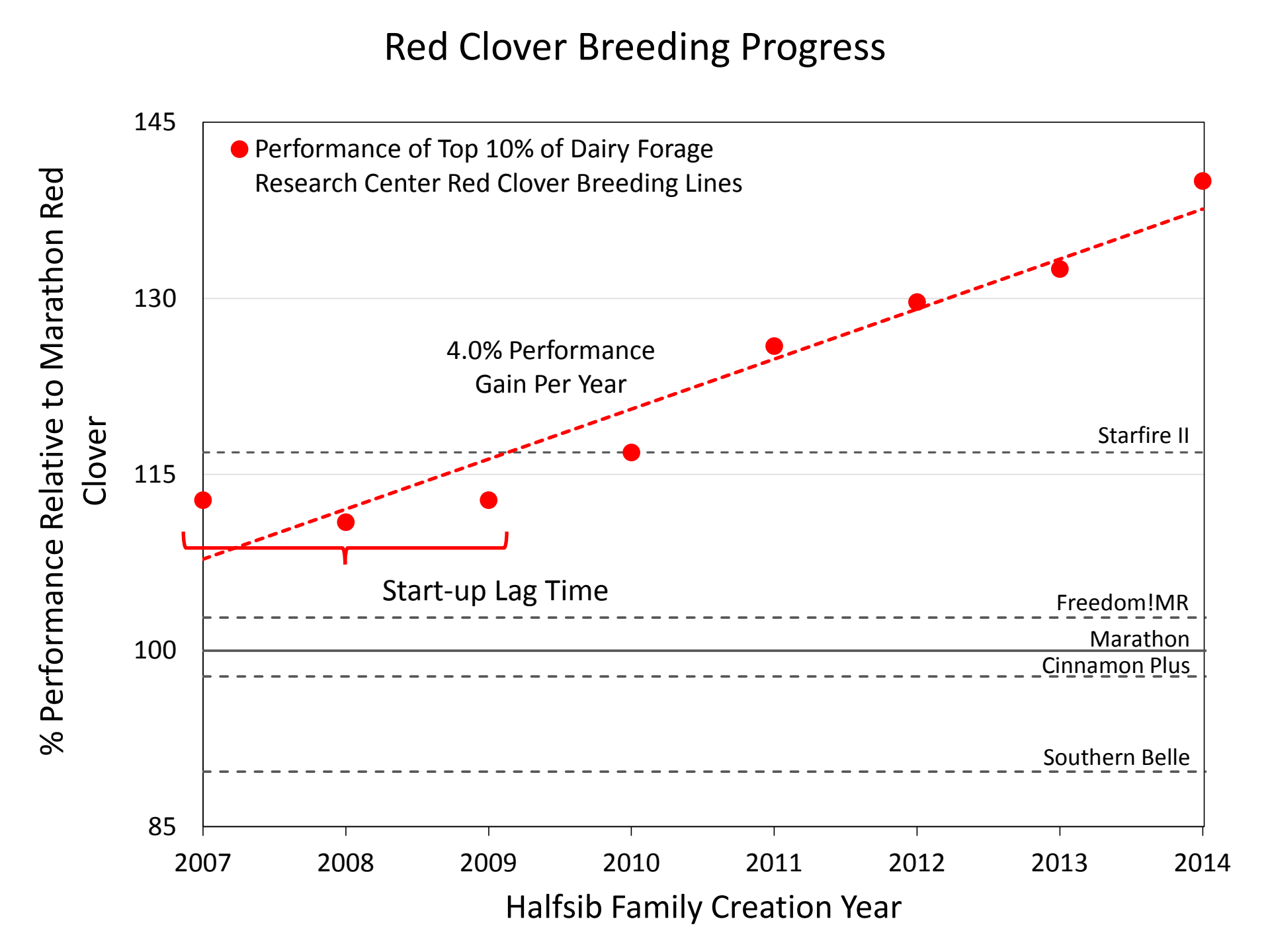
* geometric mean; different from 1 at $P = 0.098$

Rate of Obsolescence

- Since 2006 ~ 180 halfsib families added to the evaluation program each year
  - By 2016 ~1,800 halfsib families to select among

Genotypic Selection	2011	2012	2013	2014	2015	2016	Mean
No. of halfsib families selected	6	8	12	16	16	16	
Average age of halfsib family selected	5.5	4.8	5.6	5.0	4.4	3.4	4.8

- "Effective" genotypic selection intensity ~ 6/(4.8*18) ≈ 2%
- Phenotypic selection intensity ~ 5% to 8%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2014
Halfsib Family Creation Year

Conclusions

- Breeding works
- 4% estimated vigor breeding gains year^{-1}
  - 1% estimated sward biomass yield gain
- Genotypic selection program is 3.3 times more effective than the phenotypic selection program
- Halfsib families currently have an average 4.8 year utility in the program
- Apparent genetic gain lag time at the start of the program

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