Breeding Efforts and Cover Crop Choices for Improved Organic Dry Bean Production Systems in Michigan

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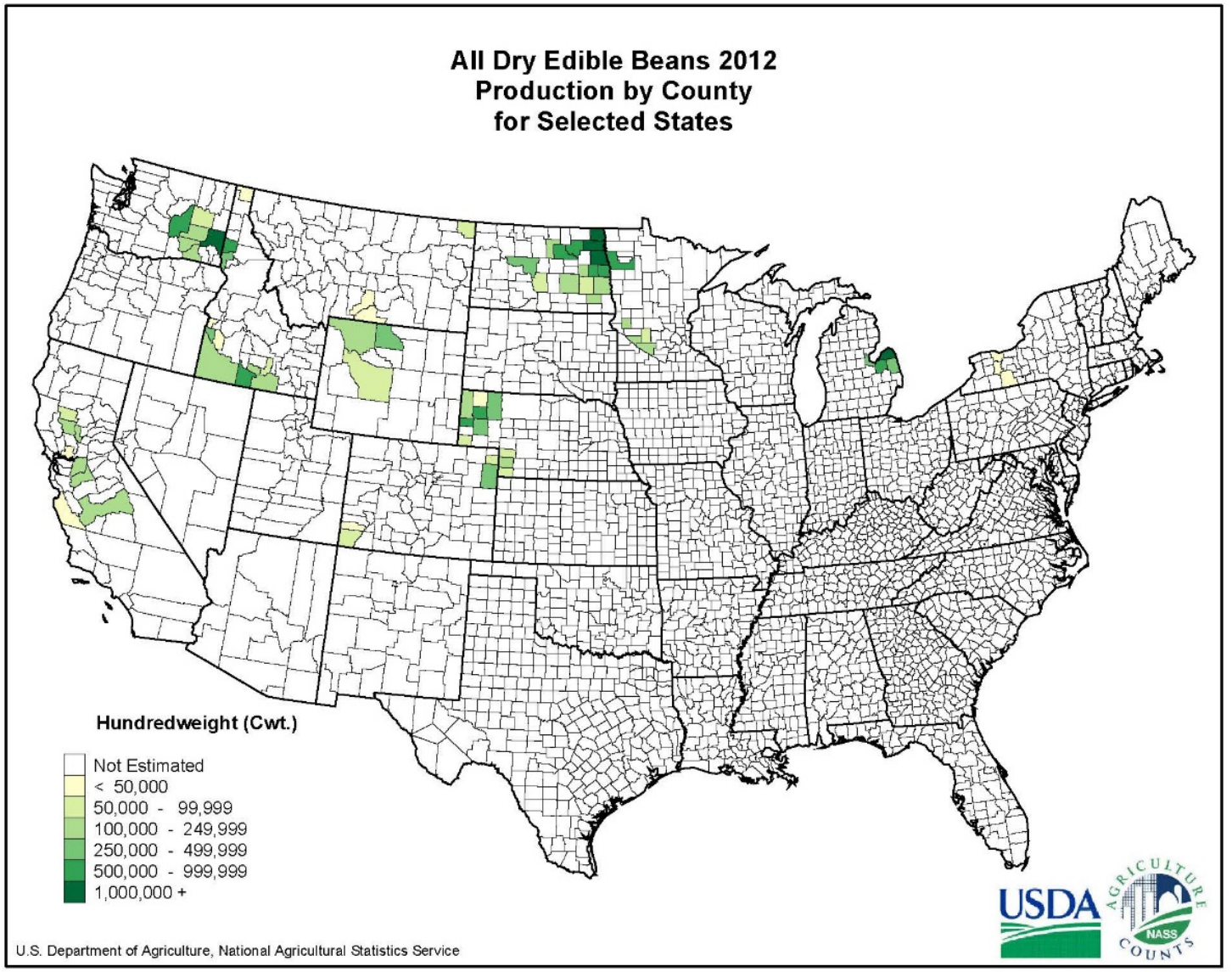
Funding provided by:
USDA-NIFA
Organic Agriculture Research and Extension Initiative

Dry bean webinar outline

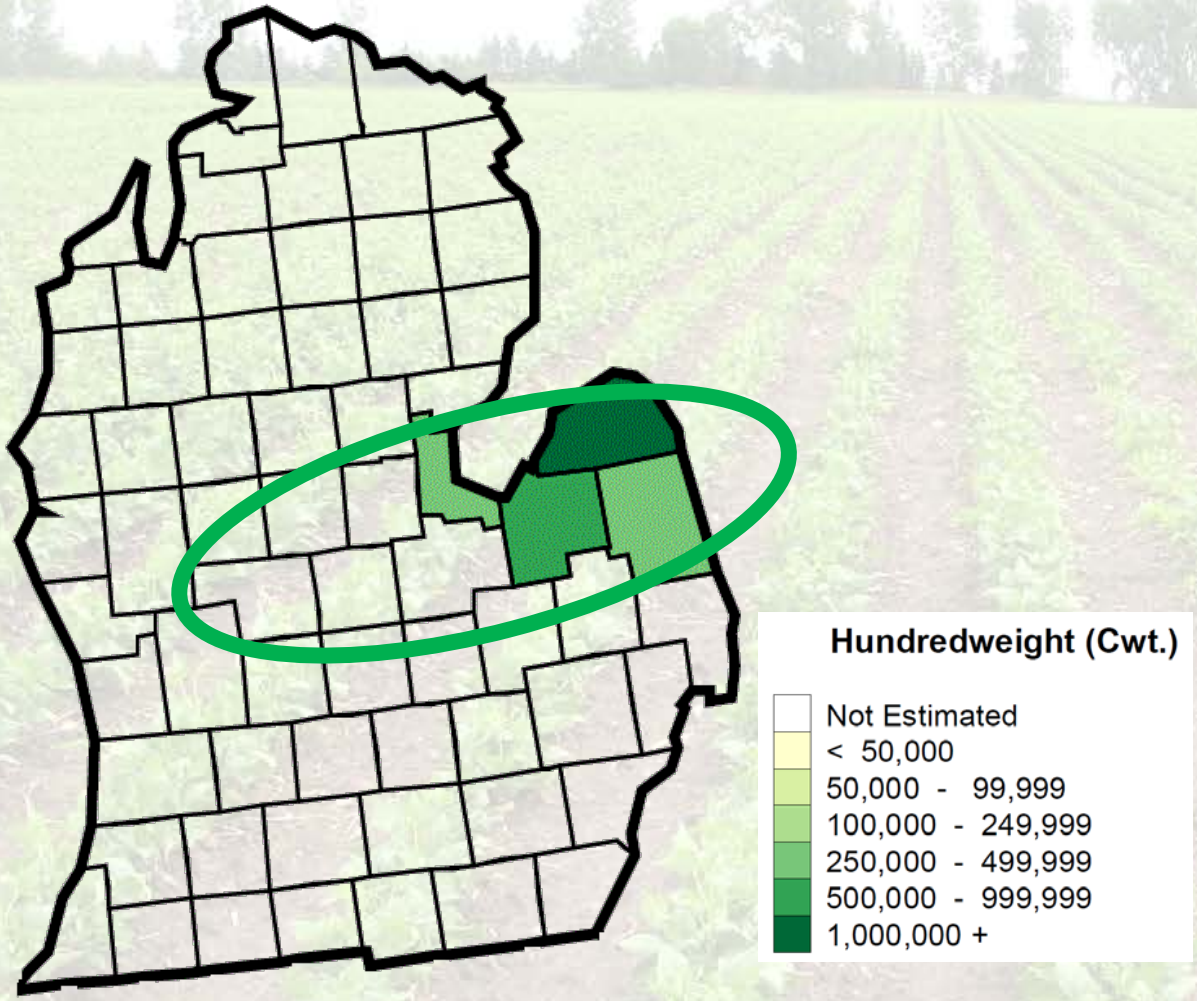
- Introduction
  - Dry bean production across US and in MI
  - Michigan growing conditions
- Dry bean breeding
  - Elite variety evaluation
  - Selecting for better nitrogen fixation
- Cover crop influence on dry beans
  - Nitrogen availability
  - Weed pressure
  - Dry bean populations and yield

Where are dry beans grown in U.S.?

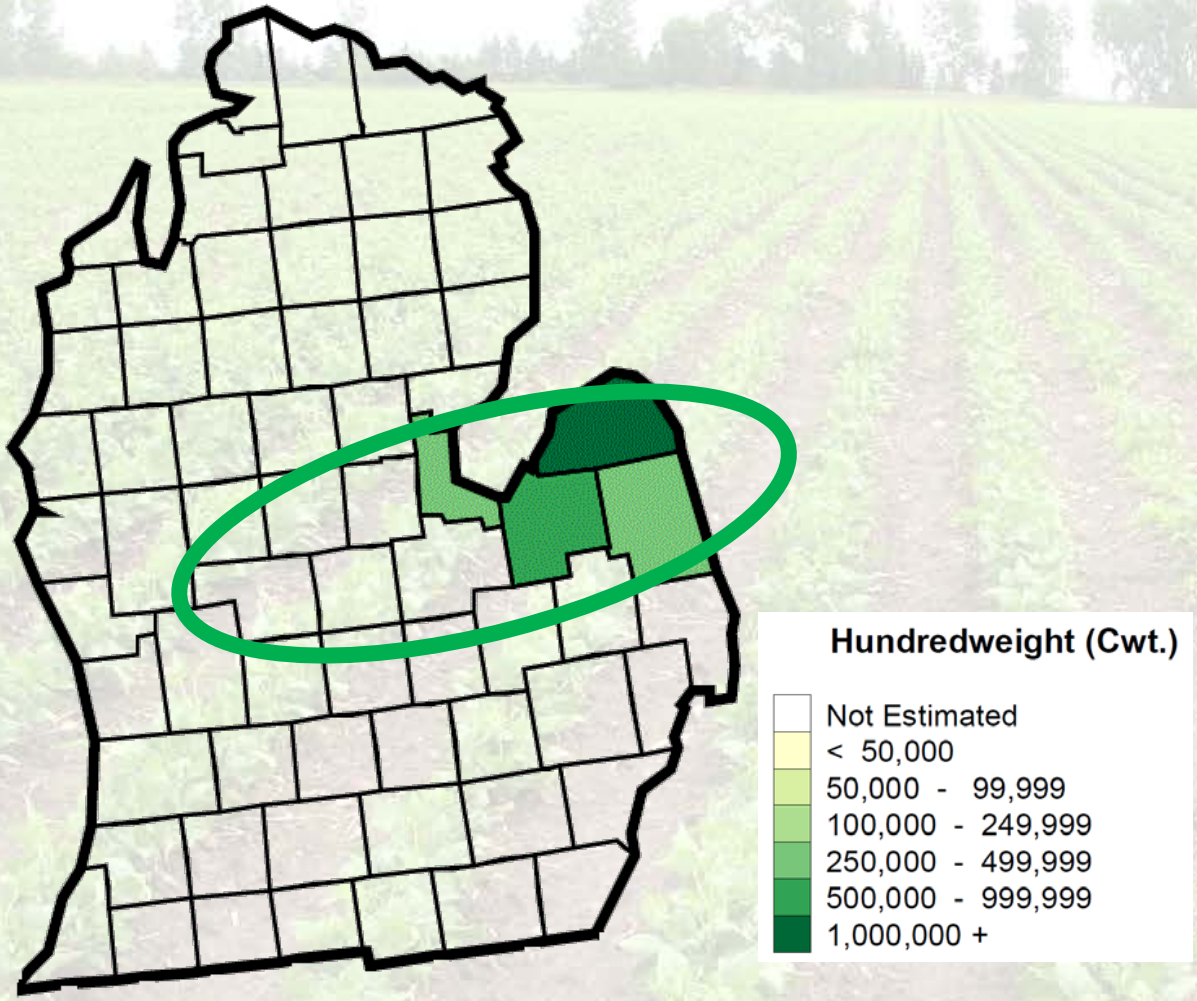


2012-USDA, NASS
http://www.nass.usda.gov/Charts_and_Maps/A_to_Z/in-dry_beans.asp

Dry bean classes grown in Michigan



Dry bean classes grown in Michigan

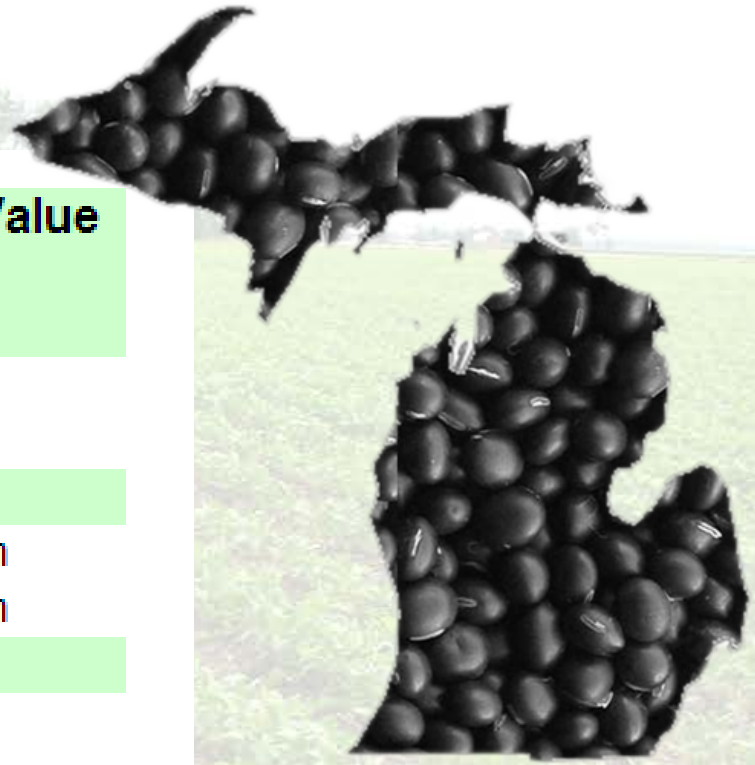


Dry bean production in Michigan

2008 USDA-NASS Organic Survey

	Farms	Acres	Production - cwt	Farm Gate Value
Organic				
Michigan	33	4,781	72,562	$3.94m
US	127	12,407	177,212	$8.47m
Conventional				
Michigan	1,150*	190,219	3,534,438	$126.96m
US	6,109*	1,432,793	25,380,788	$901.73m
Total				
Michigan	1,183*	195,000	3,607,000	$130.9m
US	6,236*	1,445,200	25,558,000	$910.2m

41%



2013 Average (cwt/A)

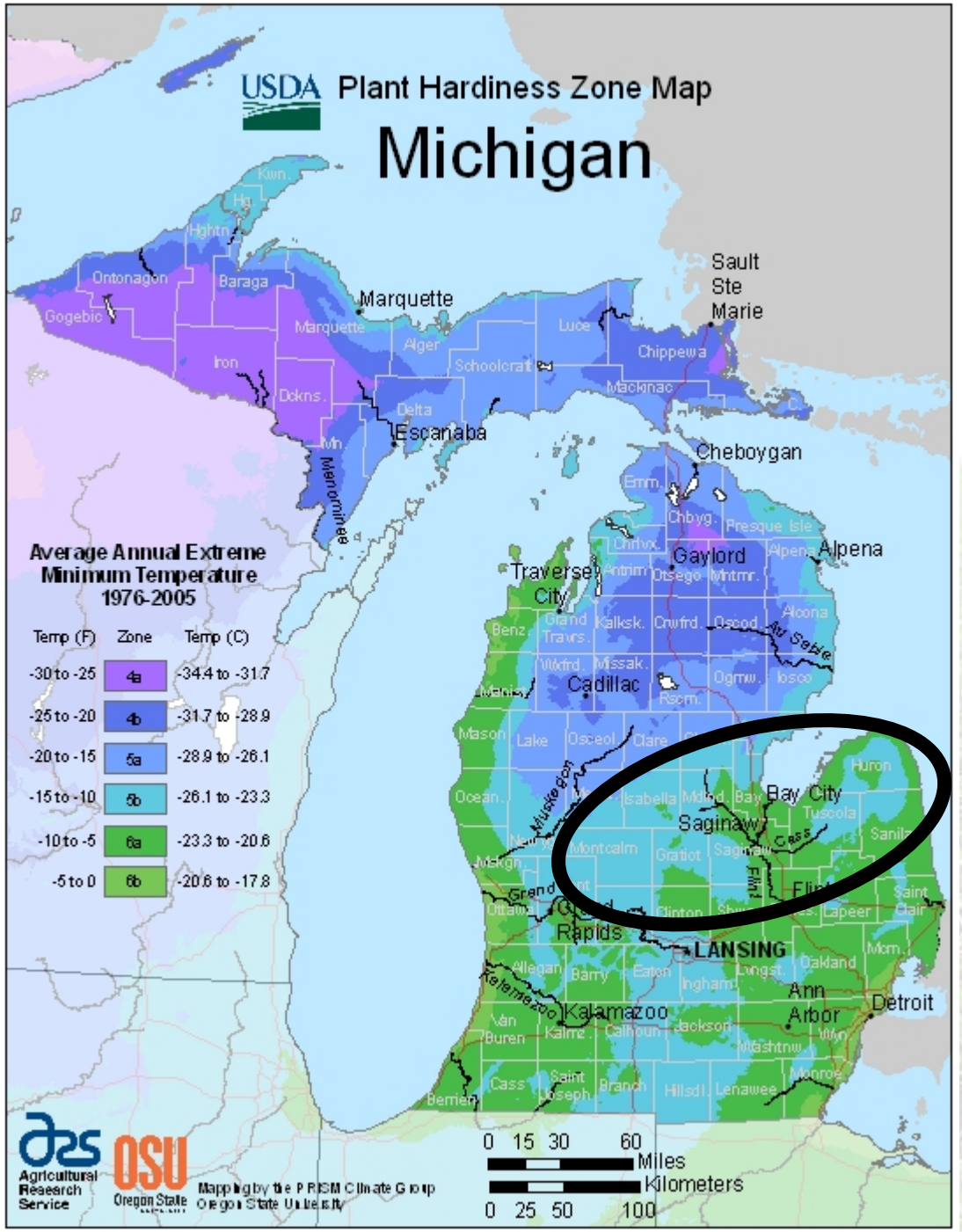
19- MI

18- US

MI growing conditions

MI growing conditions

- Hardiness zones 5-6
- Precipitation
  - 30” annually
  - Jun-Oct- ~16”
- Soil type
  - Order: Alfisols
  - Sandy clay loam to clay loam
  - Organic matter: 1-3%



2012, USDA-ARS

Common MI dry bean production practices

Common MI dry bean production practices

- Planting
  - June
  - 15-30” rows
- Harvest
  - late Sept. to early Nov.
  - Direct harvest is more common
- Mostly rain fed production >90%
- Conventional producers apply >40 lbs/A nitrogen at planting

Common MI dry bean weeds

Most common weeds

a) Annuals grasses
b) Common lambsquarters
c) Common ragweed
d) Pigweed species
e) Velvetleaf
f) Jimsonweed
g) Perennial sowthistle
h) Canada thistle

Organic weed control practices

- Rotary hoe (single or double)
- Between-row cultivation

Common MI dry bean insect pests

a) Leafhopper

b) Mexican bean beetle

c) Japanese beetle

Common MI dry bean diseases

a) Anthracnose
b) Rust
c) Root rot
d) Common bacterial blight
e) Bean common mosaic virus
f) White mold

How can plant breeders address some of the problems faced by dry beans?

Condor
black beans
No Anthracnose
(Resistant)

Vista
navy beans
Anthracnose
(Susceptible)

Huron County Michigan - 2009

Black bean advanced breeding line
Resistant to common bacterial blight

Navy bean ‘Seafarer’
Susceptible to common bacterial blight

Some previous findings

- In side-by-side plots, organic yield was approximately 20% lower than conventionally grown beans
- Large-seeded beans-Kidney and Cranberry-yielded the lowes
- Small, medium-seeded beans-Black, Navy, Pinto, Pinks, Red and Great Northern-had significantly greater yields
- Both systems had similar stresses-insect, precipitation, and disease and were controlled accordingly
- The greatest difference was in soil management-namely differing N levels

Since black and navy beans are important market classes in Michigan…

BNF-Biological Nitrogen Fixation

- Dry beans, like many legumes, are able to form associations with soil bacteria-Rhizobia-which allows them to fix nitrogen from the atmosphere
- Dry beans are typically considered poor nitrogen fixers, not able to obtain their total N needs from fixation as soybeans do
- BNF ability varies by plant variety and strain of Rhizobia in the soil
- This variation may allow development of varieties which are better able to fix sufficient amounts of N from the atmosphere

How do we measure differences in BNF?

- Natural Abundance Method
- Analyze 15N in plant tissue and seed
- Compare 15N content of a non-nodulating, non-fixing bean (R99) to the varieties fixing N

Dry bean R99, non-fixing genotype

What is 15N?

- A naturally occurring stable isotope of Nitrogen
- Has an extra neutron, increasing its atomic weight
- Rare-0.36% of N in the atmosphere (air is made up of over 78% N_2)
- Tends to accumulate in organic matter in the soil, slightly elevating its level in the soil-microbes preferentially use 15N
- Can be measured with appropriate equipment (UC Davis Stable Isotope Facility)

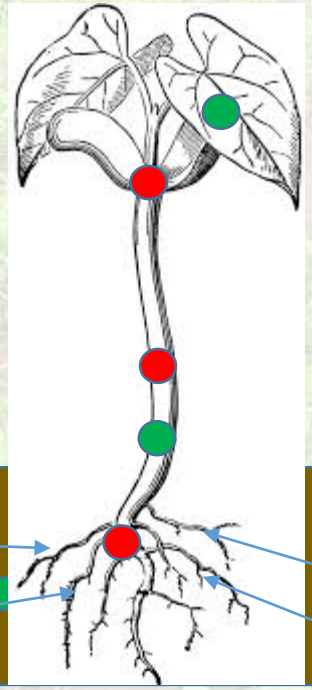
15N

14N

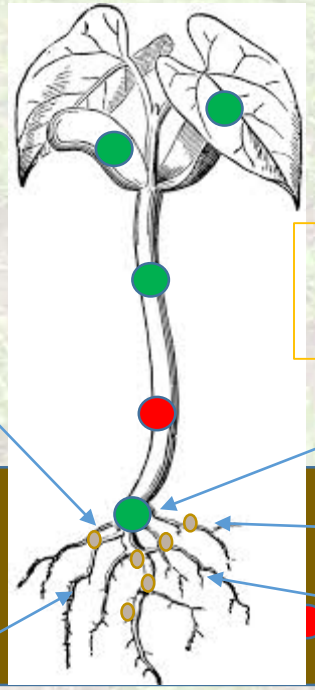
Non-Fixing Bean Plant

Fixing Bean Plant

Concentration of 15N similar to soil



Concentration of 15N lower than soil



Nodules on roots

A look at organic seed yield and percent N derived from the atmosphere

- 18 black bean and 18 navy bean advanced breeding lines, commercial checks:

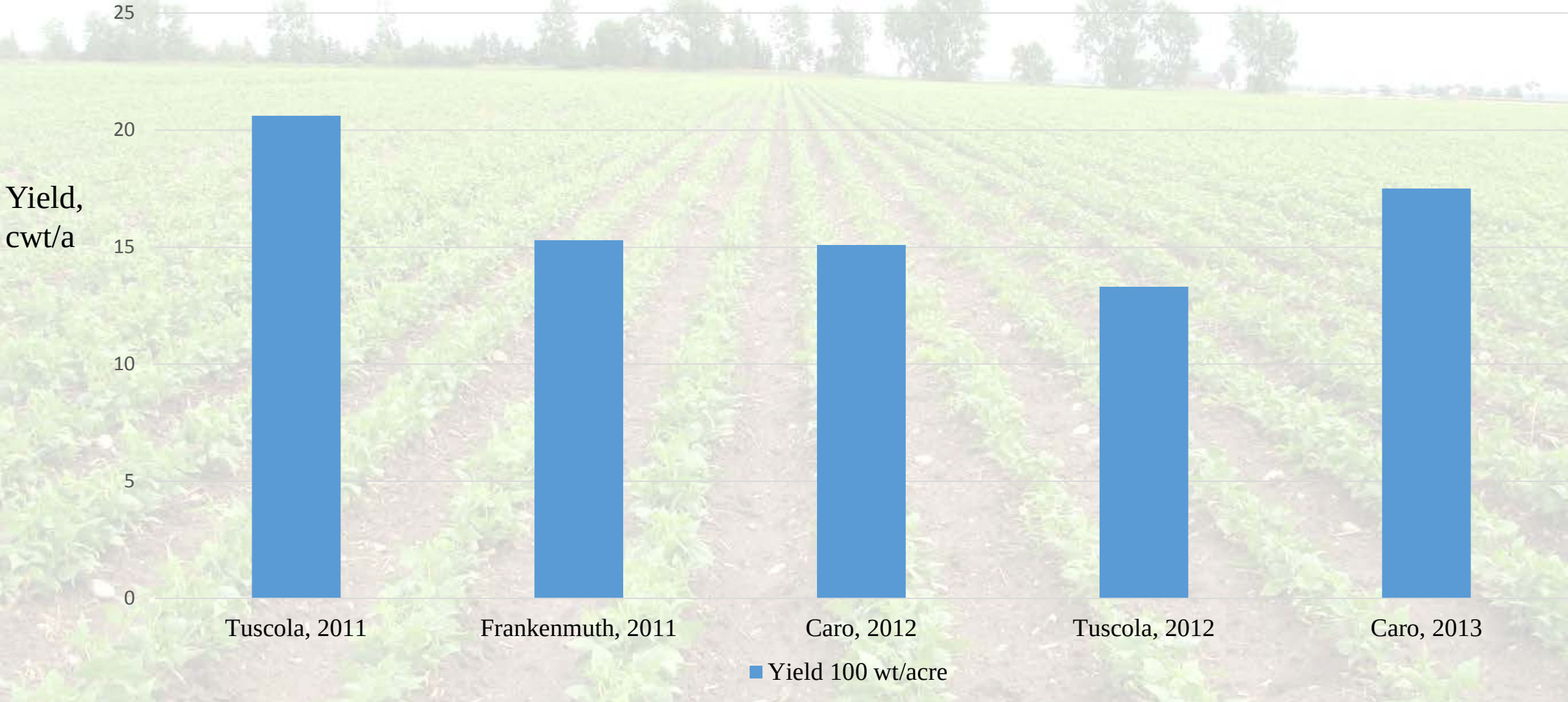
  Black Beans-Zorro and Black Velvet

  Navy Beans-Medalist and Vista

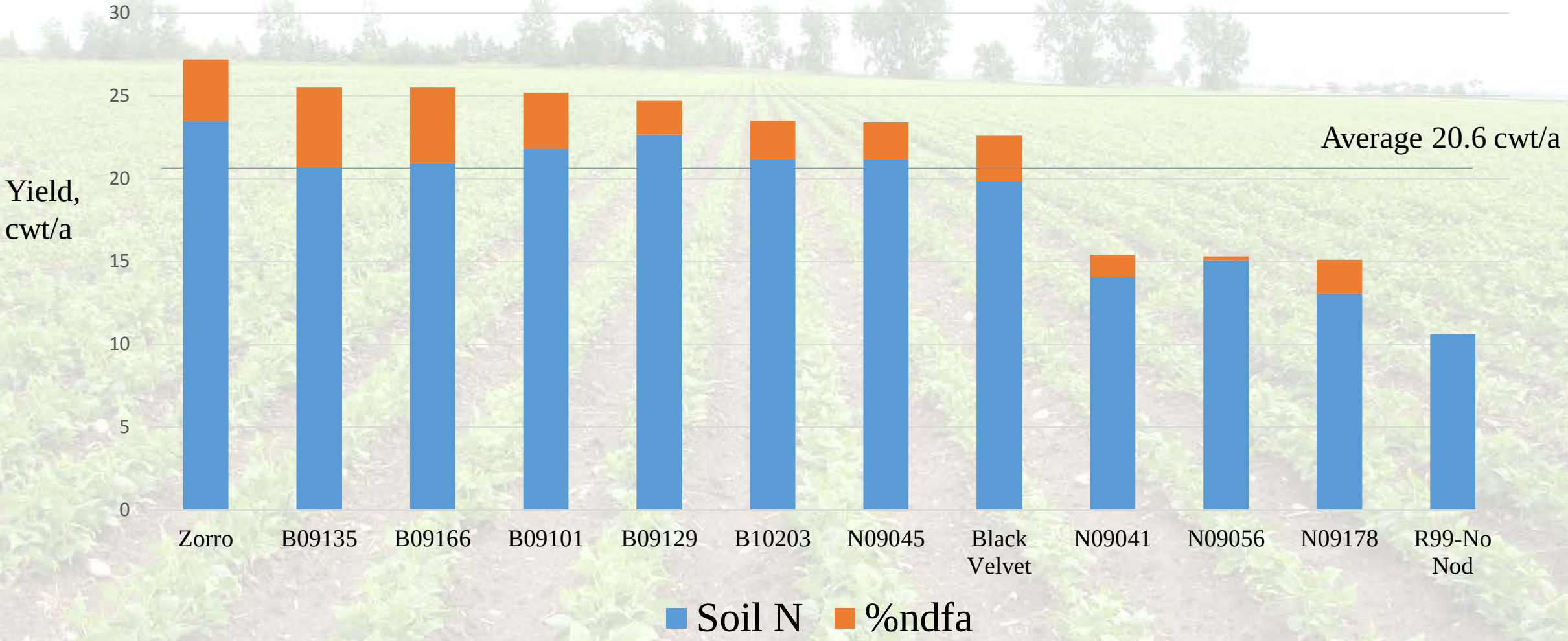
  Non-Nodulating-R99 (derived from the navy bean Bunsi)

- Each year breeding lines were updated with lines showing promise in standard trials and the BNF genetic population
- Followed organic practices for fertility, weed control, and insect control
- Seed treated with rhizobia inoculant prior to planting
- At harvest, 15N was measured to determine the percent nitrogen derived from the atmosphere (%ndfa)

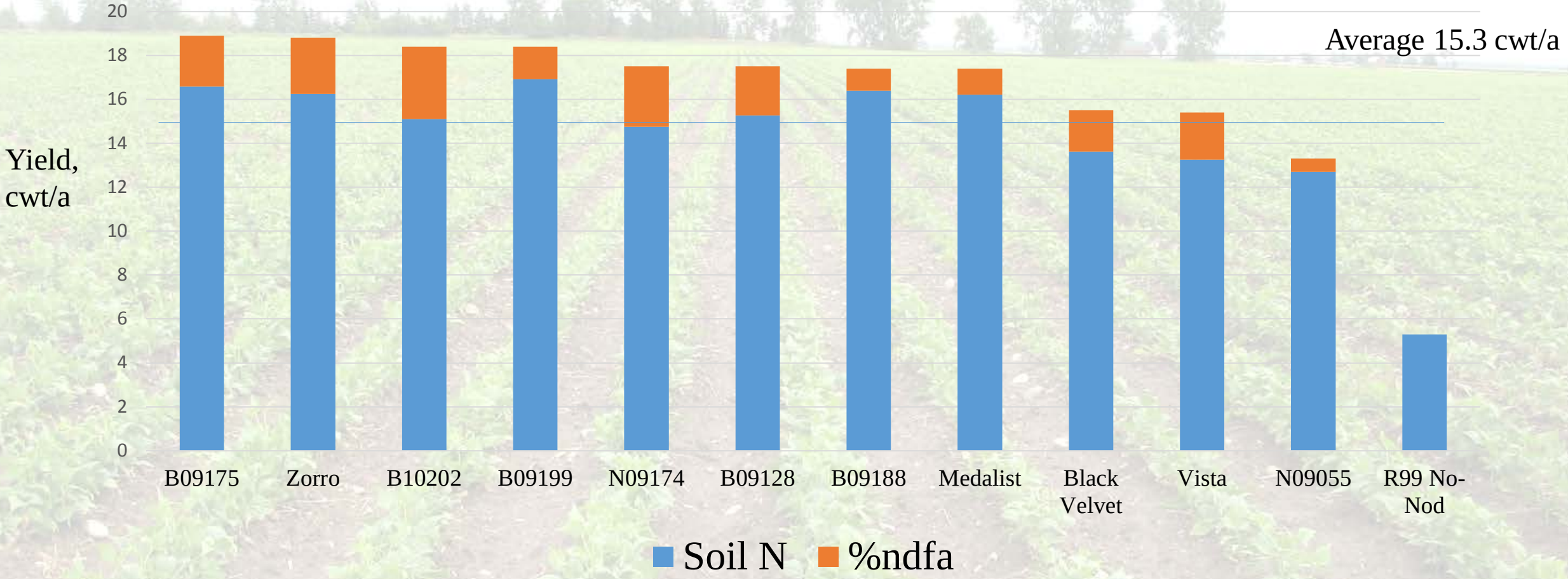
Average yield of organic variety evaluations in 2011, 2012, and 2013



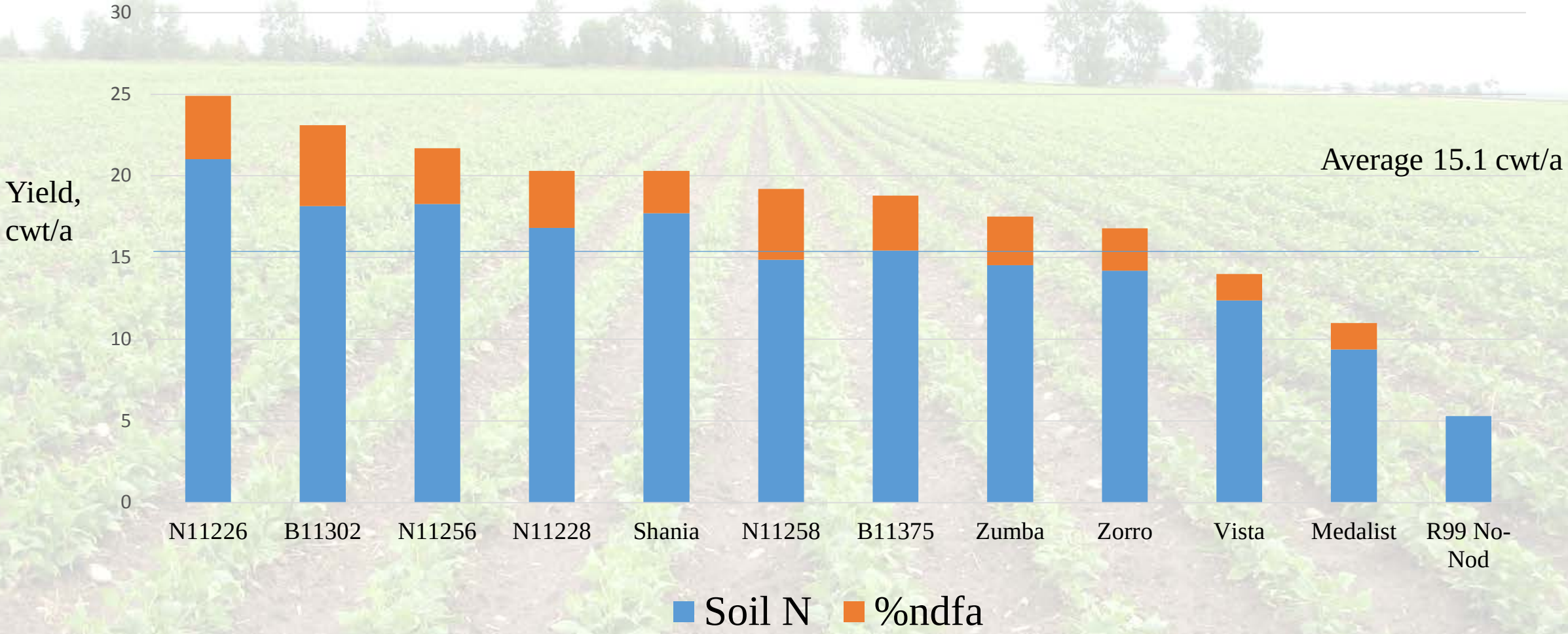
Yield and %ndfa of select dry bean varieties planted in Tuscola County in 2011



Yield and %ndfa of select dry bean varieties planted in Frankenmuth in 2011



Yield and %ndfa of select dry bean varieties planted in Caro in 2012



Yield and %ndfa of select dry bean varieties planted in Tuscola County in 2012

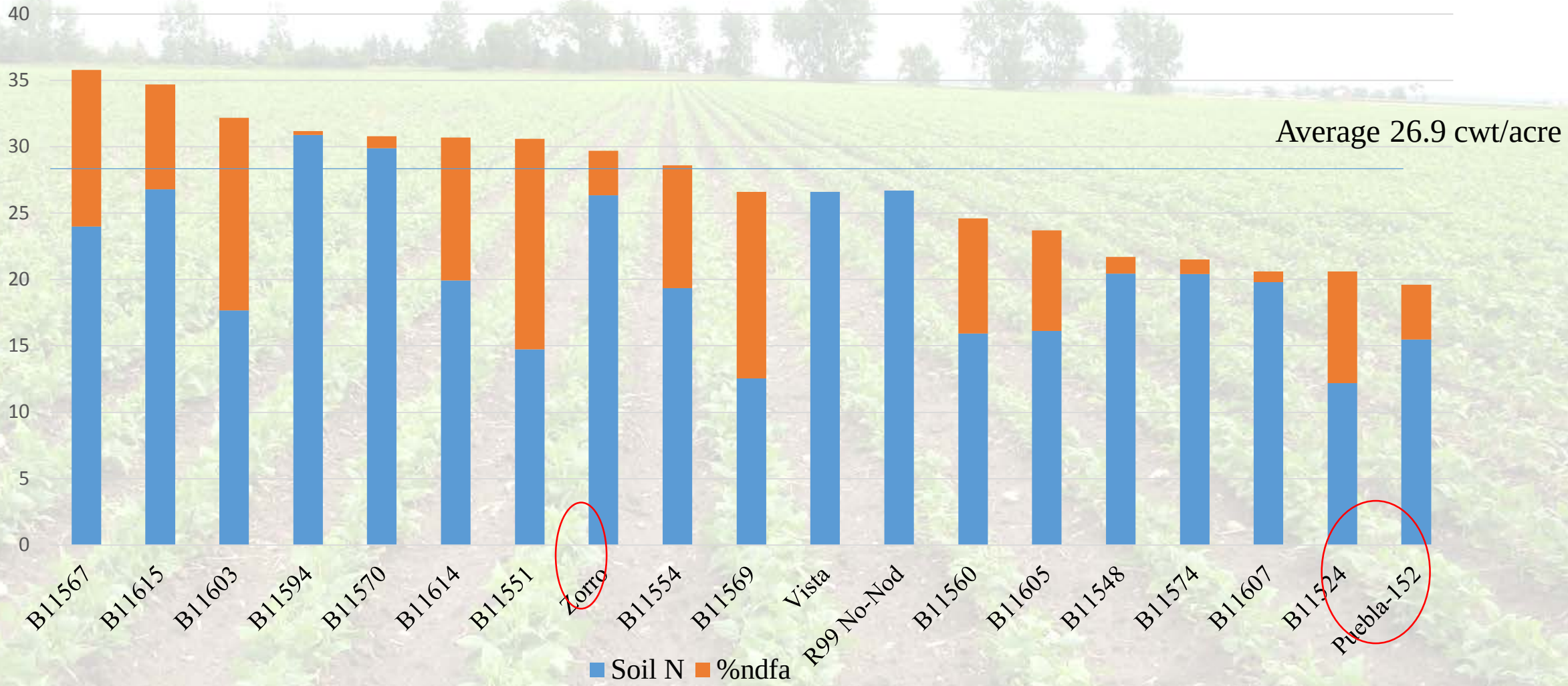
Some Observations of yield trials of navy and black beans

- Performance is quite variable from year to year
- Navy beans tend to yield lower than black beans
- Ndfa does not make up a significant portion of the N in the seed at harvest

Investigating the genetics of BNF

- Variability exists within dry bean for BNF
- The black seeded landrace Puebla-152, from Puebla, Mexico, has been identified as fixing a higher amount of N-but it is late maturing in MI
- A population of 125 Recombinant Inbred Lines (RILs) was developed by crossing Puebla-152 with the commercial black bean variety ‘Zorro’ which is adapted to production in MI

Yield and %ndfa for select BNF RILs grown in East Lansing, MI in 2011 and 2012



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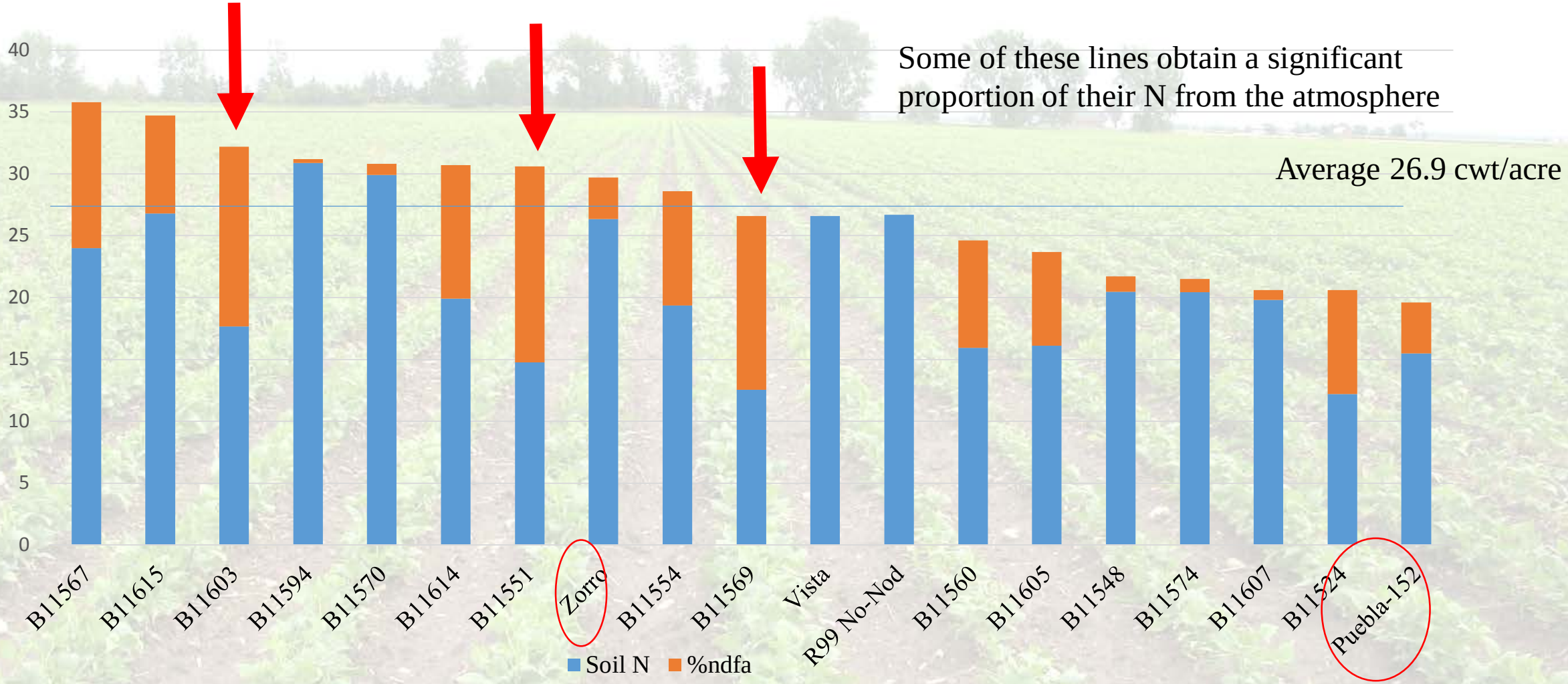

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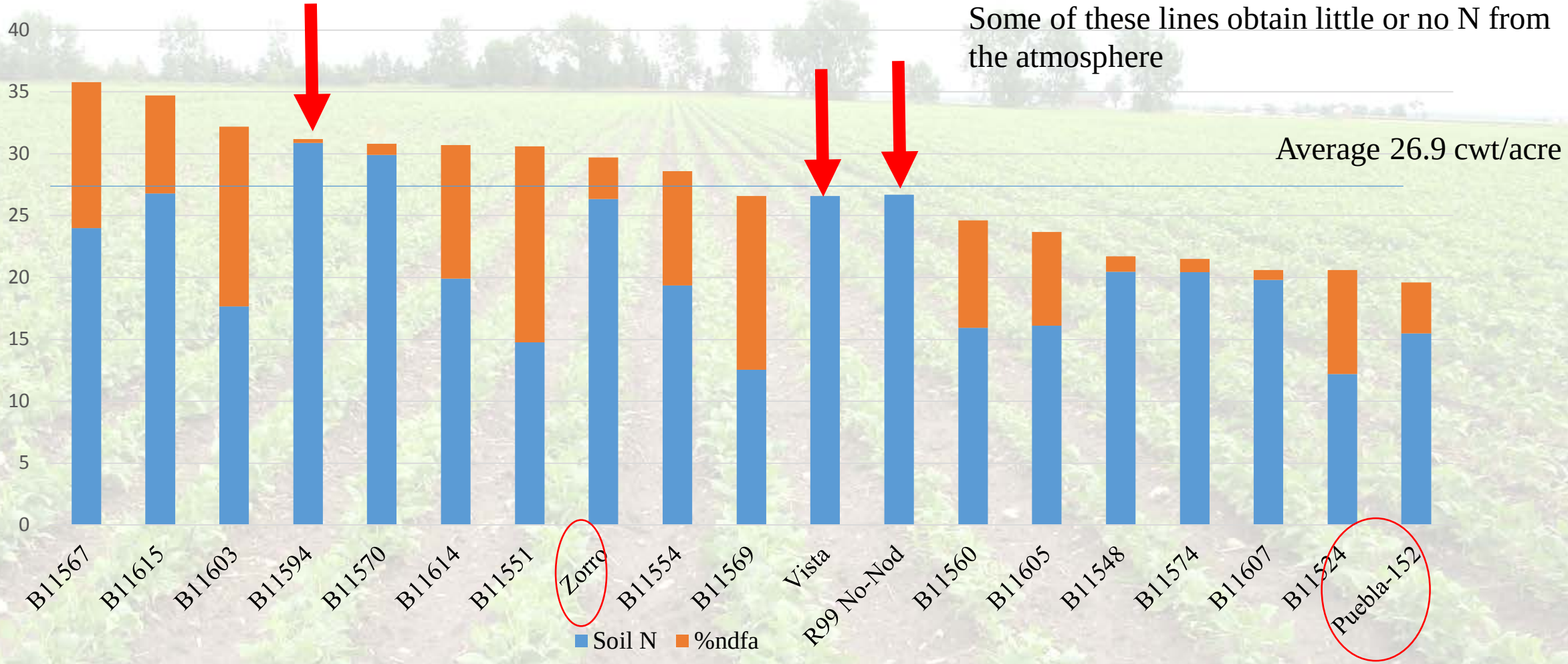

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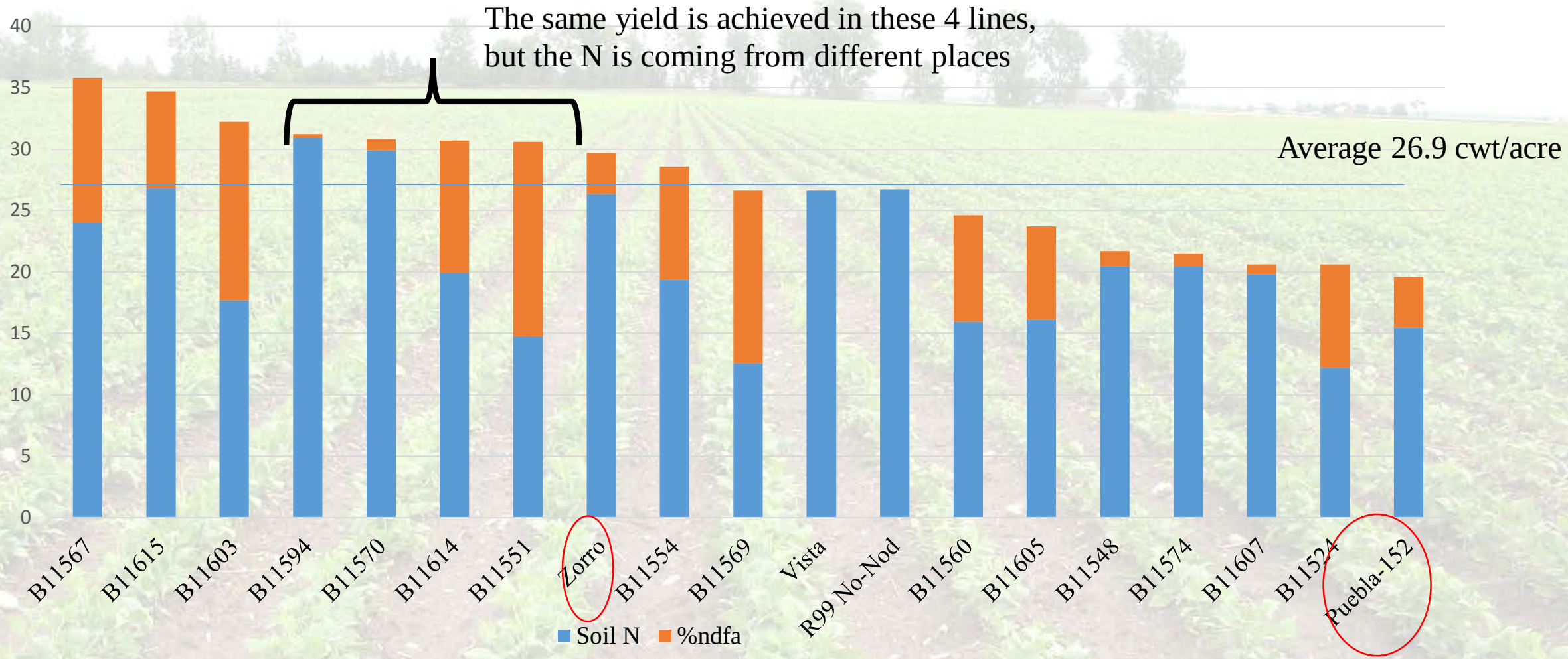
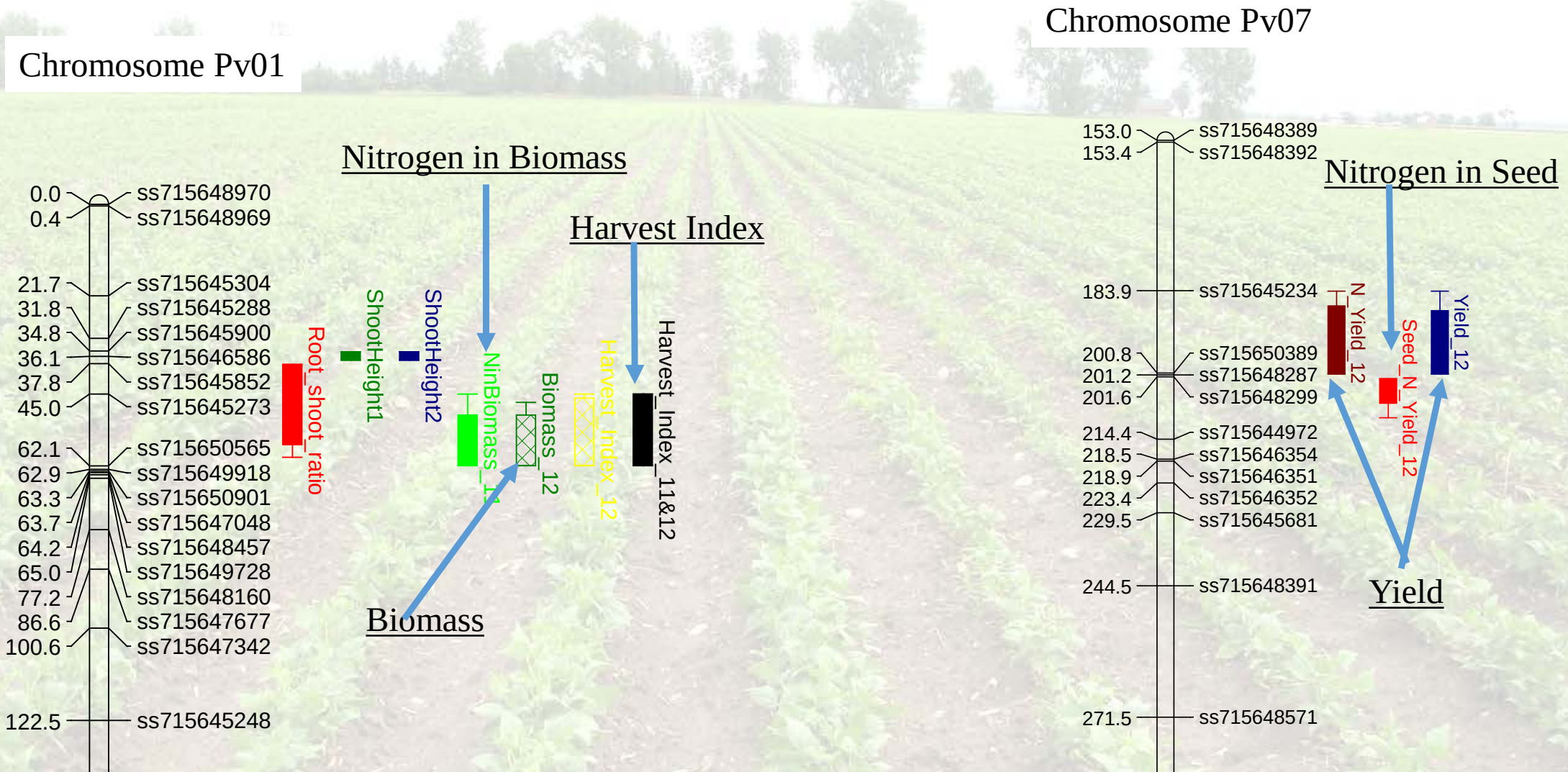
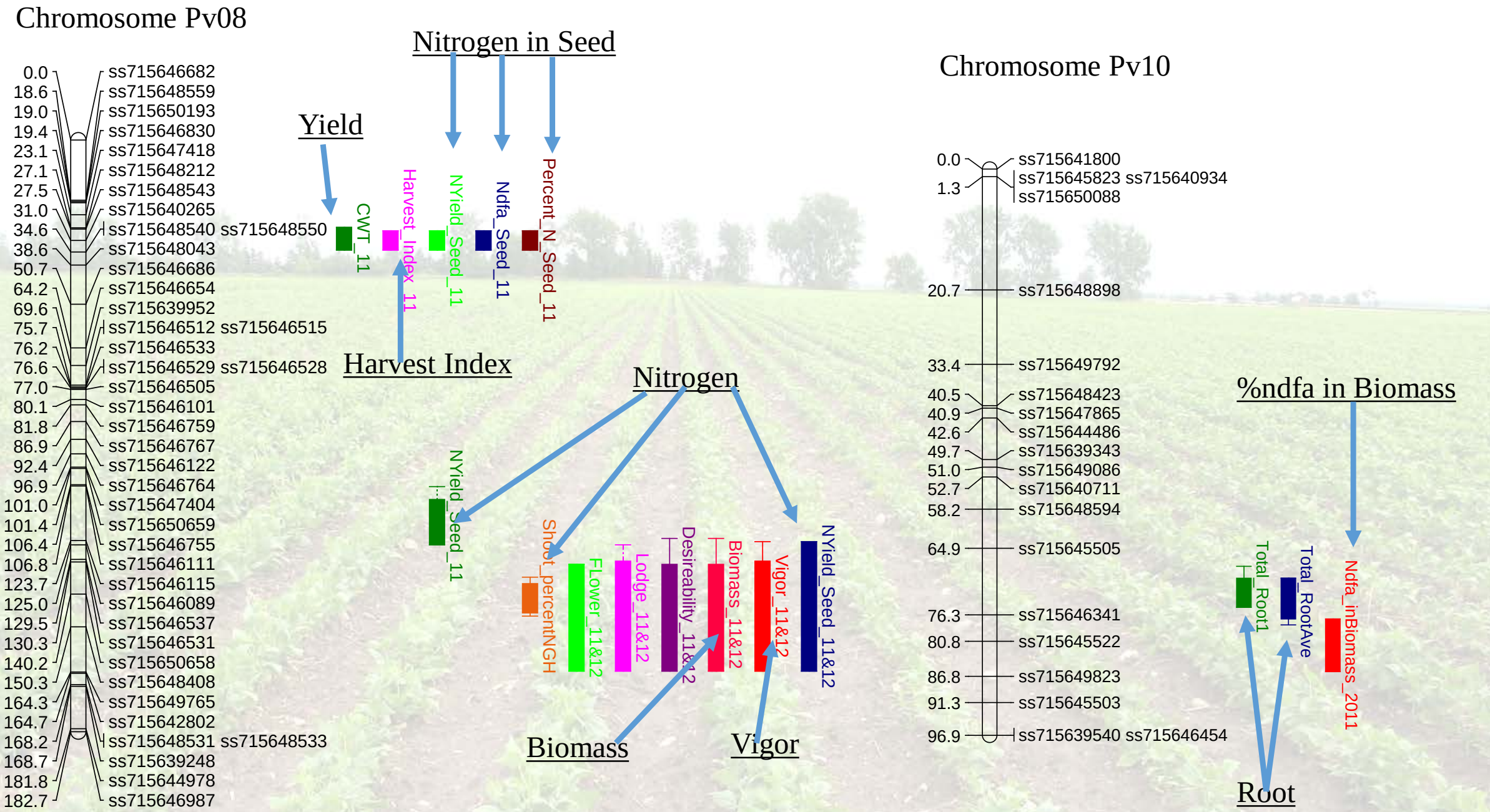


Chromosome location of BNF associated traits




Chromosome Pv08
0.0 ss715646682
18.6 ss715648559
19.0 ss715650193
19.4 ss715646830
23.1 ss715647418
27.1 ss715648212
27.5 ss715648543
31.0 ss715640265
34.6 ss715648540 ss715648550
38.6 ss715648043
50.7 ss715646686
64.2 ss715646654
69.6 ss715639952
75.7 ss715646512 ss715646515
76.2 ss715646533
76.6 ss715646529 ss715646528
77.0 ss715646505
80.1 ss715646101
81.8 ss715646759
86.9 ss715646767
92.4 ss715646122
96.9 ss715646764
101.0 ss715647404
101.4 ss715650659
106.4 ss715646755
106.8 ss715646111
123.7 ss715646115
125.0 ss715646089
129.5 ss715646537
130.3 ss715646531
140.2 ss715650658
150.3 ss715648408
164.3 ss715649765
164.7 ss715642802
168.2 ss715648531 ss715648533
168.7 ss715639248
181.8 ss715644978
182.7 ss715646987
Nitrogen in Seed
Yield
CWT_11
Harvest_Index_11
NYield_Seed_11
Ndfa_Seed_11
Percent_N_Seed_11
Harvest Index
Nitrogen
NYield_Seed_11
Shoot_percentNGH
FLower_11&12
Lodge_11&12
Desireability_11&12
Biomass_11&12
Vigor_11&12
NYield_Seed_11&12
Biomass
Vigor
Chromosome Pv10
0.0 ss715641800
1.3 ss715645823 ss715640934
ss715650088
20.7 ss715648898
33.4 ss715649792
40.5 ss715648423
40.9 ss715647865
42.6 ss715644486
49.7 ss715639343
51.0 ss715649086
52.7 ss715640711
58.2 ss715648594
64.9 ss715645505
76.3 ss715646341
80.8 ss715645522
86.8 ss715649823
91.3 ss715645503
96.9 ss715639540 ss715646454
%ndfa in Biomass
Total_Root1
Total_RootAve
Ndfa_inBiomass_2011
Root

Some Observations on the Genetics of BNF

- There is genetic variability for %ndfa in the Puebla-152 x Zorro RIL population
- Some RILs derive a substantial portion of their N from the atmosphere
- BNF characteristics colocalize in the genome, often with yield traits
- Partitioning-the ability to mobilize resources from vegetative tissue to seeds plays an important role in improving nitrogen use efficiency

Cover Crop Influence on Organic Dry beans

Erin Hill

How do cover crops influence…?

- Nitrogen availability
- Weed dynamics
  - Numbers
  - Growth
- Dry bean
  - Populations
  - Days to maturity
  - Yield
  - N content of grain

Cover crop planting scheme

Red clover
‘Marathon’
10 lbs/A

Oilseed radish
‘Groundhog’
11 lbs/A

Rye
‘Wheeler’
90 lbs/A

No cover

Cover crop planting scheme

Red clover
‘Marathon’
10 lbs/A

Oilseed radish
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11 lbs/A

Rye
‘Wheeler’
90 lbs/A

No cover

Year 1												Year 2											
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

Cover crop planting scheme

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'Marathon'
10 lbs/A

Oilseed radish
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11 lbs/A

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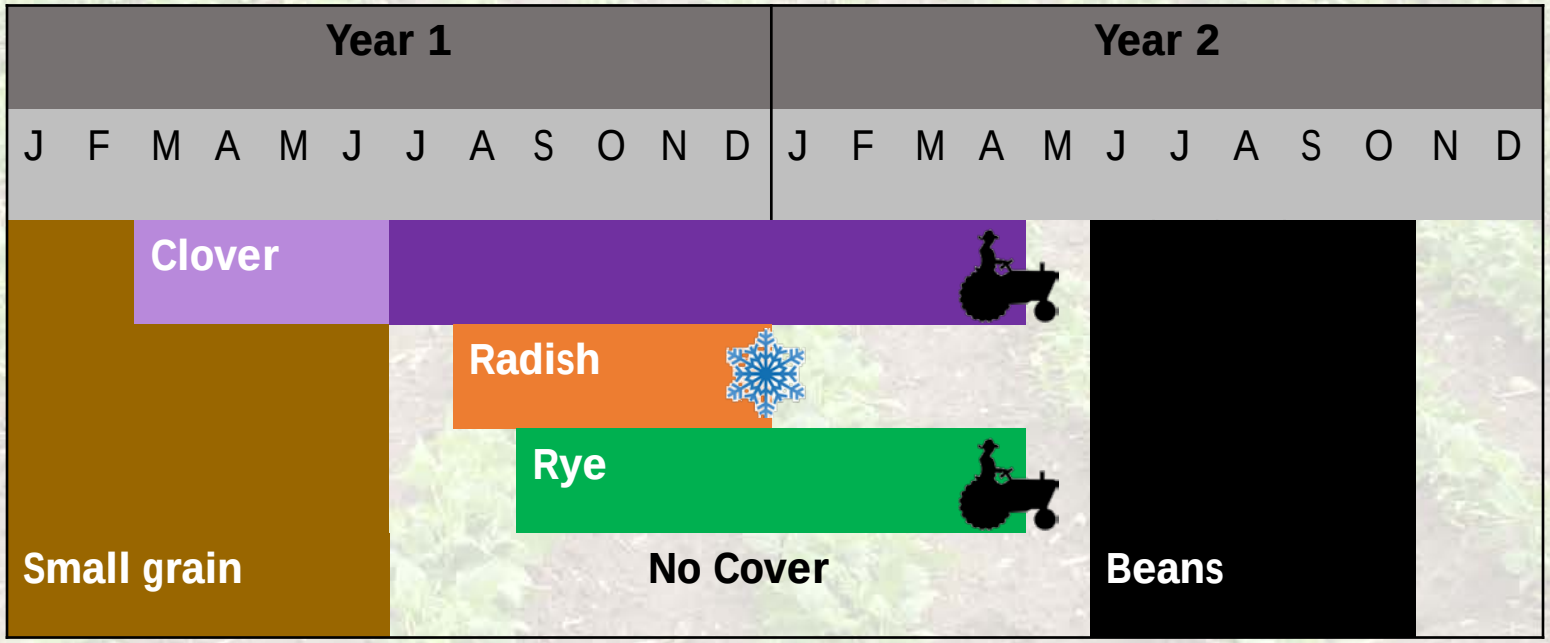
90 lbs/A

No cover



Dry bean varieties

Black- ‘Zorro’ and ‘Black velvet’

Navy- ‘Vista’ and R99 (non-nodulating)*

** The non-nodulating line, allows us to look at cover crop influence in the absence of N fixation*

MSU and On-farm sites (2011-2013)

MSU sites (2 per year)

Cover crops
- Clover
- Oilseed radish
- Rye
- No cover

Bean varieties
- Zorro
- Black velvet
- Vista
- R99

On-farm sites (up to 9 per year)

Cover crops
- Clover/Radish/Rye
- No cover

Bean varieties
- Zorro
- Vista

Timing of measurements

Pre-season	June	July	August	September	October
Peak cover crop biomass	@ Planting	2nd trifoliate (V2)	1st flower (R1)	1st full length pod (R5)	Harvest

Timing of measurements

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Peak cover crop biomass	@ Planting	2nd trifoliate (V2)	1st flower (R1)	1st full length pod (R5)	Harvest

Radish- November (prior to winter-kill)

Rye- ~1 month before planting (18” target height)

Clover- 2 weeks before planting

Timing of measurements

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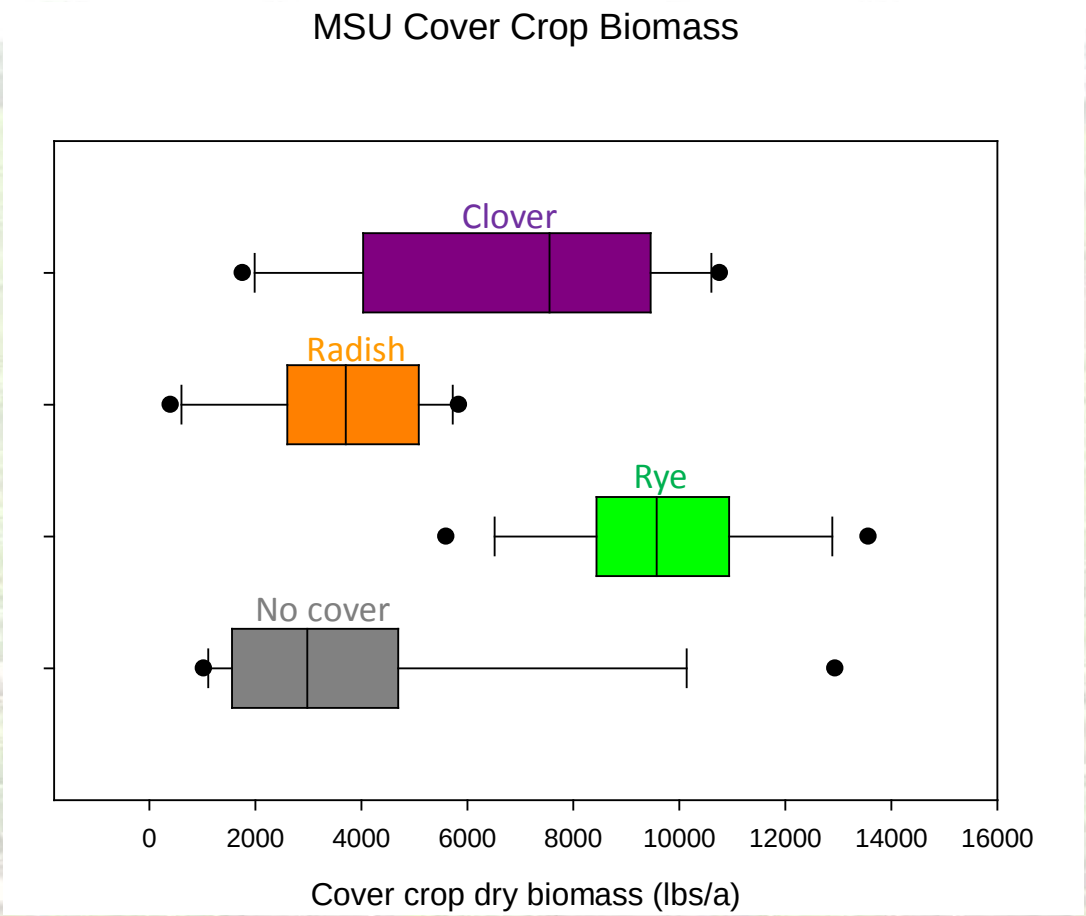
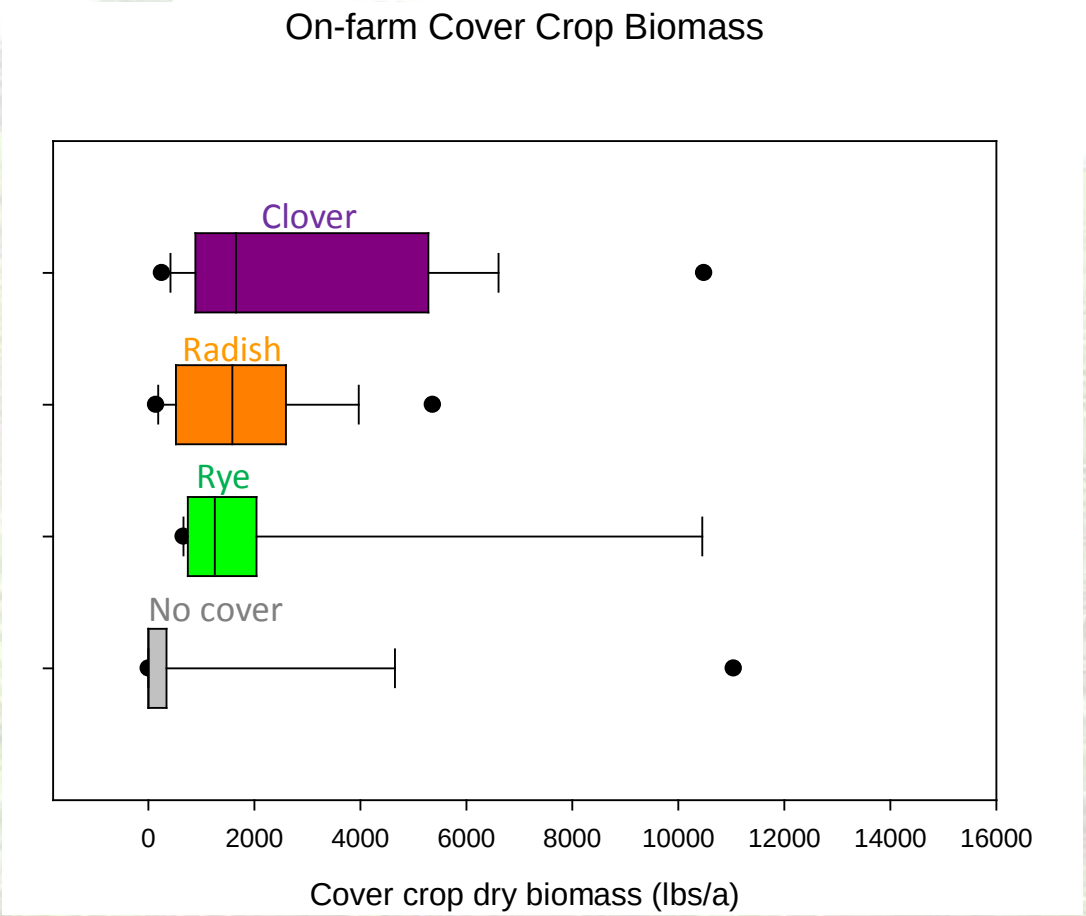
Pre-season	June	July	August	September	October
Peak cover crop biomass	@ Planting	2nd trifoliate (V2)	1st flower (R1)	1st full length pod (R5)	Harvest

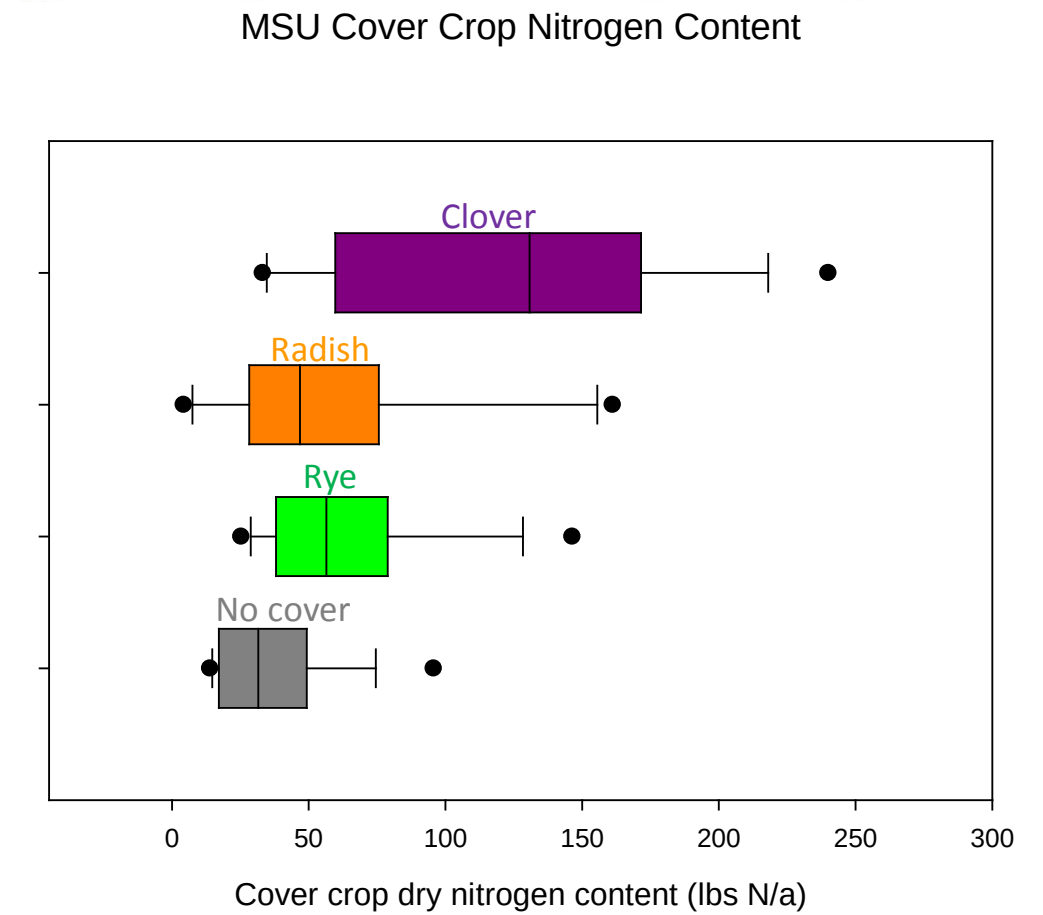
RESULTS- Nitrogen

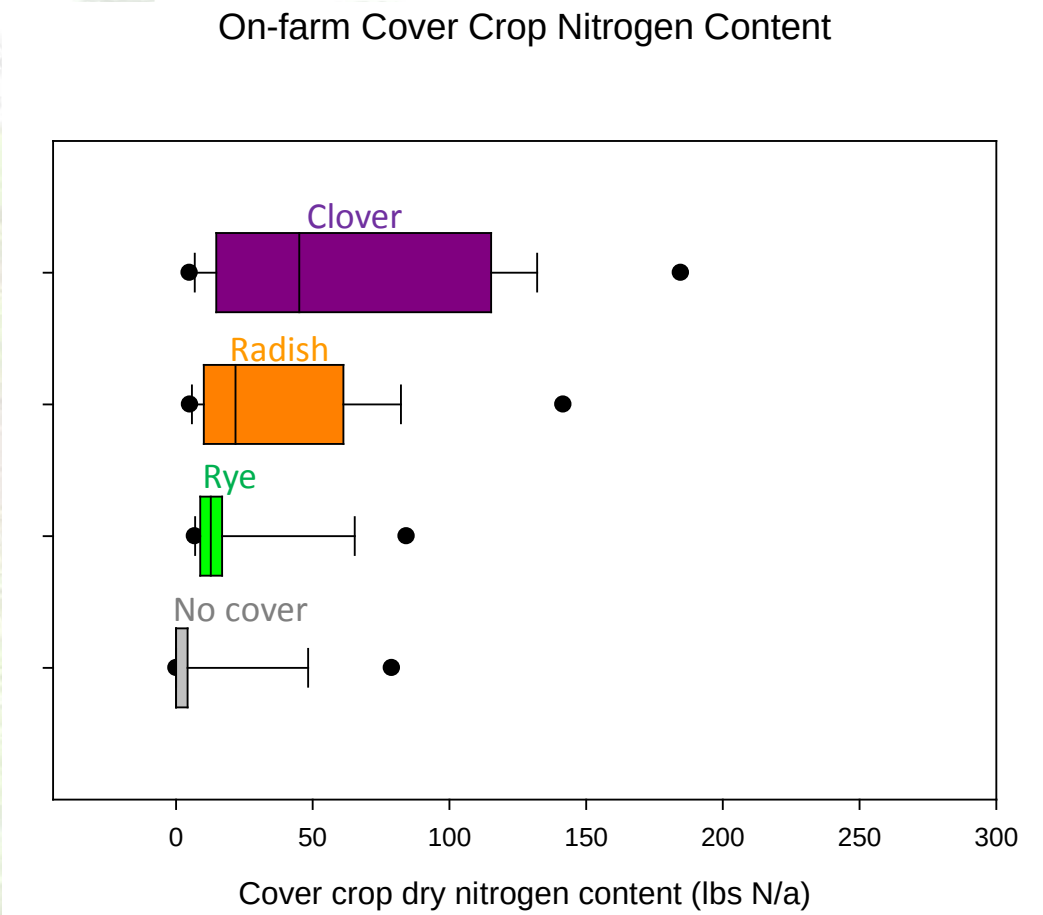
Early planting at MSU sites resulted in greater biomass production of the cover crops





Red clover produced the most nitrogen





**Not all nitrogen contained in the cover crops in immediately available to the subsequent crop*

Clover increased the nitrogen available in the soil

Clover

↑ Nitrate

- Planting: 5-20 lbs N/A more than no cover*
- V2: 10-50 lbs N/A
- R1-Harvest: more nitrogen *50% of the time*

Radish

↑ Nitrate

- V2: 10-15 lbs N/A more than no cover *50% of the time*

Rye

↓ Nitrate

- Planting & V2: 5-20 lbs N/A less than no cover *50% of the time*
- Flower-Harvest: Rarely differences

*On-farm trials sometimes mirrored these results, it seemed to be biomass dependent

RESULTS- Weed dynamics

Weed pressure increased following clover

Clover

Weed number

↑42% of time

**compared to no cover*

Weed biomass

↑ 33% or time

Radish

Weed number

No difference

Weed biomass

No difference

Rye

Weed number

↓1/12 times

Weed biomass

No difference

**On-farm trials showed no differences among cover crops with regard to weed number or biomass

Weed pressure increased following clover

Clover

Weed number

↑42% of time

**compared to no cover*

Weed biomass

↑ 33% or time

Radish

Weed number

No difference

Weed biomass

No difference

Rye

Weed number

↓1/12 times

Weed biomass

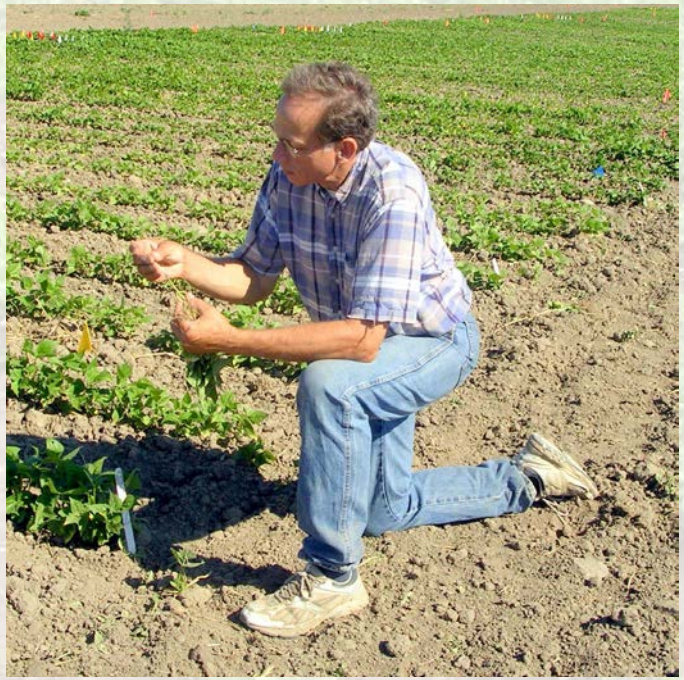
No difference

**On-farm trials showed no differences among cover crops with regard to weed number or biomass

Bean variety

- MSU- rarely influenced weed number or biomass
- On-farm- variety did not influence weeds

RESULTS- Dry bean properties



Oilseed radish and rye occasionally influenced dry bean populations

MSU

- ↑ following **oilseed radish***, occasionally
- ↑ following a large **rye** cover crop in a dry year (2012)…increased soil moisture at planting

On-farm

- Rarely differences
- ↓ following **rye**, one year due to seed corn maggot feeding

**compared to no cover*

Dry bean populations (plants/A)

Cover	V2 & Harvest
Clover	72,000
Radish	76,000
Rye	78,000
No cover	71,000

**Original planting rate ~ 106-120,000 seeds/A*
***Averaged over 3 years for the MSU sites*

Black bean populations were greater than navy bean populations

- MSU- 100% of the time
- On-farm- 50% of the time

Dry bean populations (plants/A)

Cover	V2 & Harvest
Black velvet	81,000
Zorro	82,000
Vista	67,000
R99	70,000

**Original planting rate ~ 106-120,000 seeds/A*

***Averaged over 3 years for the MSU sites*

Did cover crop or bean variety affect nodulation?

COVER CROP

- At R1 (flowering)

  ↓ nodules in beans following clover

BEAN VARIETY

- At V2 (2nd trifoliate)

  ↑ nodules in Black velvet beans

Dry bean maturity was evaluated at MSU sites

COVER CROP

- Beans following rye matured faster than the other cover crops and no cover 22% of the time

R99- September 27, 2012

Rye

No cover

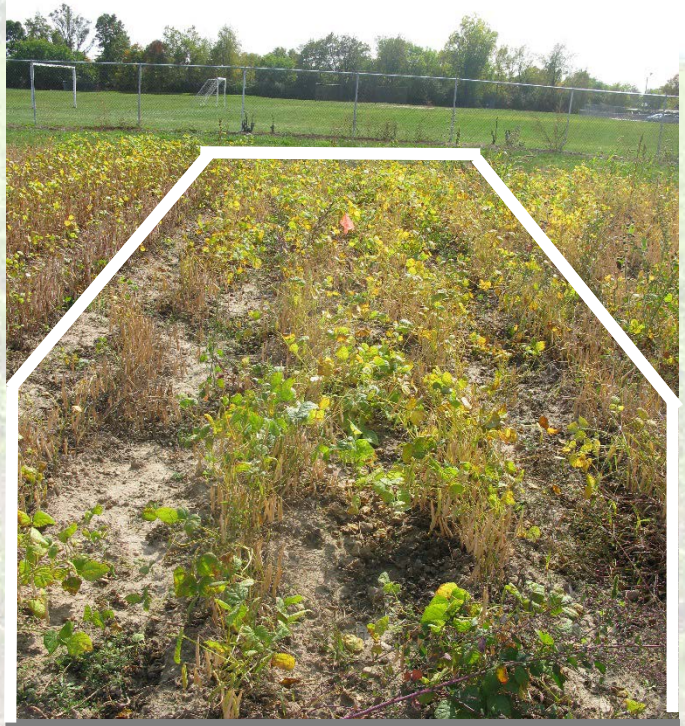
Dry bean maturity was evaluated at MSU sites

COVER CROP

- Beans following rye matured faster than the other cover crops and no cover 22% of the time

R99- September 27, 2012

Rye



No cover

Dry bean yield was sometimes reduced by a cover crop

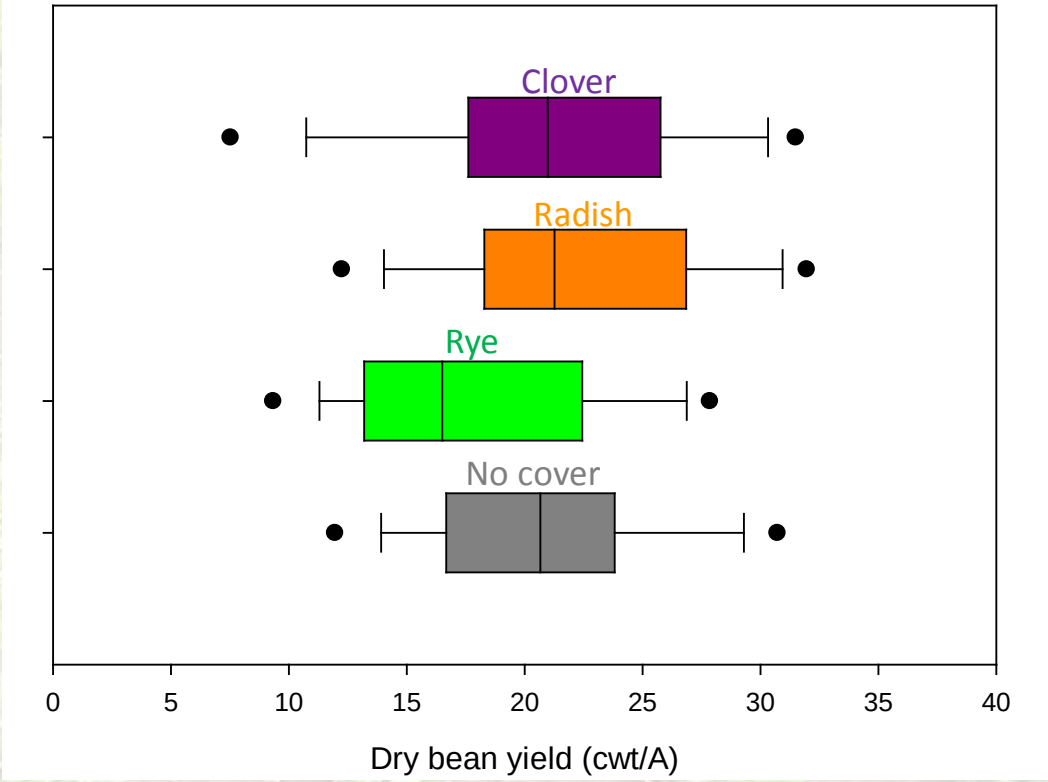
MSU

- Rye reduced yield in 1 of 6 site-years

On-farm

- Yields reduced by cover crops in 2 of 17 site-years due to seed corn maggot

MSU Dry Bean Yields (3 years, 2 sites)



Bean variety affected yield

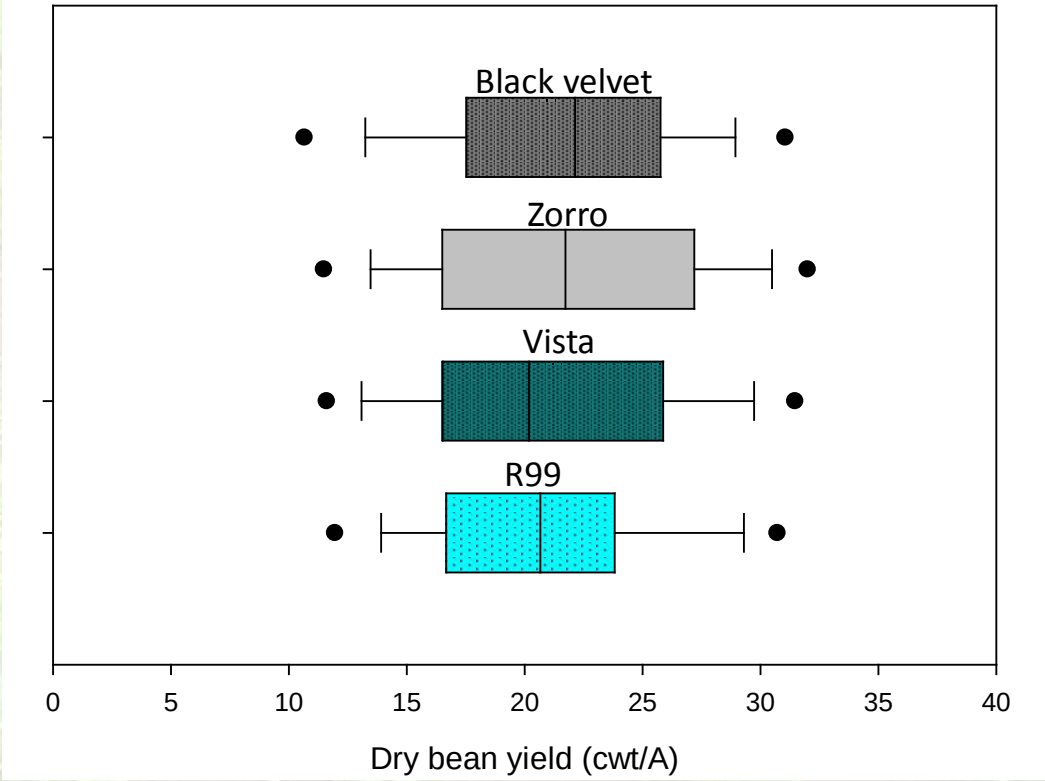
R99

- Yielded the lowest 100% of the time, showing the benefit of N fixation

Black vs. Navy (MSU & On-farm)

- Zorro yields were greater than Vista in 20% of the time

MSU Dry Bean Yields (3 years, 2 sites)



Clover may increase seed nitrogen content

- Following frost-seeded clover (2012) we observed a 30% increase in bean nitrogen content

- We are still awaiting 2013 results to see if this holds true over multiple years

Dry bean nitrogen content of grain (µg N/ mg grain)

Cover	2011	2012
Clover	34	46
Radish	31	35
Rye	32	35
No cover	33	35
	Not different	*

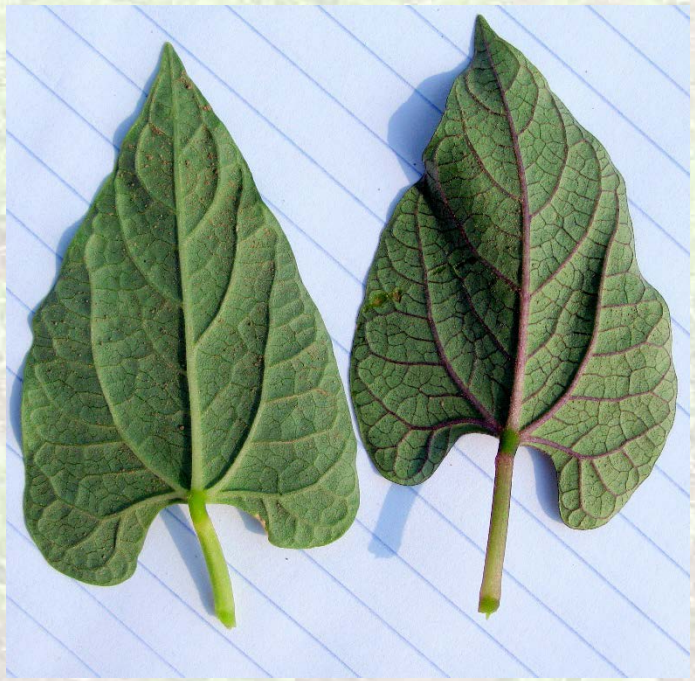
Variety sometimes impacted seed nitrogen content

- In 2012, Black velvet had higher nitrogen content in the grain than Zorro
- We are still awaiting 2013 results

Dry bean nitrogen content of grain (µg N/ mg grain)

Cover	2011	2012
Black velvet	34	40
Zorro	31	35
Vista	35	39
R99	31	37
	Not different	*

Conclusions-
Bean variety & Cover crop



Dry bean variety summary

	BLACK BEANS		NAVY BEANS	
	Black velvet	Zorro	Vista	R99 (no-nod)
Bean population	↑ than Navies			
Bean nodulation	Highest at V2			NA
Bean maturity	Latest	Earliest	Middle	Middle
Bean yield	↑ than Navies not always significant			Lowest
Bean N content	May be higher than Zorro			

Cover crop summary for organic dry beans

	Clover	Radish	Rye
Available N			
Weed # & biomass			
Bean pop.			
Bean nodulation			
Bean yield			
Bean maturity			
Bean N content			
Other observations:			

Cover crop summary for organic dry beans

	Clover	Radish	Rye
Available N	+		
Weed # & biomass	–		
Bean pop.	.		
Bean nodulation	–		
Bean yield	.		
Bean maturity	.		
Bean N content	+		
Other observations:	Stimulation of N-loving weeds		

Cover crop summary for organic dry beans

	Clover	Radish	Rye
Available N	+	.	
Weed # & biomass	–	.	
Bean pop.	.	+	
Bean nodulation	–	.	
Bean yield	.	.	
Bean maturity	.	.	
Bean N content	+	.	
Other observations:	Stimulation of N-loving weeds	Difficult to fit into rotation	
		Winter-kill = easier spring management	

Cover crop summary for organic dry beans

	Clover	Radish	Rye
Available N	+	.	–
Weed # & biomass	–	.	.
Bean pop.	.	+	+
Bean nodulation	–	.	.
Bean yield	.	.	–
Bean maturity	.	.	–
Bean N content	+	.	.
Other observations:	Stimulation of N-loving weeds	Difficult to fit into rotation	Potential for seed corn maggot
		Winter-kill = easier spring management	

How to increase success with these cover crops

Clover

Terminate > 2 weeks before planting if biomass is large

Clover may be more beneficial before a crop which competes better for nitrogen, e.g. corn

Radish

Planting time is critical to establish a good stand of radish

Rye

Termination timing is important:

- ≥2 weeks before planting to avoid seed corn maggot
- 18” or less to avoid ↓ nitrogen…this may be difficult in a wet spring

Questions?

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