THE CHANGING FACE OF BEAN BREEDING; PAST AND FUTURE

BIC

2013 Frazier- Zaumeyer Lecture

Jim Kelly, Michigan State University

CHANGES IN BEAN PLANT ARCHITECTURE

- In Willamette Valley, Oregon - Tex Frazier – Developed first bush blue lake garden bean variety in 1960's
- Architecture change – revolutionized garden bean industry – Pole bean to bush bean – facilitate widespread production and mechanized harvest
- Acreage in Oregon
- 14-17,000 acres
- Farm-gate value $20m

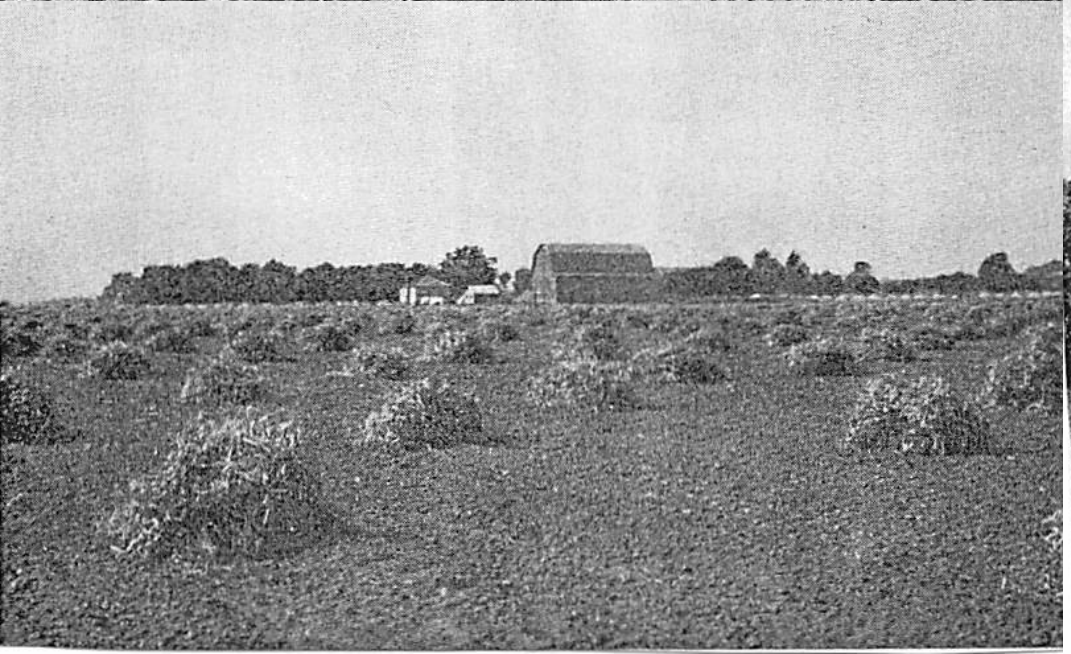
Chronology of Blue Lake Varieties

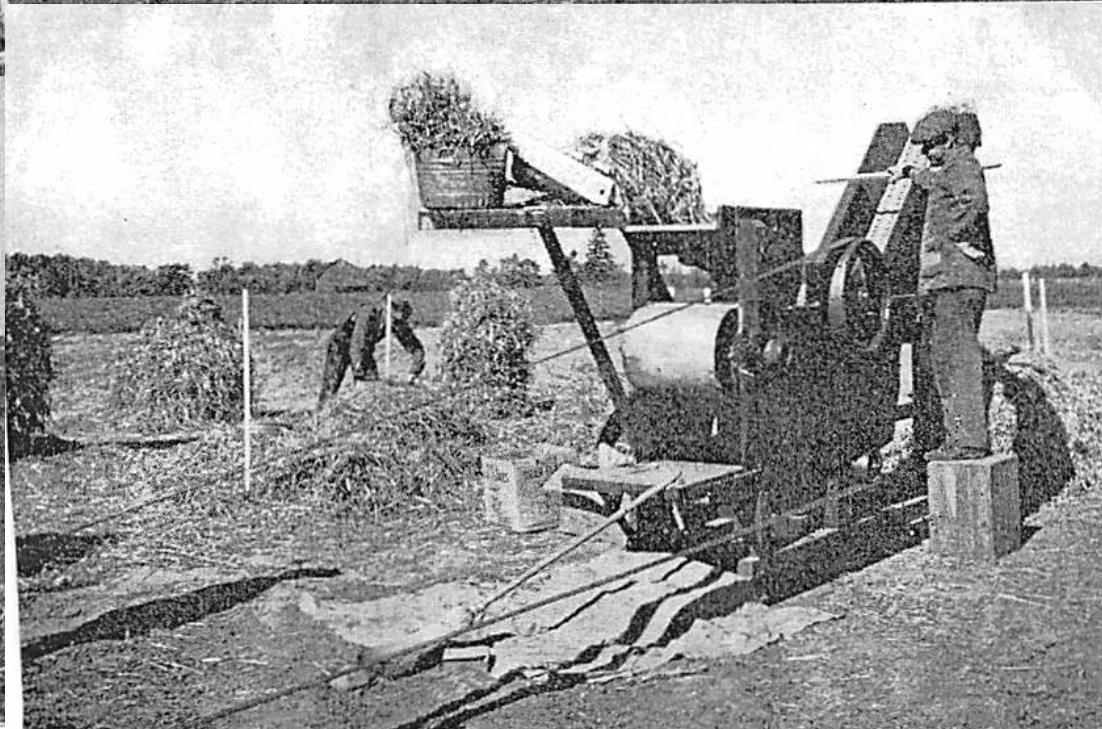
1950	POLE X POLE CROSSES - W.A. (Tex) Frazier BUSH X POLE CROSSES BACKCROSSES TO POLE BEANS
1965	OSU 941 • OSU 2065
1970	OREGON 58
1972	OREGON 1604 • OREGON 190
1980	OREGON 91G • ORE. 83 • ORE. 17 – Jim Baggett
1981	OREGON 43 • ORE. 55
1983	OREGON TRAIL (Home Garden)
1990	CASCADE GIANT POLE (Home Garden)
1992	OREGON 54
2005	OSU 5630 --- Jim Myers

SOURCE: OREGON HORTICUTURAL SOCIETY

Plant Architectural Types

Type I, bush **Type II, upright** **Type III, vine** **Type IV, climber**





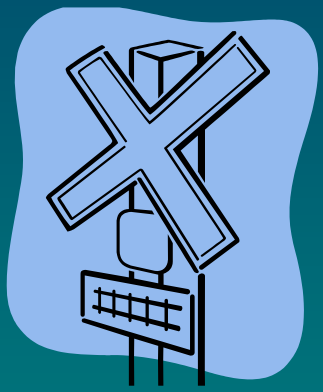
BN

IGURE 15.—Pulling and windrowing Sanilac beans in Michigan with a harv
and an attached windrower.

CHANGES IN BEAN PLANT ARCHITECTURE

- In Michigan – traditional varieties prostrate vine type III navy beans, Robust…. Michelite
- Dr. Downs pioneering scientist / breeder
- Release of Sanilac bush navy bean in 1957 – X-ray mutation breeding
- Why not use convention breeding?
- In 1926 cross of Robust navy x Wells Red Kidney noted as inferior
- Genetic incompatibility between gene pools, DL factors

CLASSICAL BUSH KIDNEY



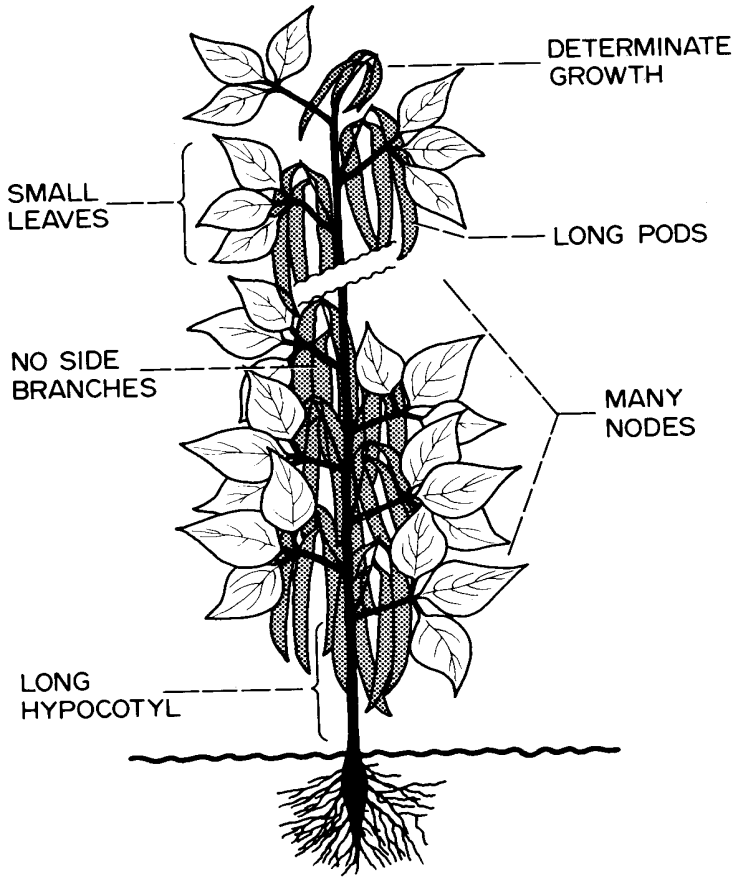
TRADITIONAL VINE TYPE

White Gold of Saginaw Valley – Sanilac Navy Bean ….. Seafarer

CHANGES IN MICHIGAN AGRICULTURE

- In 1970's yields in Michigan declined
- Less alfalfa, soil compaction, air pollination
- Competition from new production areas
- Lack of diversity limiting breeding progress
- Dr. Adams proposed new Bean Ideotype
- Search initiated to diversify germplasm
- Led by Dr. Adams – Rockefeller support
- Spawned the Bean / Cowpea CRSP
- Adams, Wallace, Barnes-McConnell

Bean Ideotype



Source; Adams 1982

HEIGHT
MATURITY
STEM STRENGTH
LODGING RESISTANCE

Plant Architectural Classification

Genetics	Type	Type Refined	Description
Determinate	I	Ia	Erect Bush
		Ib	
Indeterminate	II	IIa	Upright short vine
		IIb	Upright vine
	III	IIIa	Prostrate Vine
		IIIb	
	IV	IVa	Climbing
		IVb	

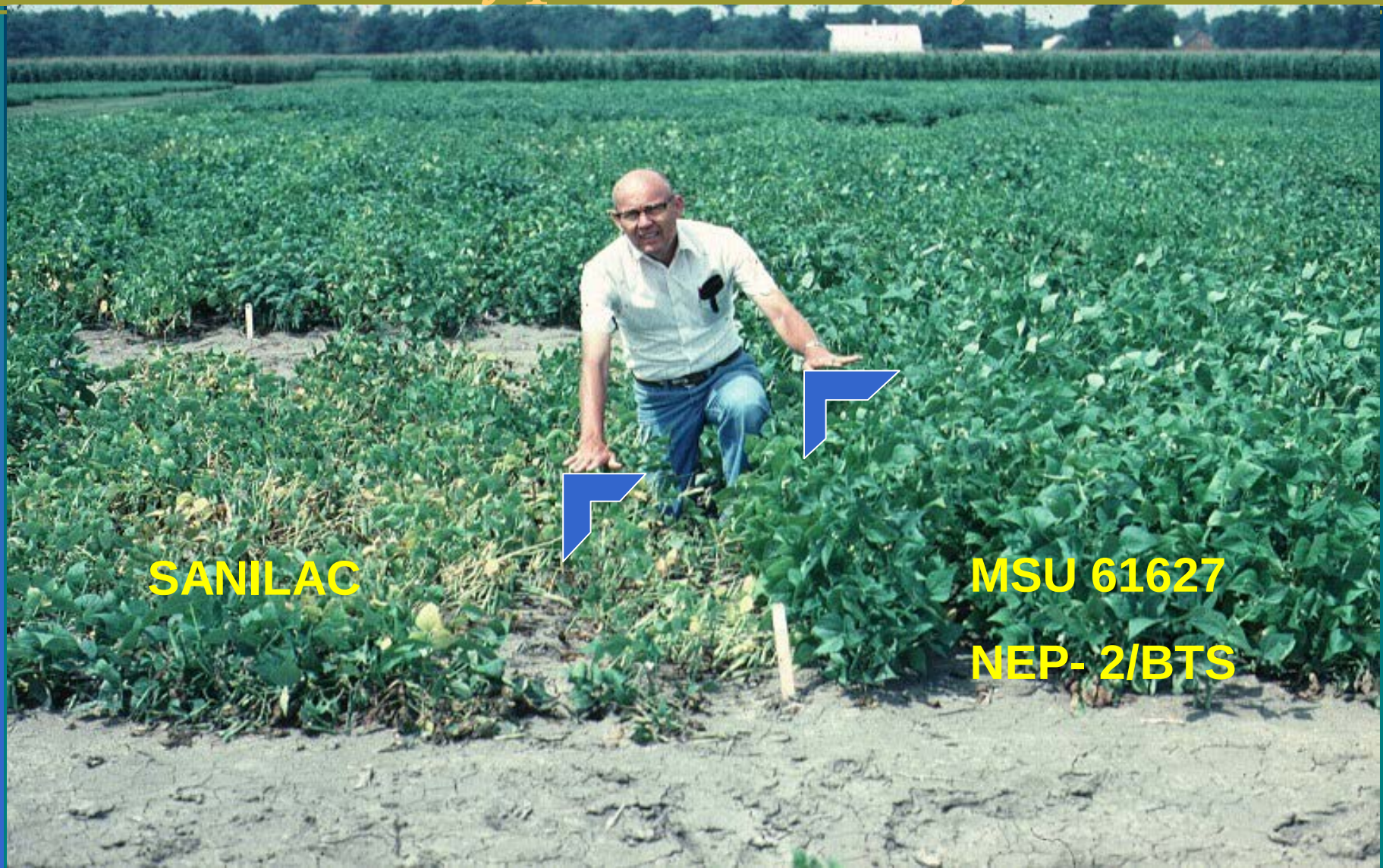
Source: Singh, 1982

CHANGES IN BEAN PLANT ARCHITECTURE

- Search for germplasm – led to small seed black beans from Mexico, Central America
- Jamapa – Mexico
- S-182-N – tested in El Salvador – Dr. Zaumeyer in 1950s through PCCMCA network
- Released in Costa Rica as San Fernando
- NEP-II was white seeded EMS mutant
- Four lines S-182-N were released in NY as Midnight by Dr. Sandsted at Cornell
- Cornerstone in breeding first upright black and navy bean varieties in Michigan

Ideotype Breeding

MSU Architype – Dr. Wayne Adams



Chronology of Upright Varieties

1970s	NEP II X BTS - W. Adams
	JAMAPA/NEP II // KENTWOOD – J. Kelly
1982	DOMINO, BLACK MAGIC
1982	SWAN VALLEY, NEPTUNE
1983	C-20
1987	MAYFLOWER
1989	BLACK HAWK
1994	RAVEN
1999	JAGUAR
2003	SEAHAWK
2008	ZORRO

Seed Color Variants from NEP II Background

P- black

- Pv07

pp - white

Upright Black Bean Varieties

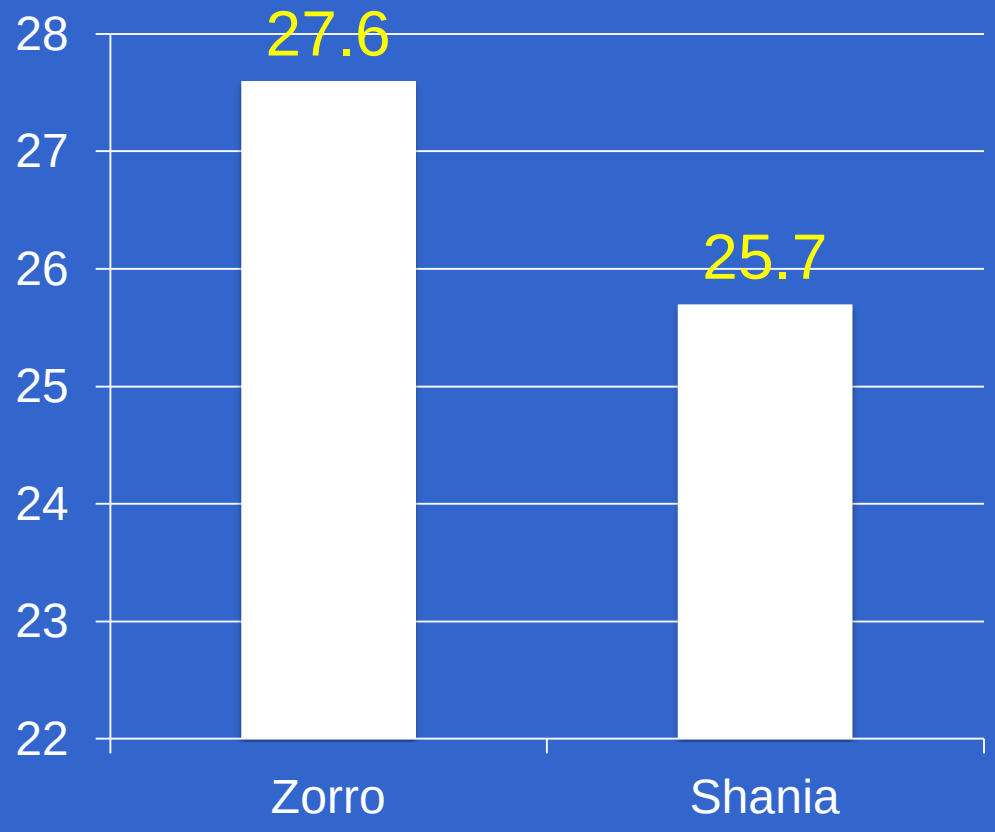
Yield (T/ha) Zorro Black Bean in Different Row Widths

Row width	2011 EL	2010 SVREC	2011 SVREC
38 cm	4.29 a	2.13 a	2.86 a
76 cm	3.61b	2.04 a	2.63 b
Percent	19	4	8

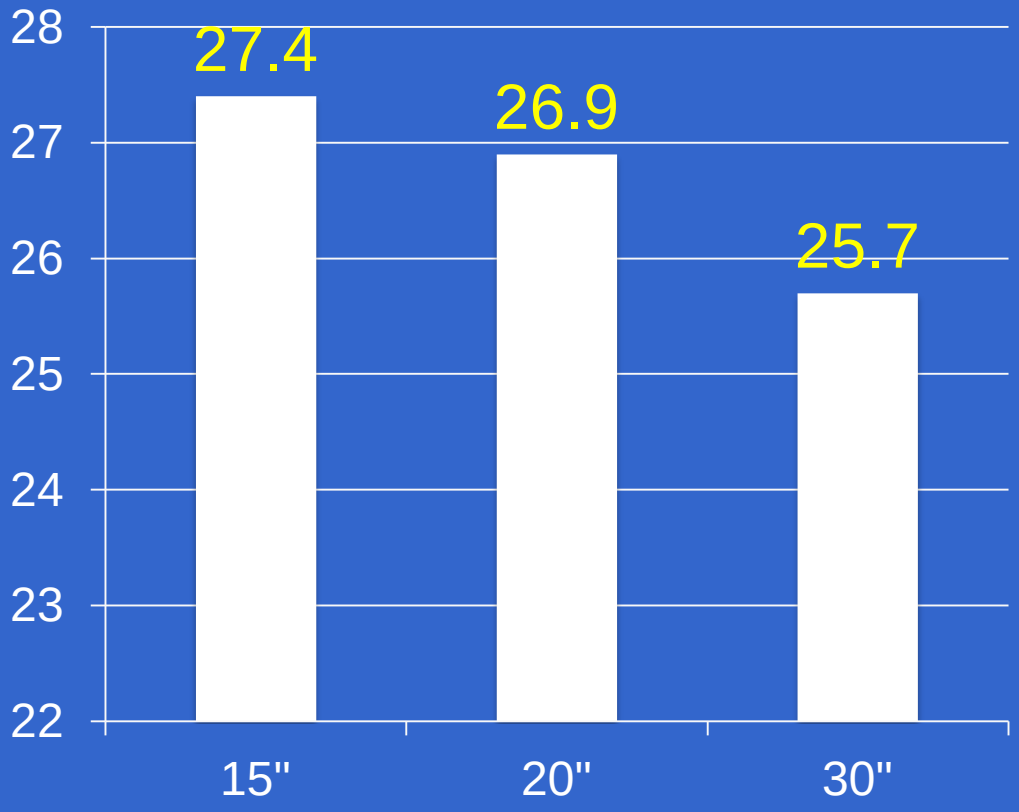
Source: Holmes & Sprague, 2013

2012 Black Bean Row Width
Saginaw Valley Research and Extension Center

Yield in cwt/acre

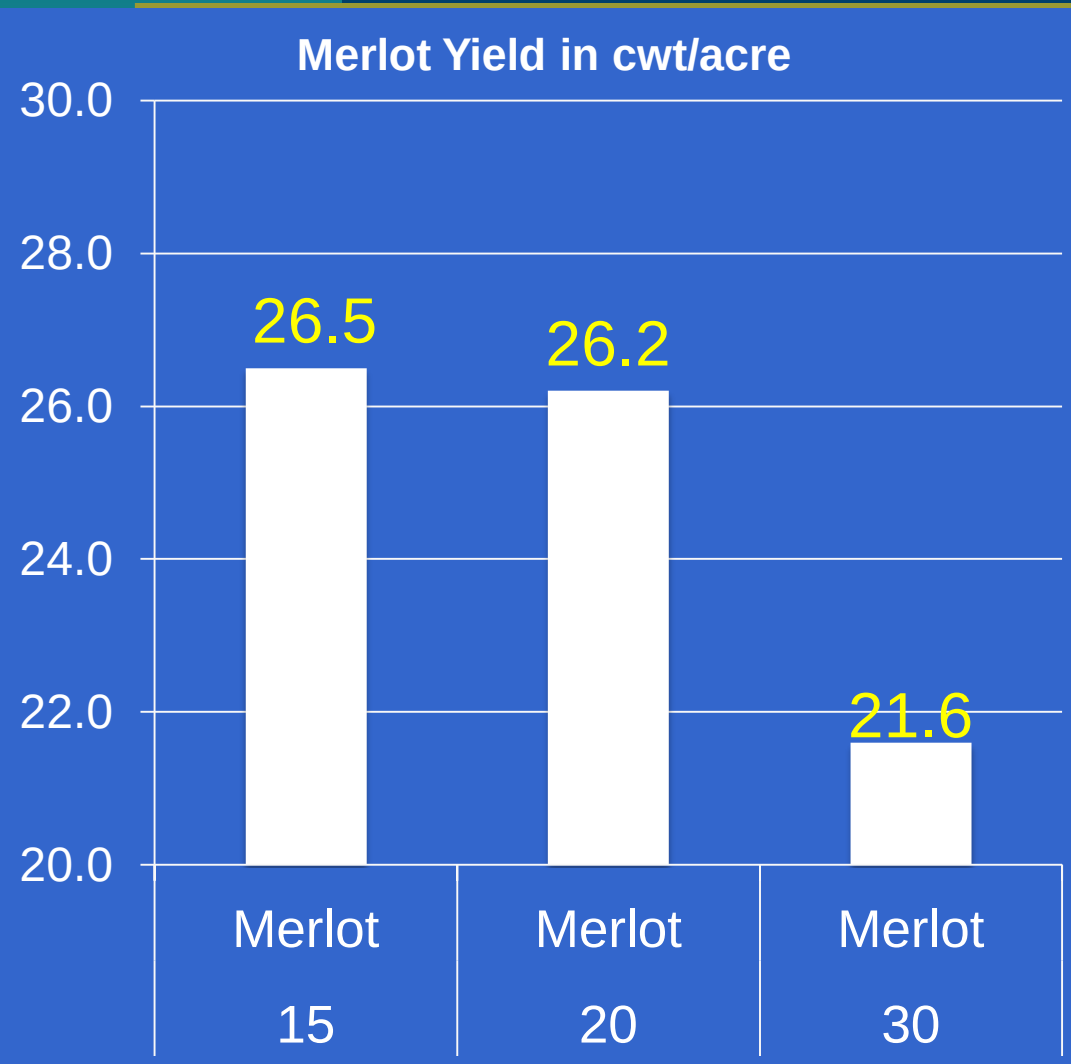


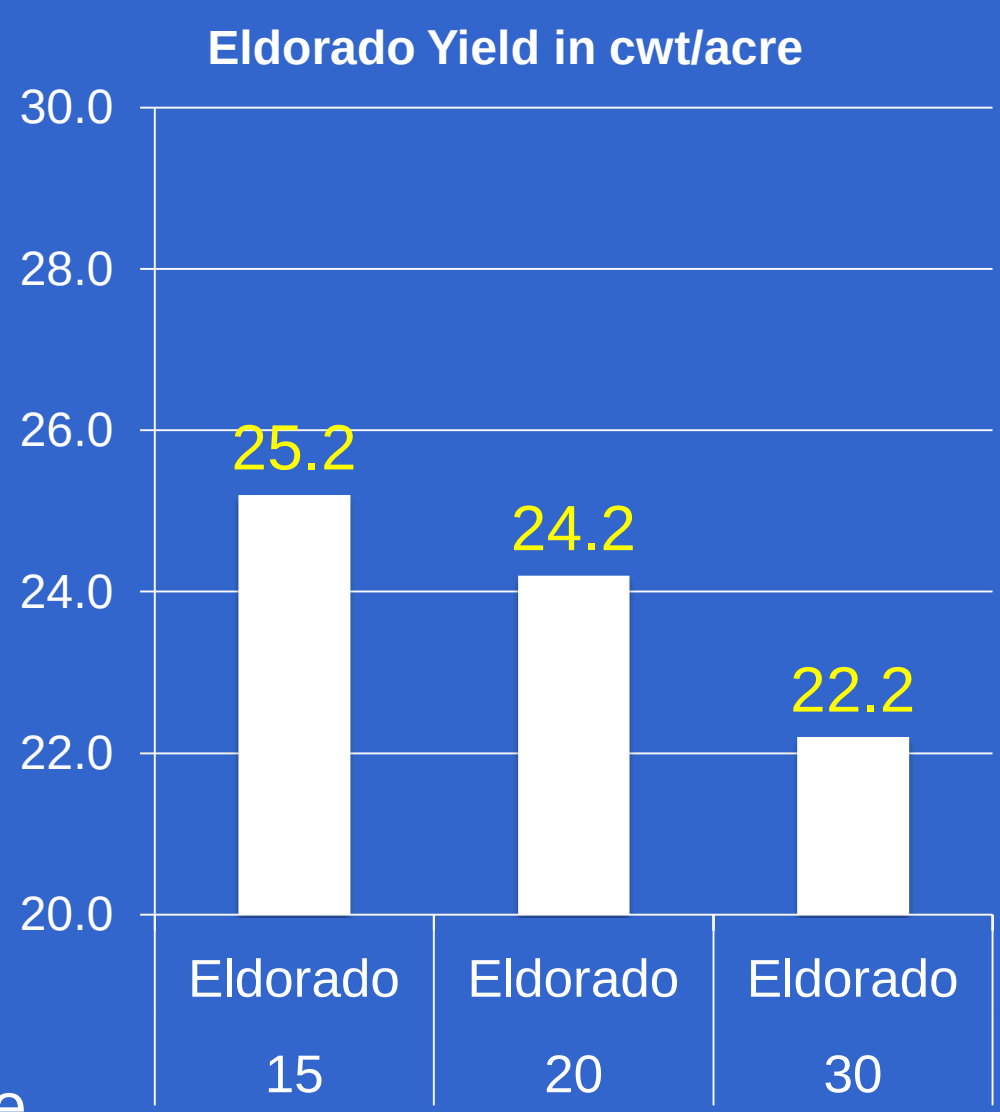
Average Yield for each Row Width



Source; Varner, 2012 SVREC web site

2012 Merlot Small Red &Eldorado Pinto Row Width Study- SVREC





Source; Varner, 2012 SVREC web site

Conventional harvest

1) Pulling or knifing followed by windrowing
2) Harvest – pick up reel

Direct harvest

"Straight cutting"

--Clipping

Durango

Meso

Jalisco

Middle American Gene Pool

Pinto

Great Northern

Navy

Black

Small Red

Pink

Andean Gene Pool

Light Red Kidney

Soldier

Dark Red Kidney

Cranberry

White Kidney

Yellow Eye

CHANGES IN PLANT ARCHITECTURE RACE DURANGO

- Clear need to diversify market classes in Michigan in 1980's
- Traditional Durango race pinto, great northern types were all type-III – high risk alternatives
- Initiated Recurrent Selection Program to transfer type II architecture into medium seed types
- Release of Sierra pinto and Matterhorn great northern
- Valuable as parents for upright plant structure
- Breeding extended to Jalisco race small red, pink seed types – G. Hosfield
- Release of Merlot and Sedona pink

TYPE III PINTO; TYPE II PINTO; TYPE II BLACK

Eldorado Pinto | Powderhorn GN | Merlot small red | Rosetta Pink

100 PLOTS/HR

80% Beans are Direct Harvested in MI

- Savings in labor, equipment,
- Improved Quality
- More acreage
- Flexibility

CHANGES IN BEAN PLANT ARCHITECTURE

- Best architectural types are small seeded navy and black beans – 20g/100 seeds
- Medium seed (40g/100 seeds) have greater tendency to lodge – WHY?
- Less breeding effort for erectness
- Trade off between plant structure and yield
- More uneven weight distribution in larger seeded beans
- Requires more plant structure to prevent lodging – ground clearance – longer pods

Bean Ideotype – Weight Distribution

- Weight at each node in navy bean with 7 seeds/pod – 20cg/seed =140cg x2 pods =280 cg – at each node
- Medium pinto seed with 6 seeds/pod – 40 cg/seeds =240cg/seed x 2 pods = 480 cg at each node
- More plant structure (lignin) to retain an upright stature
- Competition nutrients to seed

Bean Plant Ideotypes by Race

Mesoamerica

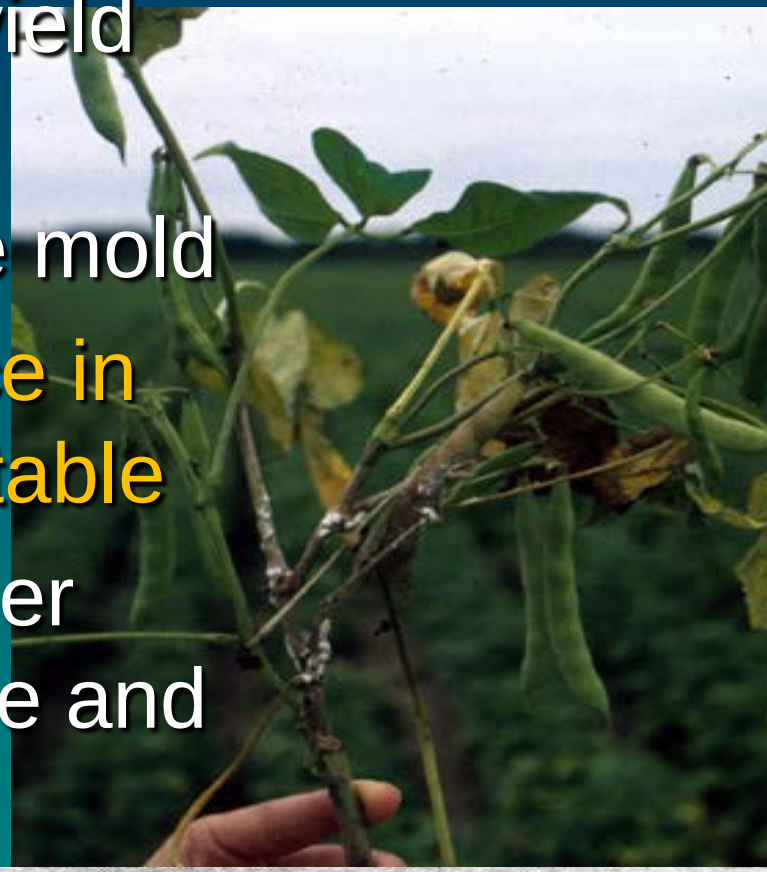
Durango

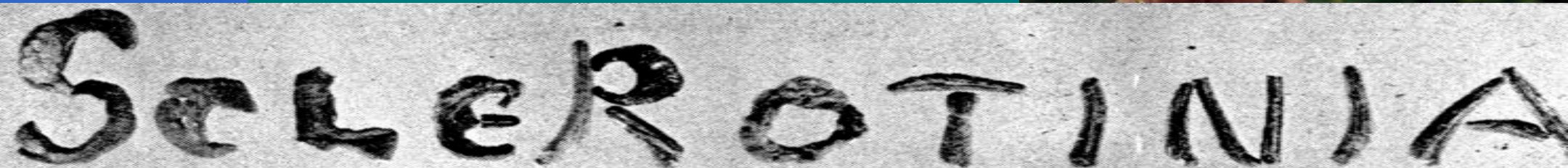
Jalisco

Growth Habit Differences – Race Jalisco

Architecture & White Mold Avoidance

- White mold is a harbinger of high yield environments
- Farmers-Accept low levels of white mold
- High levels of white mold resistance in low yielding genotypes is unacceptable
- Focus is to combine high yield under white mold pressure with avoidance and partial resistance





Upright Eldorado Pinto Architectural Avoidance

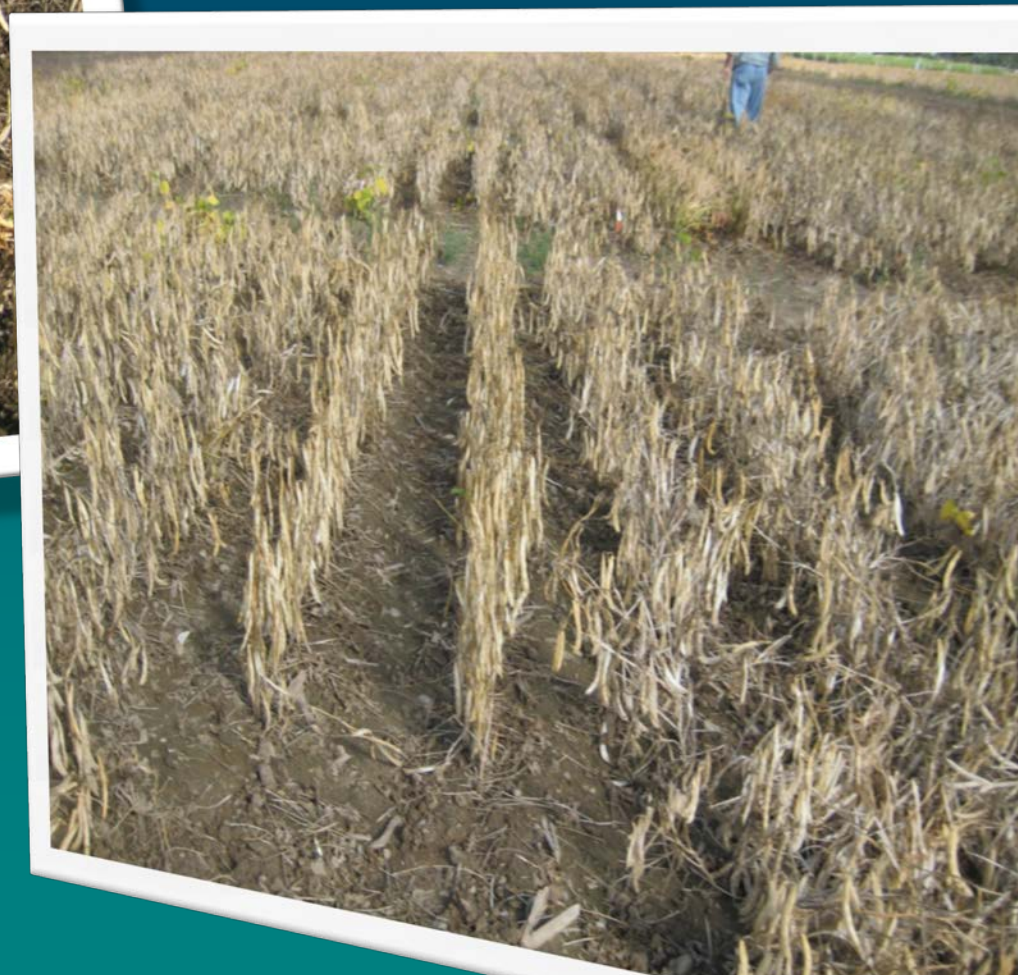
Decumbent Vine Pinto

Scatter Plot of 26 Selected Genotypes Yield & % White Mold, 2007-2009

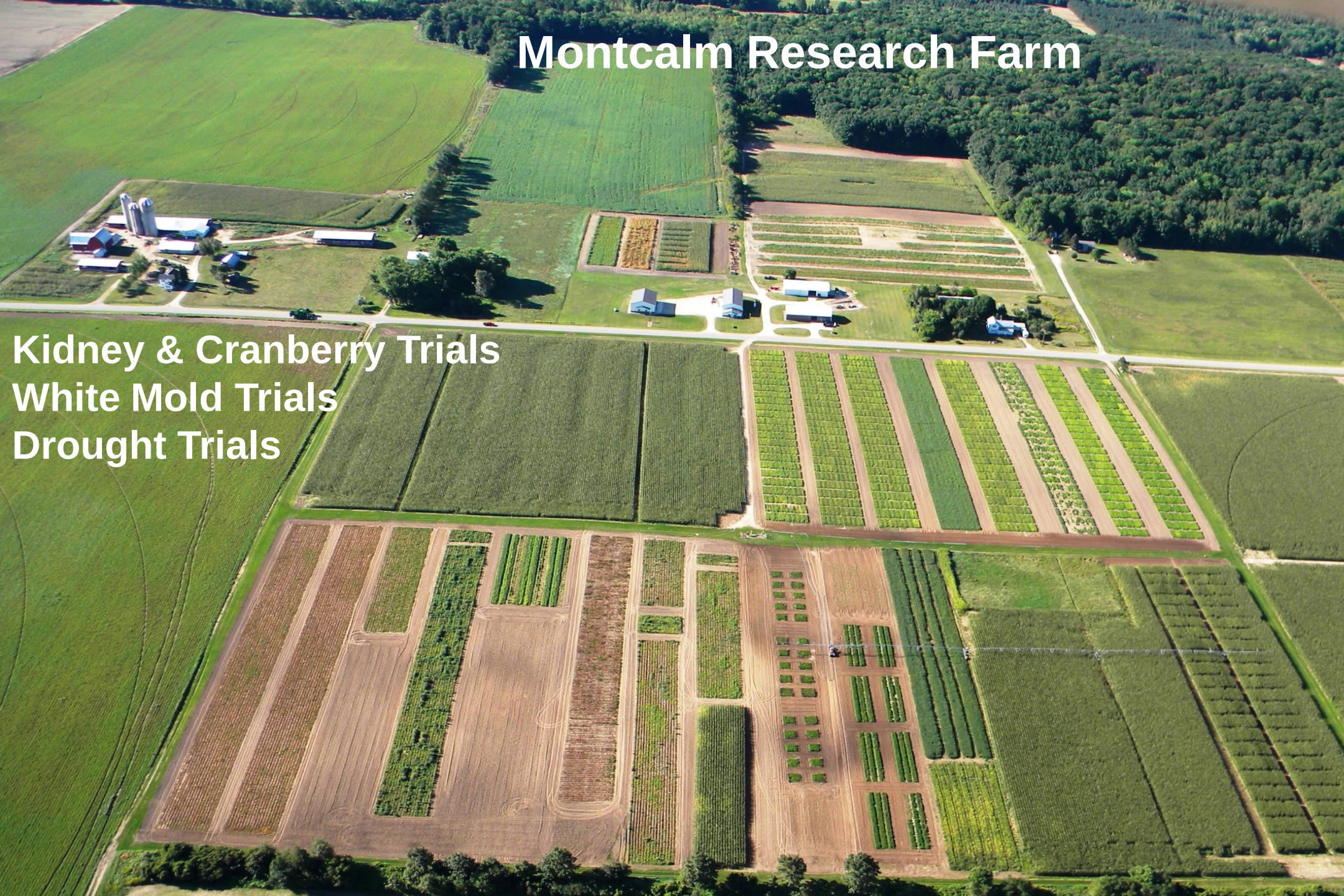
Pinto Bean Yield (T/ha) under white mold pressure

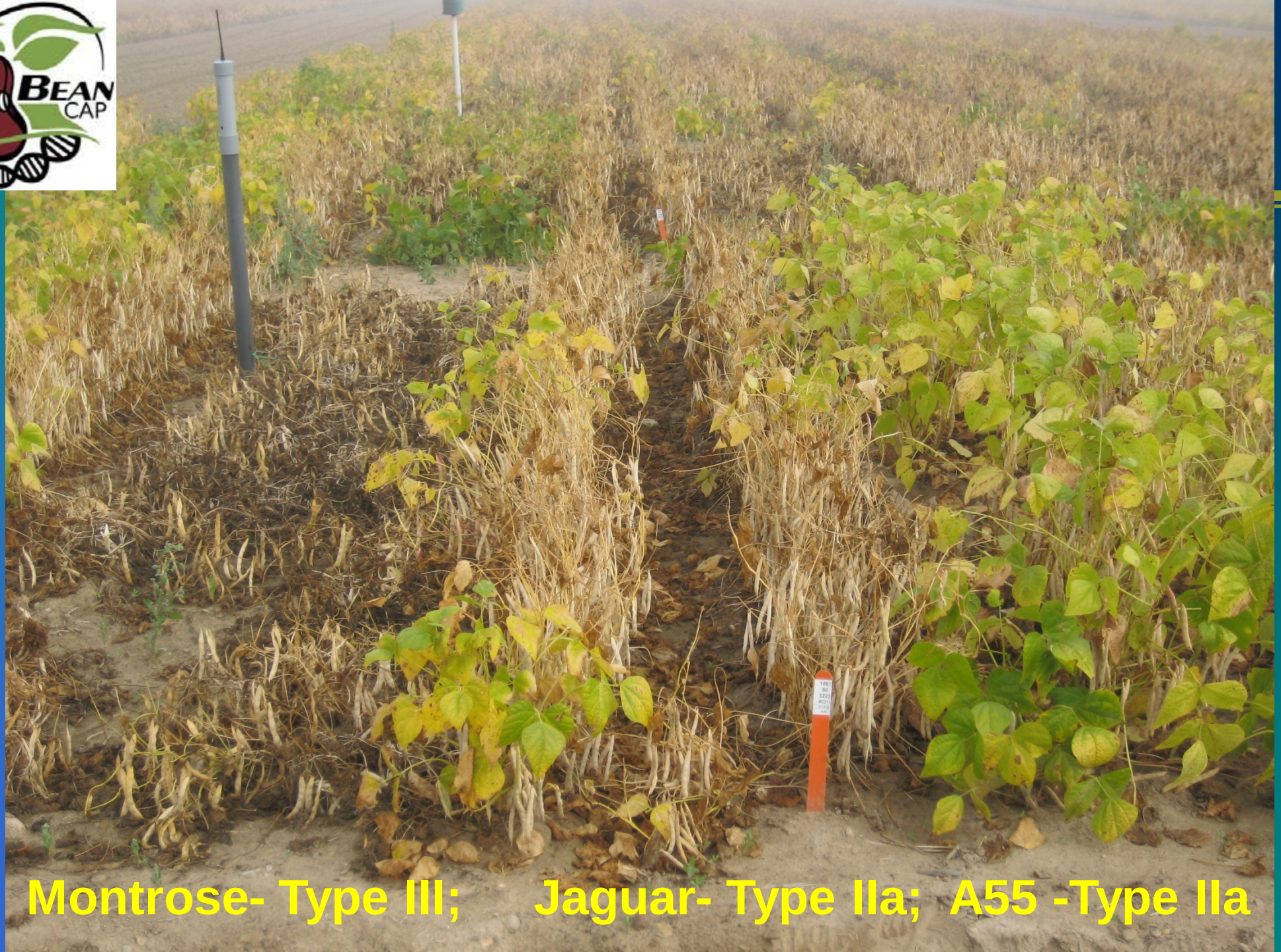
Year	% White Mold	Eldorado	Santa Fe	Beryl GN
2007	52.8	5.15	3.86	2.90
2008	35.6	6.01	4.80	3.17
2009	37.8	3.42	2.80	1.29
2010	63.3	3.64	2.93	2.99
2011	39.5	4.28	3.85	2.95
2012	40.9	4.80	3.73	2.53
2013				
	MEAN (6)	4.55	3.66	2.64
PERCENT	MEAN	173	139	100

White Mold Trials- Montcalm 2013

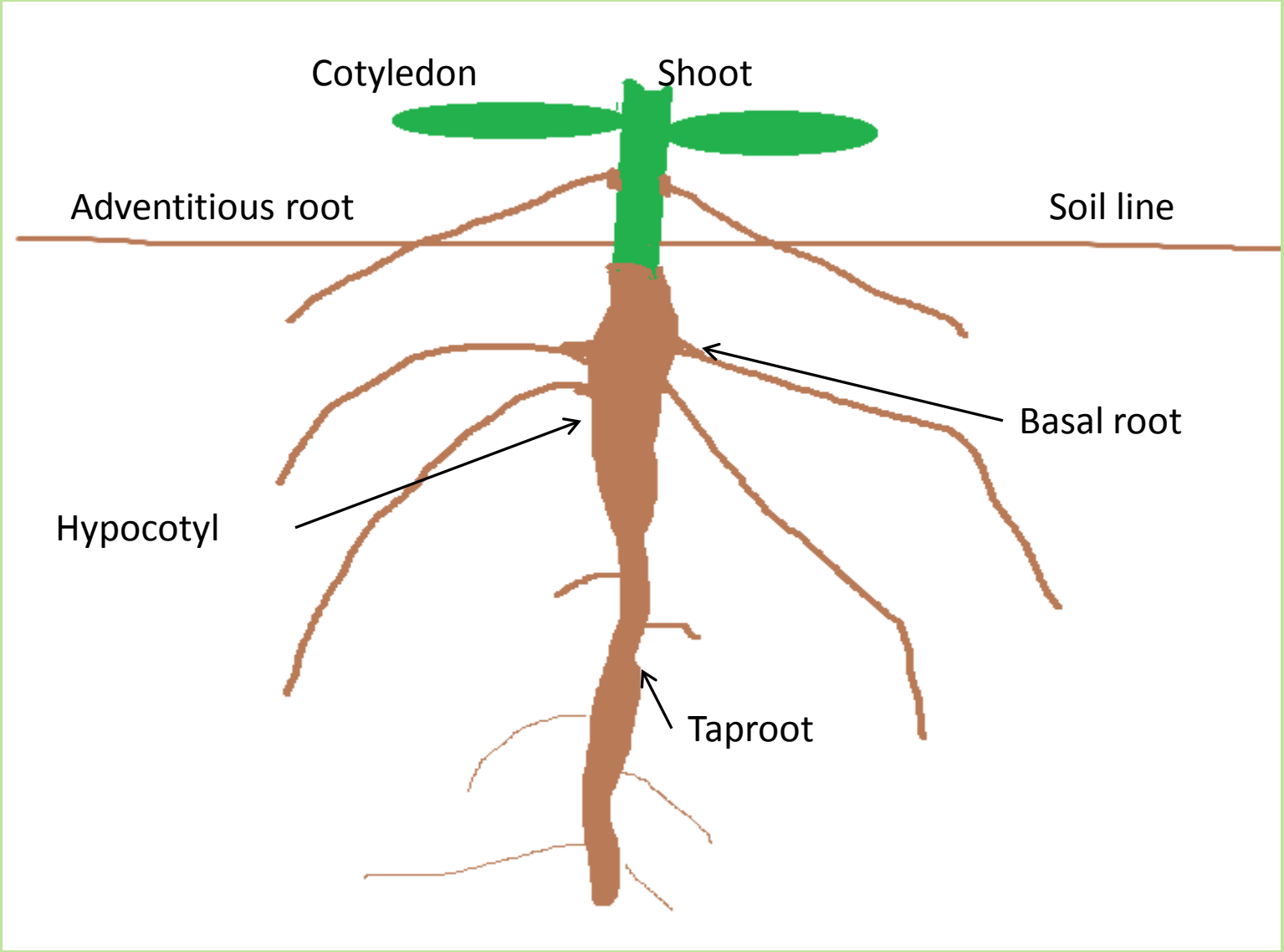


Importance of Architectural Avoidance against White Mold


Montcalm Research Farm
Kidney & Cranberry Trials
White Mold Trials
Drought Trials


Montrose- Type III;
Jaguar- Type IIa;
A55 -Type IIa

Root Architecture - Morphological Coordination between Root and Shoots?



ROOT SYSTEMS

ZORRO

PUEBLA 152

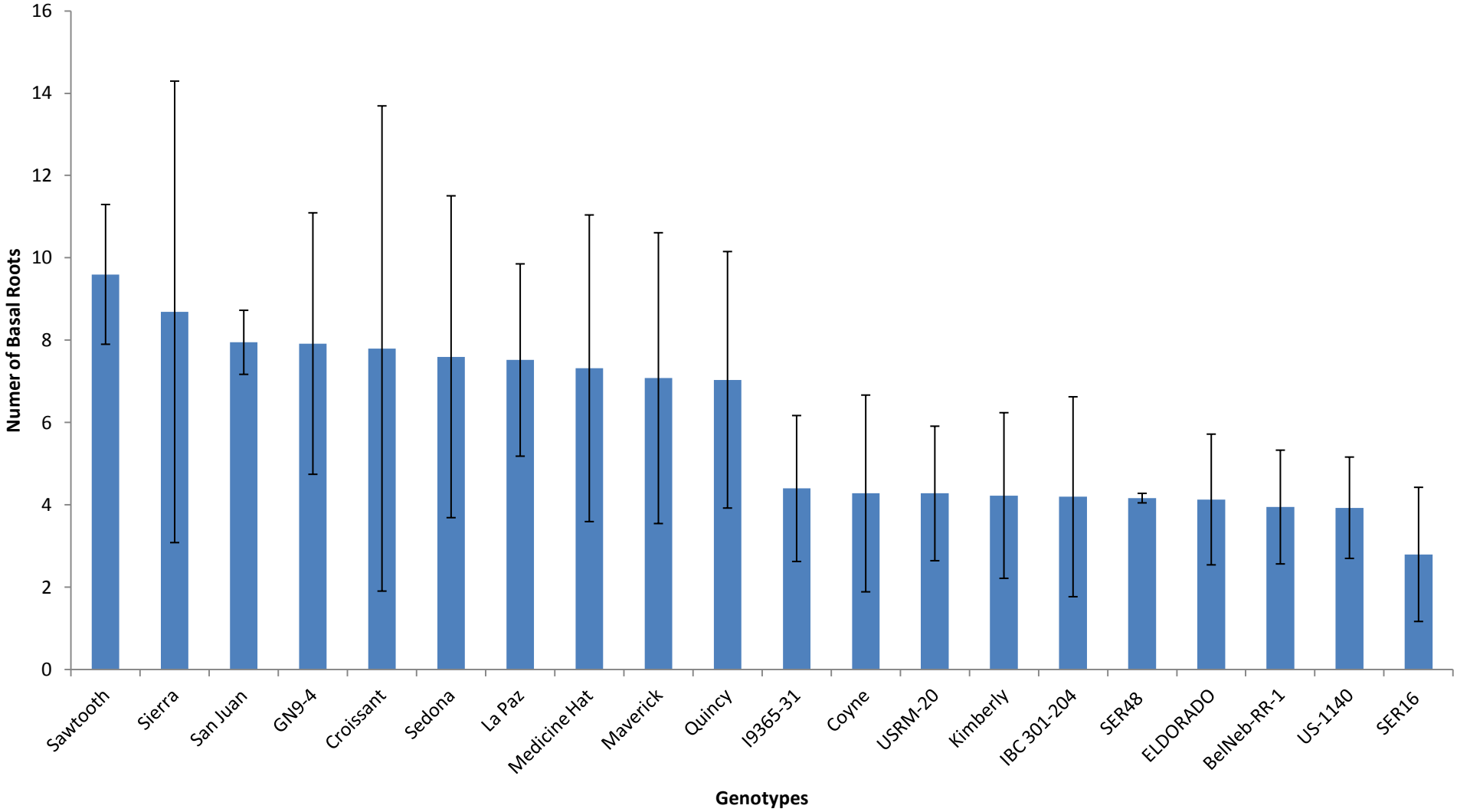
Source UCR-
Ibarra, Waines

Shovelomics – Montcalm MI 2011-2013

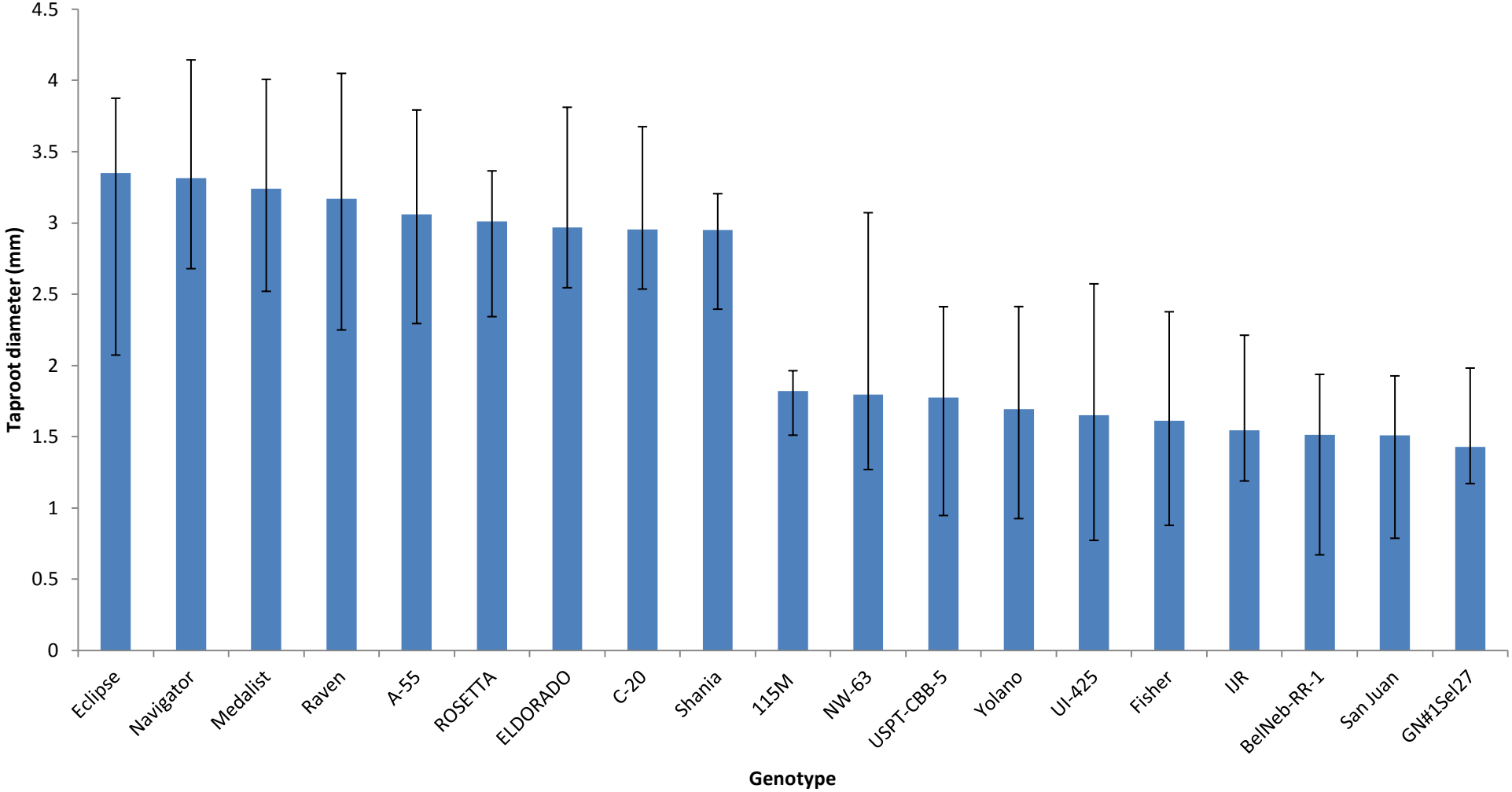
Are. Root Traits Associated with Shoot Traits ??

- Basal root number
- Basal root angle
- Taproot diameter
- Overall Root Score
  - 0-3= poor
  - 4-7= average
  - 8-10= excellent
  - Pictured: 4 – average
- Conduct Association Mapping Analysis

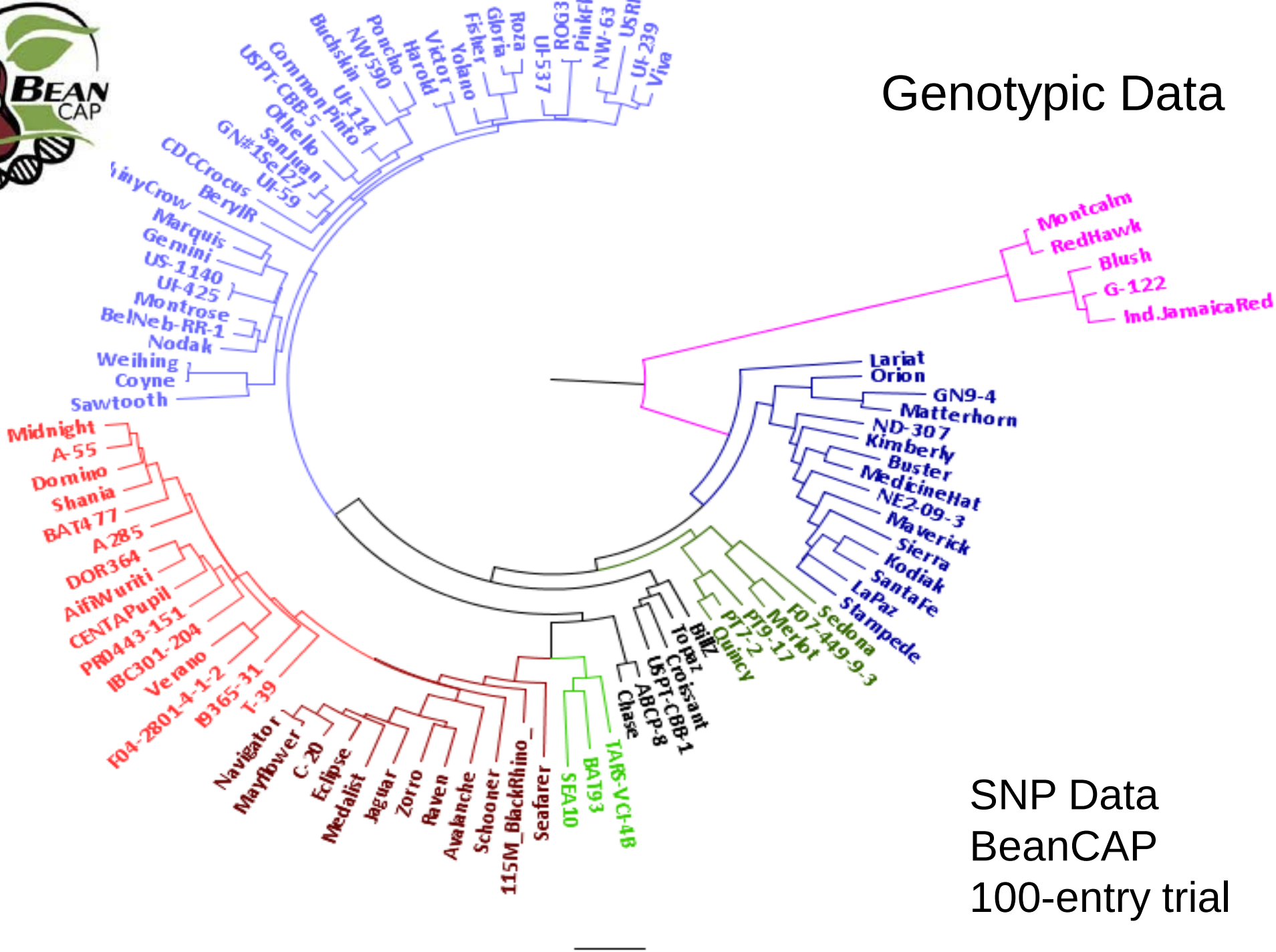
Basal Root Number



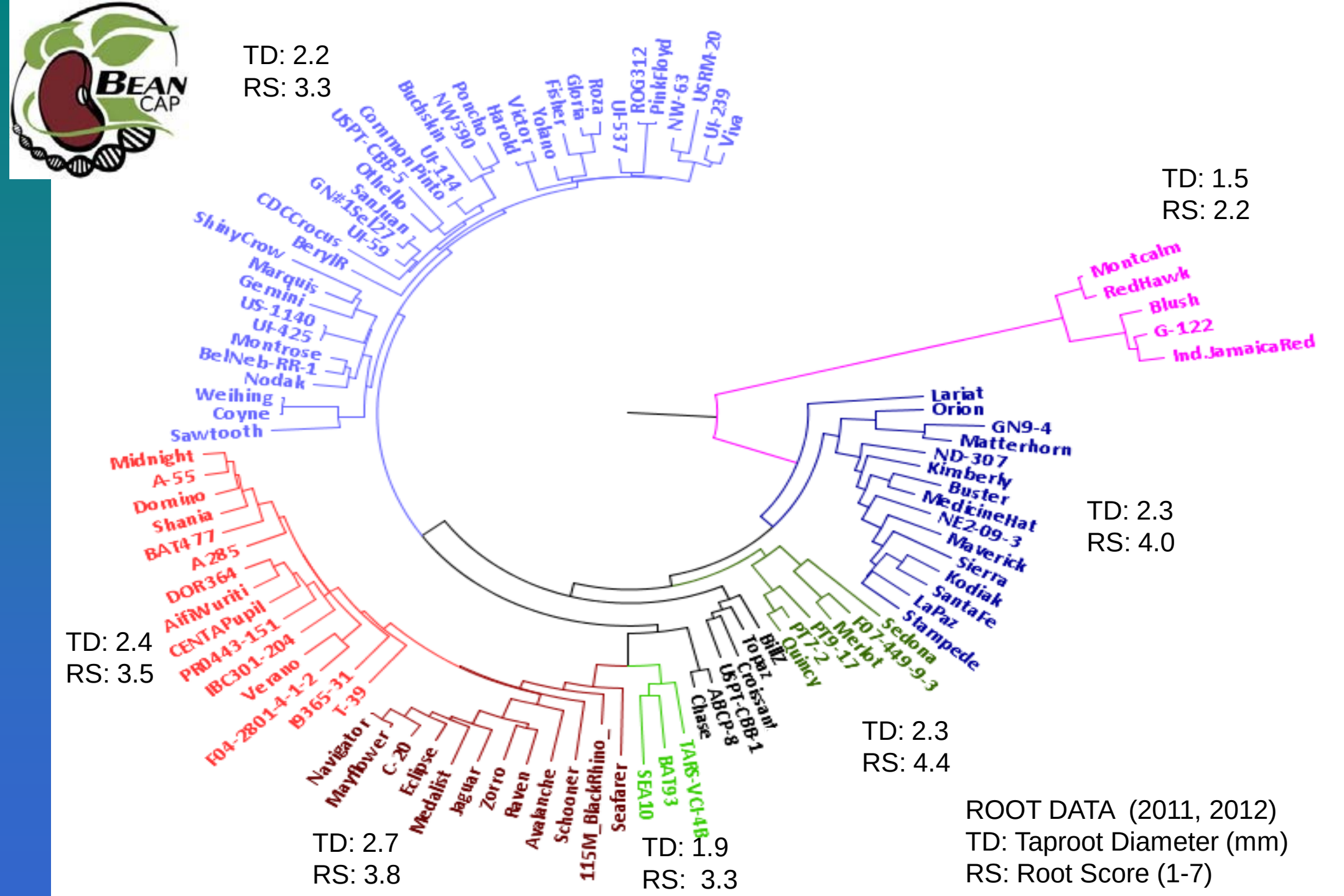
Taproot Diameter



Genotypic Data

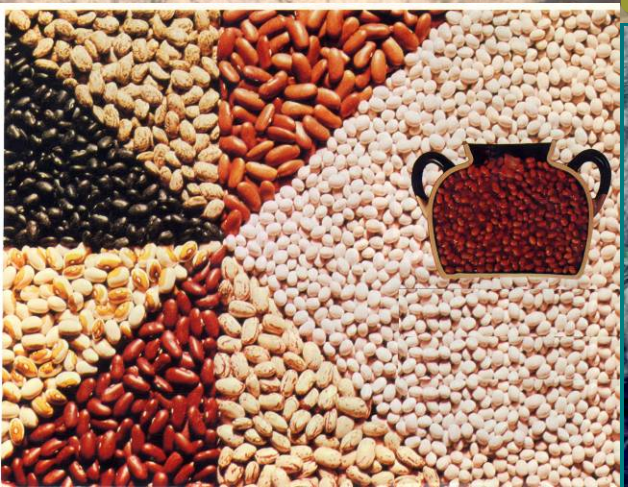


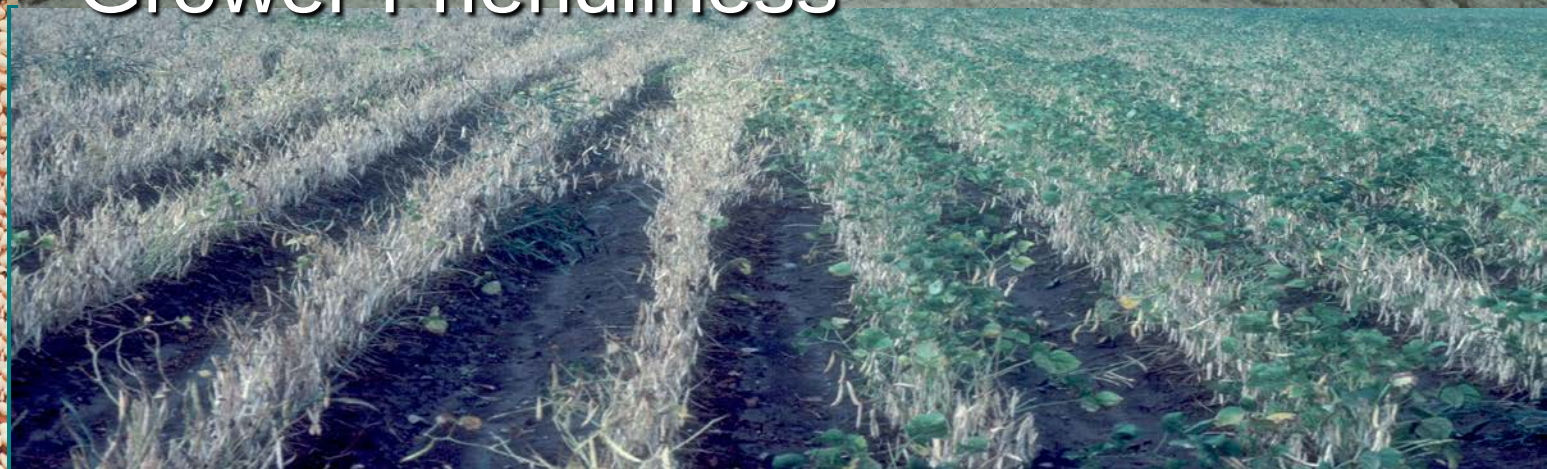
SNP Data
BeanCAP
100-entry trial


TD: 2.2
RS: 3.3
TD: 1.5
RS: 2.2
TD: 2.3
RS: 4.0
TD: 2.4
RS: 3.5
TD: 2.3
RS: 4.4
TD: 2.7
RS: 3.8
TD: 1.9
RS: 3.3
ROOT DATA (2011, 2012)
TD: Taproot Diameter (mm)
RS: Root Score (1-7)
Montcalm
RedHawk
Blush
G-122
Ind.JamaicaRed
Lariat
Orion
GN9-4
Matterhorn
ND-307
Kimberly
Buster
MedicineHat
NE2-09-3
Maverick
Sierra
Kodiak
SantaFe
LaPaz
Stampede
Sedona
F07-449-9-3
Merlot
PT9-17
PT7-2
Quincy
BillZ
Topaz
Croissant
USPT-CBB-1
ABCP-8
Chase
TARS-VCI-4B
BAT93
SEA10
Seafarer
115M_BlackRhino_
Schooner
Avalanche
Raven
Zorro
Jaguar
Medalist
Eclipse
C-20
Mayflower
Navigator
Midnight
A-55
Domino
Shania
BAT477
A285
DOR364
AifiWuriti
CENTAPupil
PR0443-151
IBC301-204
Verano
F04-2801-4-1-2
B365-31
T-39
Sawtooth
Coyne
Weihing
Nodak
BelNeb-RR-1
Montrose
UI-425
US-1140
Gemini
Marquis
BeryllR
ShinyCrow
CDCCrocus
GN#1Sel27
SanJuan
Othello
USPT-CBB-5
CommonPinto
Buckskin
UI-114
NW590
Poncho
Harold
Victor
Volano
Fisher
Gloria
Roza
UI-537
ROG312
PinkFloyd
NW-63
USRM-20
UI-239
Viva
UI-59

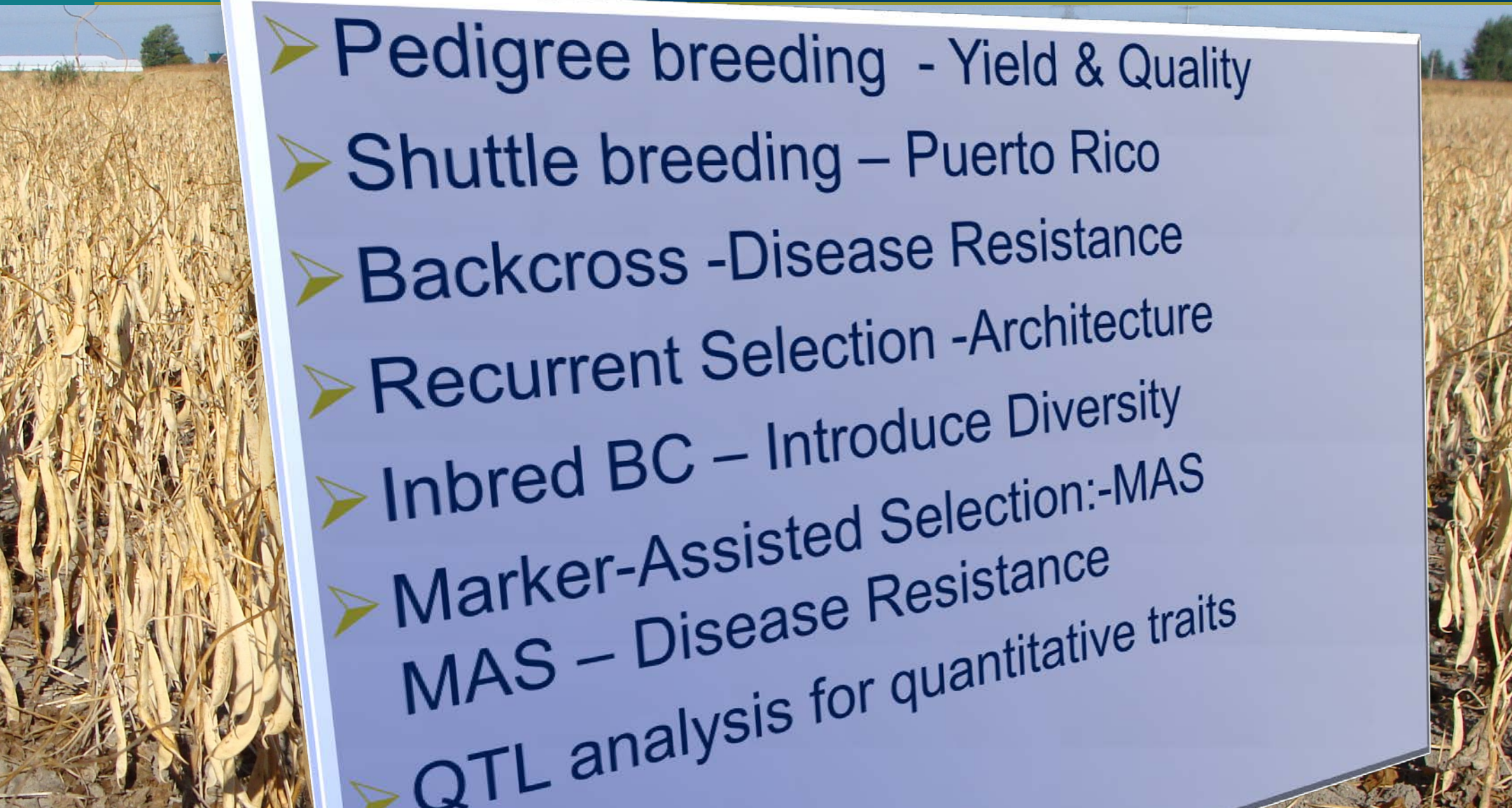
MSU Dry Bean Breeding

- Yield
- Processing Quality
- Architecture & Agronomic Adaptation
- Disease & Insect Resistance
- Stress Tolerance
- Grower Friendliness



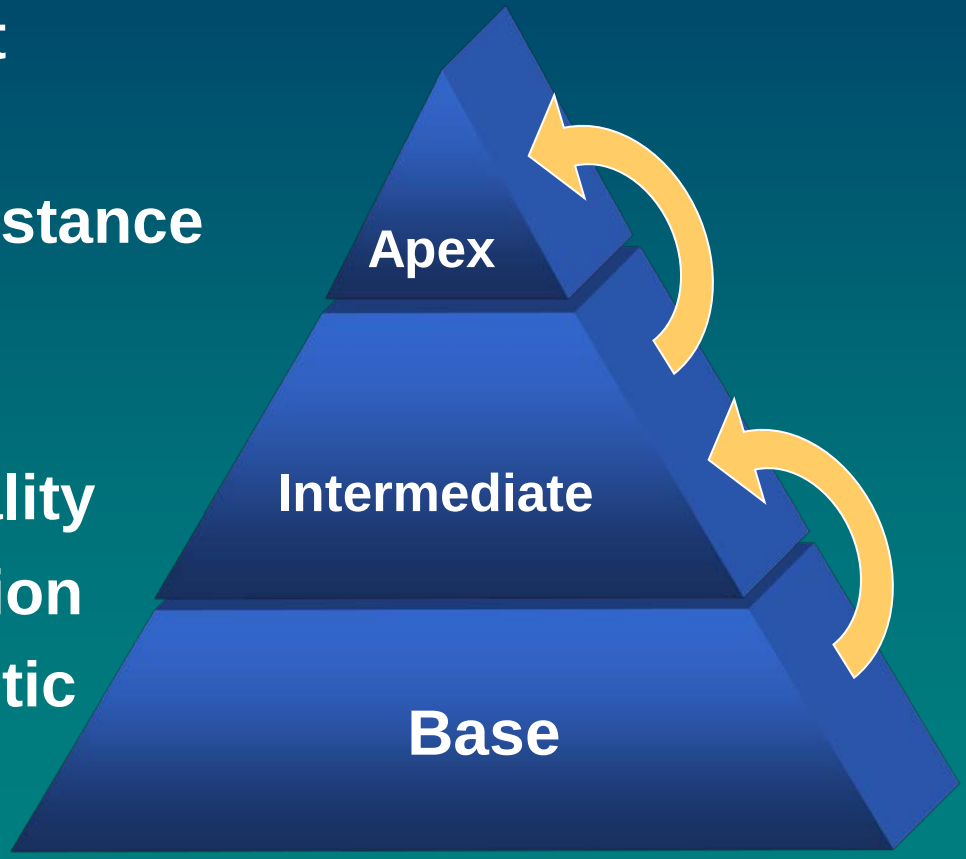


Breeding Systems – Different Classes & Traits



Bean Breeding Pyramid

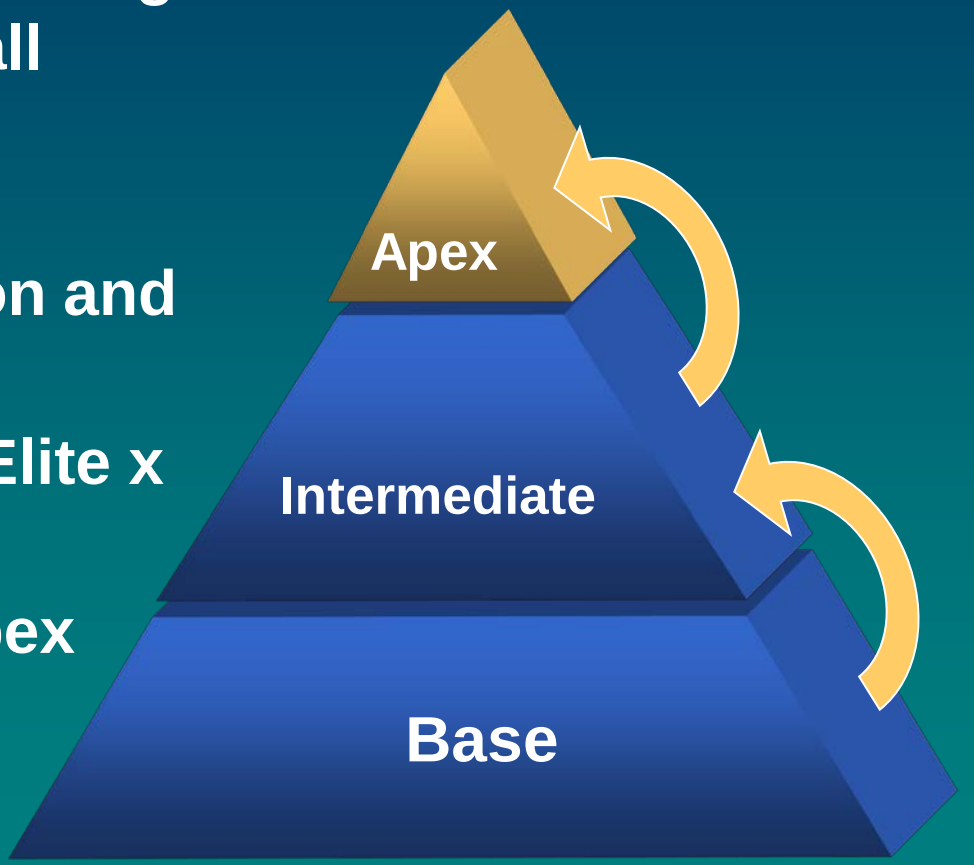
- **Yield Improvement**
  - **Growth Habit**
  - **Maturity**
  - **Disease Resistance**
  - **Market class**
  - **Seed Traits**
  - **Canning Quality**
- **Broad Foundation**
- **Adequate Genetic Variability**



*Adapted from Kelly et al. (1998) Breeding for yield in dry bean. Euphytica 102:343-356

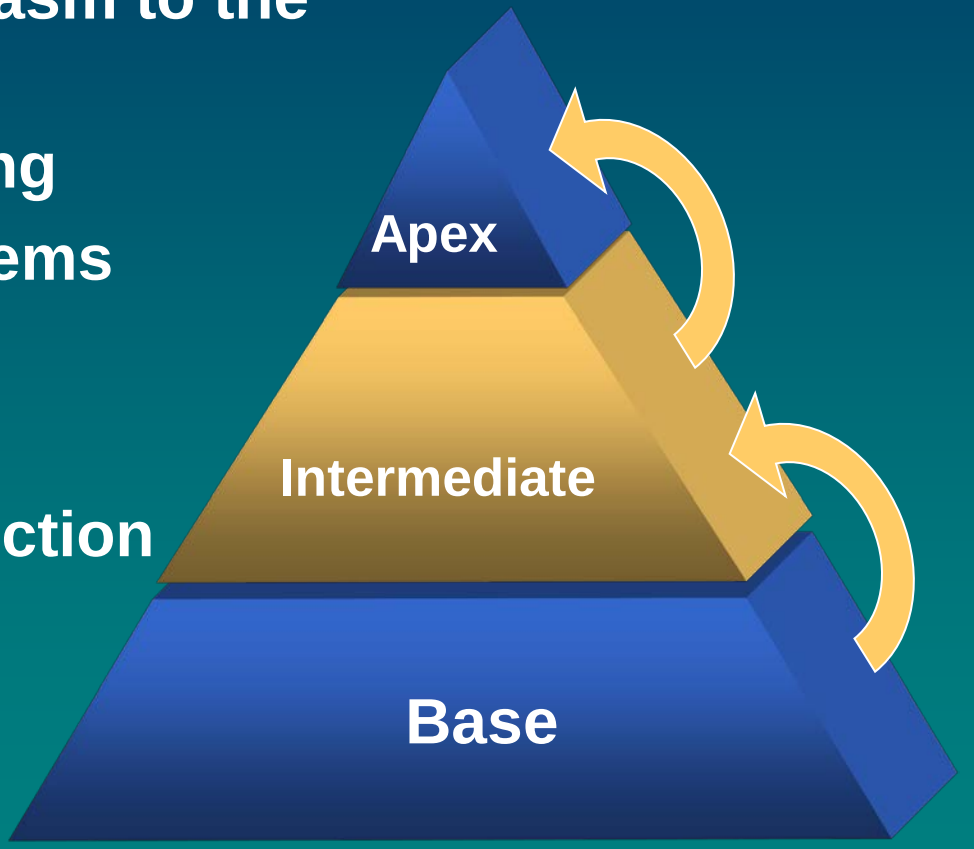
Breeding Pyramid

- University public bean breeding programs must focus on all levels of pyramid
- New varieties, advancing science, training, education and extension
- New varieties come from Elite x Elite crosses - Apex
- Private sector focus on apex
- USDA programs focus on germplasm enhancement
- Focus on intermediate and base levels



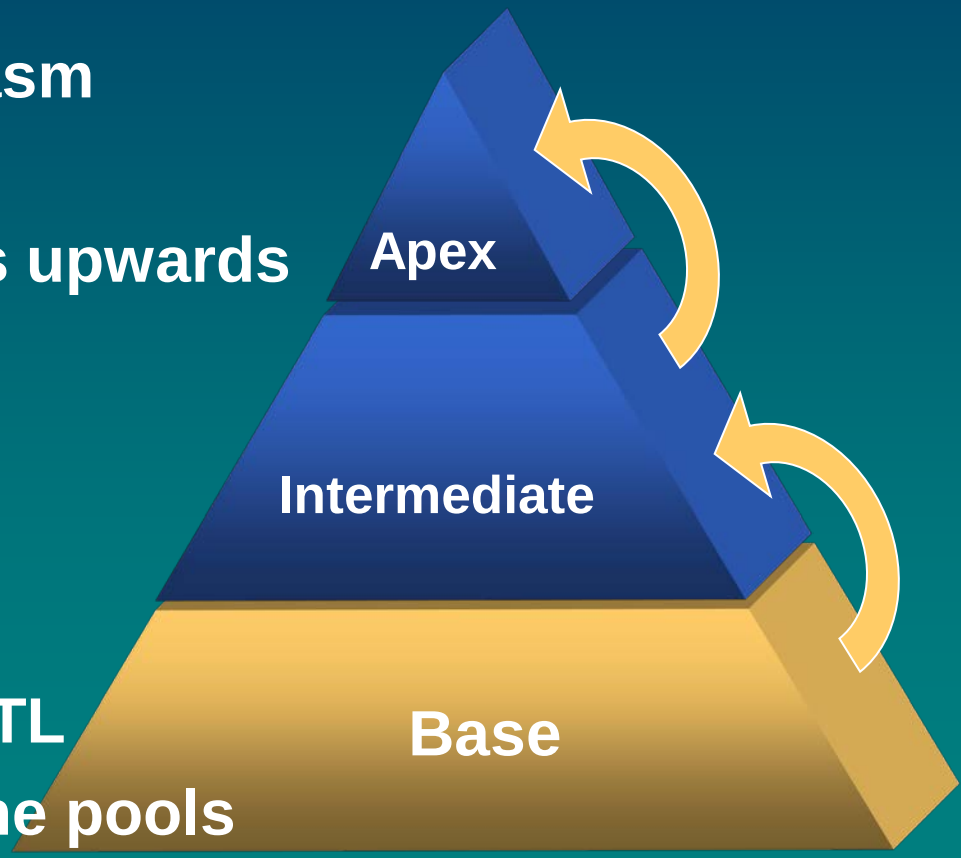
Breeding Pyramid

- Genetic studies contribute new information and germplasm to the breeding program
- Graduate student training
- Different Breeding Systems
  - Recurrent backcross
  - Inbred backcross
  - Marker Assisted Selection
  - Conical crossing
- Be innovative
- Approaches, Ideas



Breeding Pyramid

- Long term solutions
- Basic studies
- Introgressing wild germplasm
- Other species
- Still have to work materials upwards
- Cyclic Intermating
  - Recurrent Selection
  - Congruity backcross
  - Conical crossing
  - Advanced Backcross-QTL
- Force Introgression b/t gene pools
- Improve Andean bush beans



Ecuador

PULSE CRSP

Dry Grain Pulses Collaborative
Research Support Program

MICHIGAN STATE
UNIVERSITY

Climbing Beans Higher Elevations

97,000 Hectares

Bush Beans Lower Elevations

23,000 Hectares

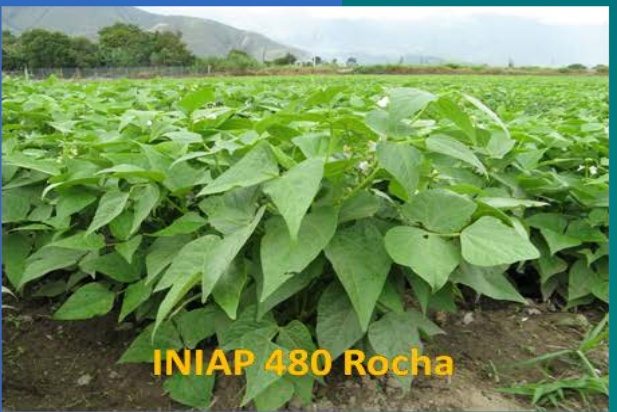
Dry Seed

Green Shell

RECENT BRED VARIETIES - INIAP

PARA-
GACHI
ANDINO

PORTILLO



ROCHA

Screening for Root Rot Resistance

Release of Centenario - 2012

INIAP
INSTITUTO NACIONAL AUTÓNOMO DE INVESTIGACIONES AGROPECUARIAS

PRONALEG - GA

CENTENARIO

RESISTENCIA GENÉTICA A:
- Roya
- Antracnosis
- Mancha angular
- Pudrición de raíz

RESISTENCIA GENÉTICA A:
- Roya
- Antracnosis
- Mancha angular
- Pudrición de raíz

USAID

PULSE CRSP

MICHIGAN STATE UNIVERSITY


Louis Butare

Rwanda

Hillside Farming Terraces in Rwanda

Climbing Bean Varieties

LAND USE EFFICIENCY 3: 1 BUSH BEANS

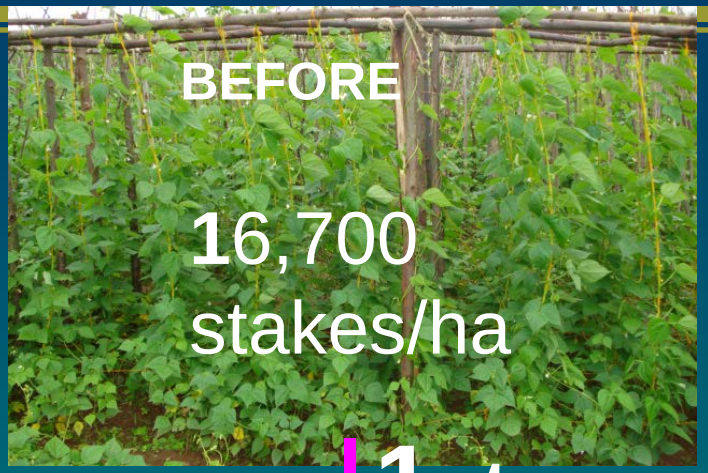
STAKING INNOVATION TRIAL

- Used 6 treatments of wood, wood and strings with normal and no staking (20,000 stakes per grower)
- 15,000 to 50,000 stakes per ha as controls
- Farmer participatory evaluation at 3 sites
- Yield ranged 1.73 to 3.13 t/ha

Participatory selection group

Farmers' preferences

6th



1st

Krista Isaacs

- Mother-baby-grandbaby trials- testing climbing bean-maize cropping system interaction over two seasons
  - Mother trial: Two research stations, 6 bean genotypes
  - Baby trials: 8 farmers' fields
  - Grandbaby trials: 70 farmers selected two bean genotypes for experimentation on their own farms


DERN
R.A: MUKO
HIGH IRON BEANS
ISAR - HARVEST PLUS
Var: RWV 3006
RWV 2872
RWV 3316
GASIRIDA


M+BI

Climbing Beans – Mono & Intercrop Yields Musanze (1860m), Rwerere (2116m), Rwanda

Location	IC	TC	BO	MO
MS S1	1.7	1.8	3.7	6.4
MS S2	1.0	2.3	2.6	8.8
MS total	2.7	4.1	6.3	15.2
RS S1	1.9	2.4	4.4	2.0
RS S2	1.2	1.4	3.0	4.0
RS total	3.1	3.8	7.4	6.0

IC-Intercrop Rows; TC-Traditional intercrop; BO-Beans only; MO-Maize only

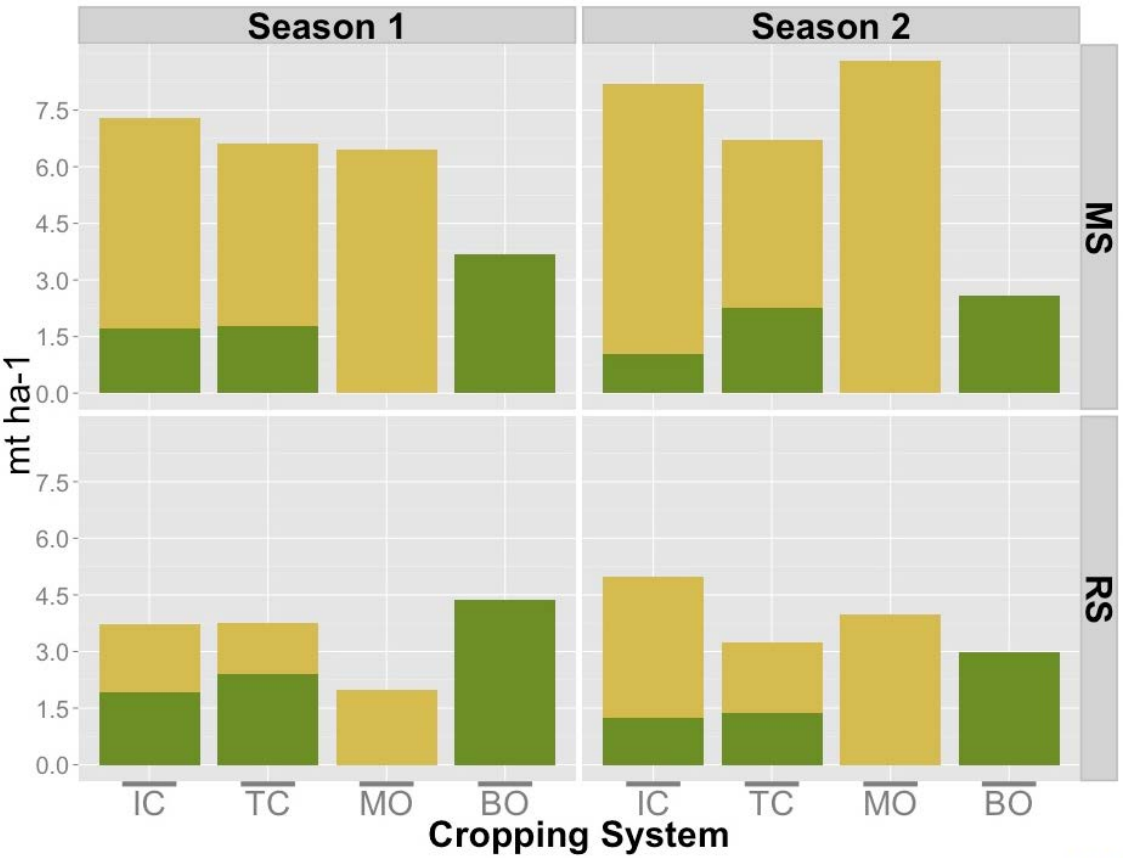
Land Equivalent Ratio - Climbing Beans Rwanda

Location	IC	TC	BO	MO
MS S1	1.65	1.48	1.09	1.27
MS S2	1.78	1.55	0.76	1.74
MS Average	1.72	1.52	0.93	1.51
RS S1	0.94	0.98	1.29	0.39
RS S2	1.14	0.73	0.88	0.78
RS Average	1.04	0.86	1.09	0.59

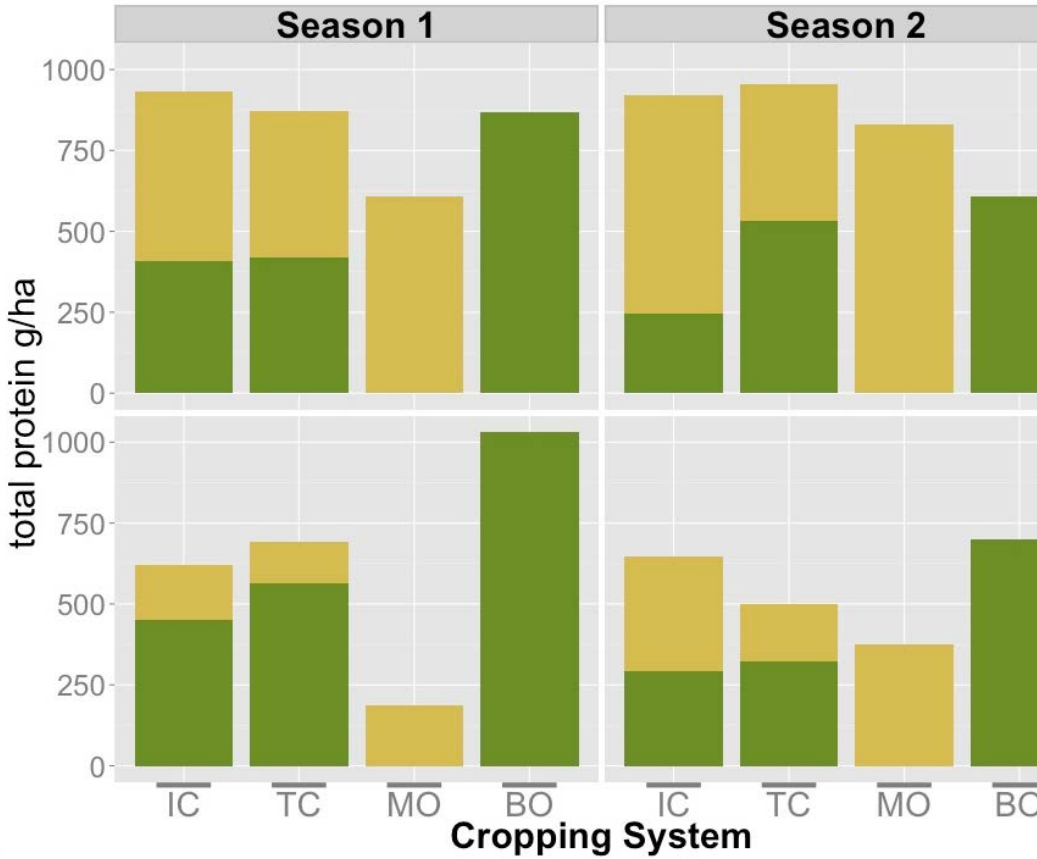
LER – yield intercrop/yield mono for beans + maize; Source Isaacs, 2013

Climbing Beans – Mono & Intercrop Seed & Protein Yields, Rwanda

Total Grain Yield T/ha

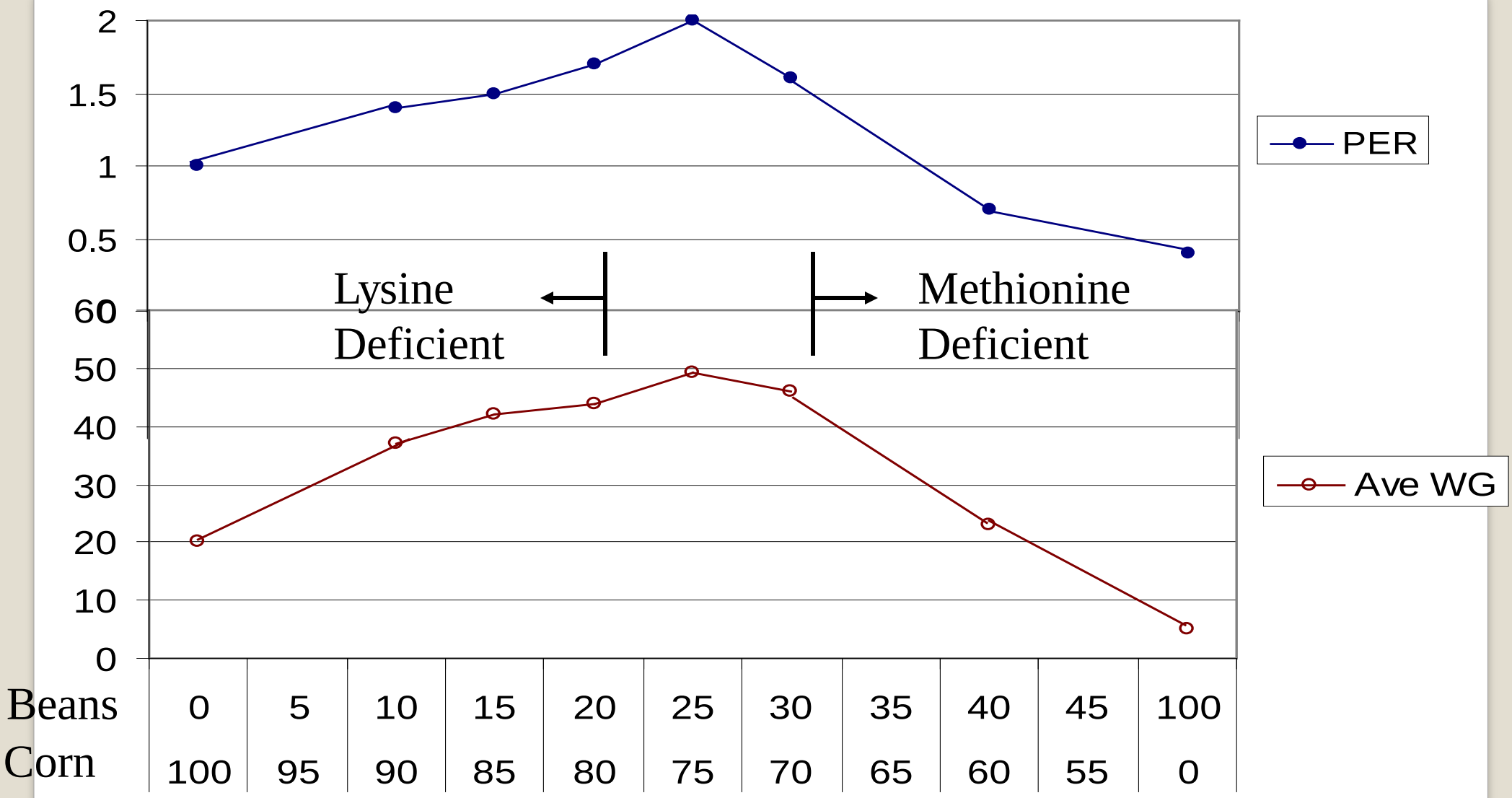


Total Protein Yield g/ha



Maize
Beans

Protein Quality of Corn and Black Bean Protein Combinations



Actual % Distribution of Beans to Corn in Diet

Bressani, 1973
INCAP

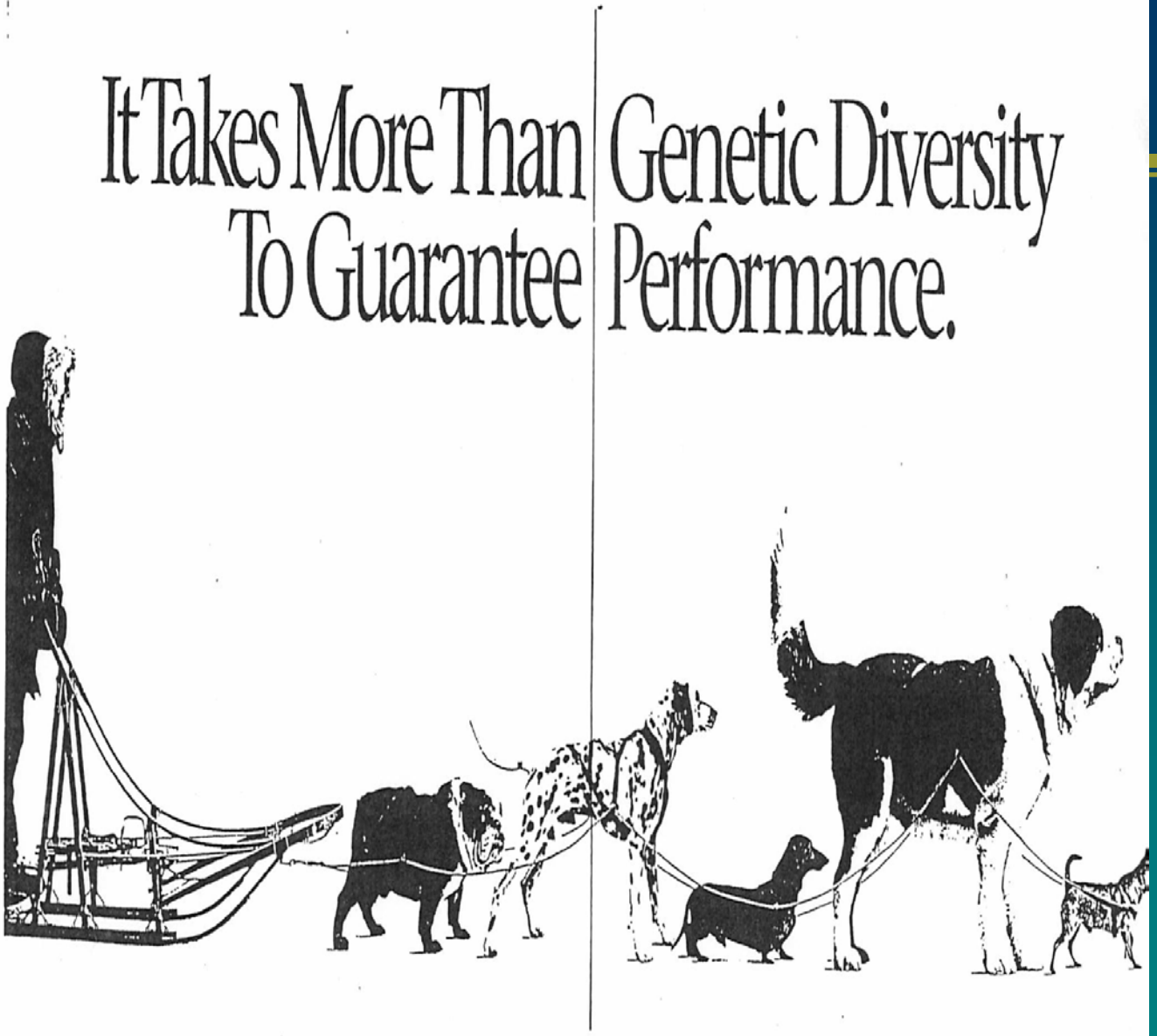
How do we produce more beans?

- Climbing beans offer potential to increase yields
- High yielding – well adapted – consumer preference for seed/ pod types
- Lack resistance to seed borne pathogens, local races of anthracnose, rust, ALS, CBB
- Introgress major gene resistance
- Backcross – MAS
- Effect minimal change, correct major deficiency
- Robust markers –utilize bean genomic sequence to find SNP and convert to SSR markers

Critical Needs in Climbing Beans – Resistance to Seed Borne Pathoge

Issues in Bean Breeding in the Future

- Bean breeders have to focus more on cyclic intermating to generate new genetic recombinations
- Less likely to emerge from single crosses
- Robust markers could help in that process
- Short term funding does not support long term cyclic intermating schemes that are needed
- SNP data continues to show the narrow genetic background of classes
- Progress will require new variability



- Future in utilizing wild bean germplasm
- Not as convinced that related species offer potential
- Despite the major genes for CBB from Tepary bean
- Use cyclic inter-mating is needed
- Assisted with MAS

Issues in Bean Breeding in the Future

- Inability to effectively introgress strengths of the Middle American gene pool into Andean germplasm – Why?
- Genetic incompatibility – physiological differences in terms of yield processes
- Efforts to force recombinations are lacking
- Do climbing beans offer new genetics to bush types – JeMa variety in Ecuador
- Calima germplasm offers a better gene pool bridge that does NA kidney germplasm

Issues in Bean Breeding in the Future

- Caution as we enter the genomics era
- Most economic traits are not under single gene control
- Haste to identify underlying genes is premature
- Still have to effect change and develop new genetic combinations
- RNA seq data – Differential display is interesting
- Goal is to sequence genes
- Rather simplistic approach given what we know or don’t know of genetics controlling yield

Issues in Bean Breeding in the Future

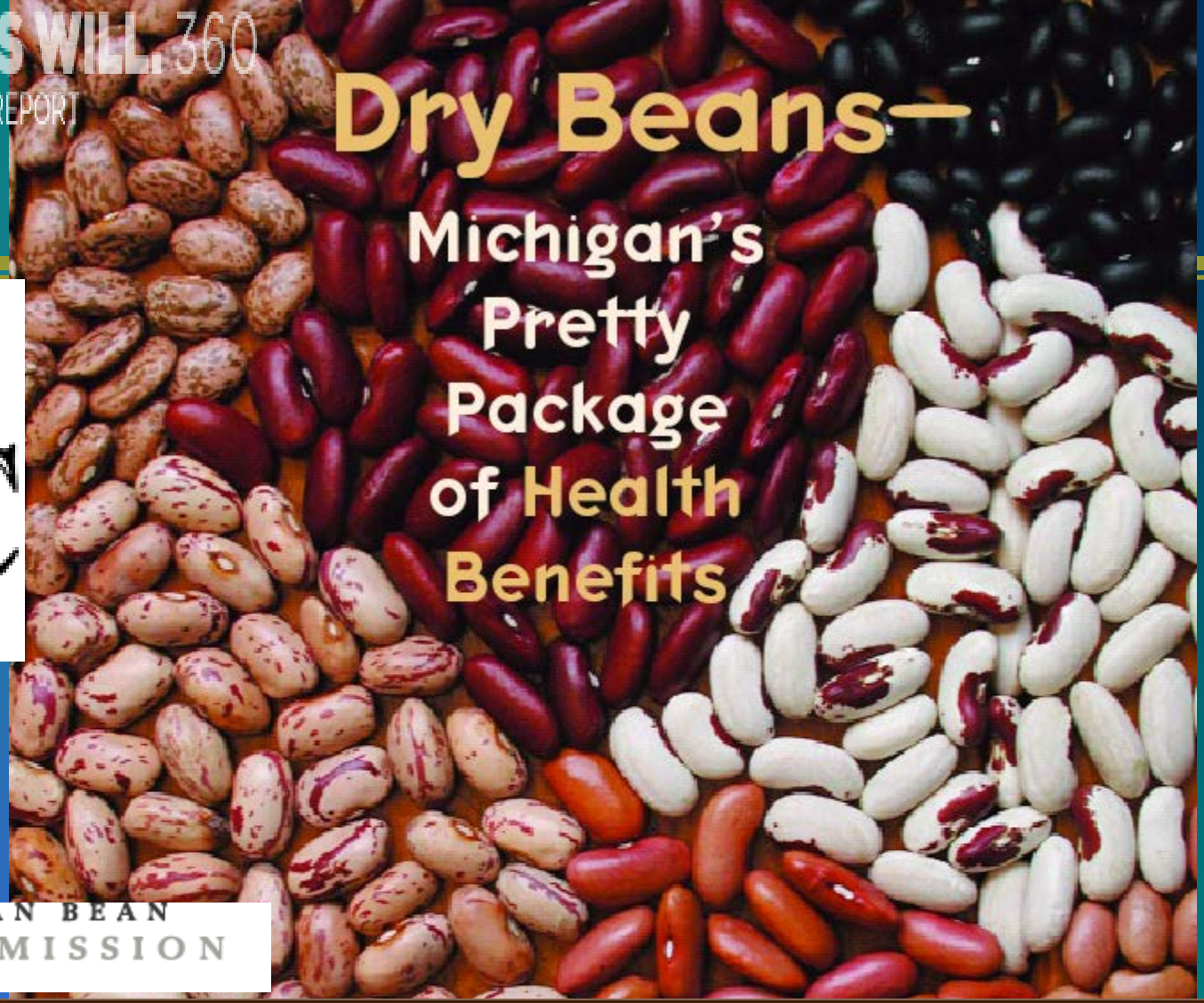
- Association mapping is a static approach to crop improvement
- Generate Genomic information - associations
- Does not generate new genetic recombinations
- Underlying assumption that new markers translates into new varieties
- Experience differs with that assumption
- New varieties come from extensive crossing and field testing
- Continue to give this aspect increased priority

MSU Bean Breeding & Genetics Lab 2013

SPARTANS WILL. 360
MSU PRESIDENT'S REPORT

Dry Beans—

Michigan's Pretty Package of Health Benefits



BEAN CAP

BIC

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

National Sclerotinia Initiative

THE MICHIGAN BEAN COMMISSION

USAID
FROM THE AMERICAN PEOPL

PULSE CRSP
Dry Grain Pulses Collaborative Research Support Program
MICHIGAN STATE UNIVERSITY

Michigan Crop improvement association

Michigan State University
AgBioResearch

MSU Beans

Eldorado

Rosetta

Zorro

Merlot

Red Hawk

Matterhorn

Beluga

Sierra

Mayflower