Plant Genome, Genetics and Breeding Project Directors' Meeting

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January 8, 2010
San Diego, CA

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Bean Production Trends

Yield Increases Flat

Crop	% Increase since 1980
Dry bean	11%
Corn	81%
Soybean	60%

Improvements needed to maintain common bean competitiveness

- ***Nutrition***
- ***Agronomics***

(Source: USDA Ag Statistics)

BeanCAP: What is it?

1. Crop Improvement Project

- ***Nutritional traits***
- ***Agronomic traits***

2. Nutrition Education Project

- ***Multiple themes***
- ***Multiple media***

3. Plant Breeding Recruitment/Training Project

- ***Get them early***
- ***Get them involved***

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Phaseolus vulgaris
A Societally Important Crop

Nutrition

Represents *50% of grain legumes* consumed worldwide

- **A major source of calories and proteins in some countries**
  - **Burundi and Rwanda**
    - **15% of total daily calories**
    - **30% of daily protein intake**

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Phaseolus vulgaris
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Beans and AIDS

Beans high in vitamins and minerals

- **Zinc and iron**
  - **Diets rich in zinc and iron improve the health status of HIV+ patients**
  - **South Africa Dept of Health recommends beans for HIV+ patients**

Improved nutrition = greater food security

- ***Beans may play an important role in food security through its nutritional benefits***

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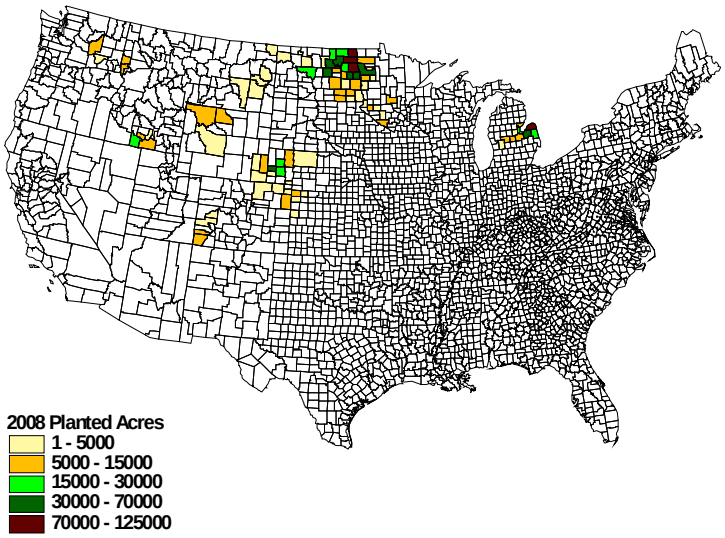
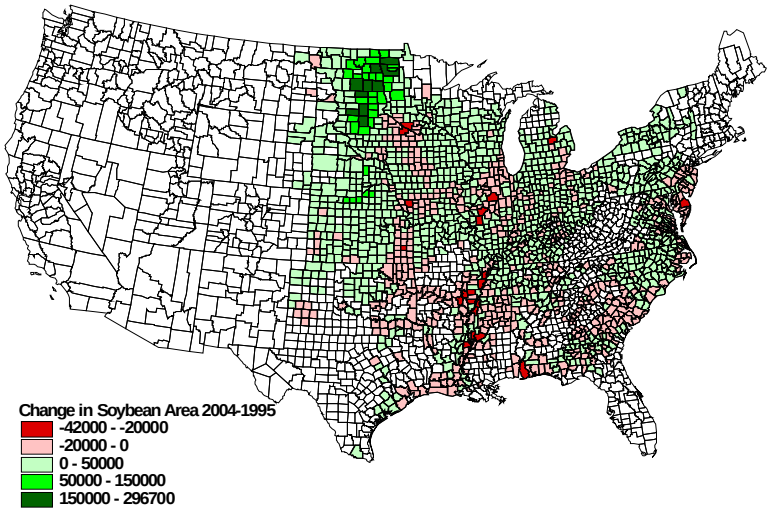
County-by-County Distribution of US Bean Production



US Dry Bean Acres 2008



Change in soybean acres 2002 - 2008

Dry bean competing for acres in upper Midwest

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Source: Bill Wilson, NDSU Agriculture and Applied Business Department

Bean Production Data

Bean type	US Acreage
Dry bean	1,530,000
Snap bean	103,000

Farm Gate Value of All Beans - 2008

- $1.5 billion
- #17 crop for value in US
- 17% increase in value from 2007
  - 6% increase average for all crops

Value Increase of Dry Bean (2004-2008)

- 116% (more than double)

(Source: USDA Ag Statistics)

BeanCAP Background

USDA-AFRI Grant Program

Plant Genome, Genetics, and Breeding Program

- Supports **Coordinated Agricultural Projects** (CAPs)
  - Projects that **integrate research, education, and extension**

2007-08 Solicitation

- Letter of intent submitted
  - Selected for full proposal (one of five)
- **Not funded**
  - **Lukewarm reviews,** but
    - **Encouraged to submit again**

BeanCAP Background (cont.)

2008-2009 Solicitation

- Funded!!
  - **$4 million** funded at **$1 million/year**
  - Annual **renewal required**

Positive point from reviews

- **Tight integration** among research, education, and extension activities was well received
- Will provide **significant resources for bean research community**
- **Nutritional** genomics and genetics **theme** was current
- **Self-organized community** with well-balanced project group

Project objectives

Objective 1: Develop **high throughput, market-class-specific markers** for the predominant common bean market classes produced in the US; convert those markers into **breeder-friendly markers**; and **genotype breeder-defined populations** with these markers.

Objective 2: Discover **genetic loci associated with nutritional traits** that define "healthy beans" by combining genotype and nutritional profile data of **association mapping populations**.

Objective 3: **Integrate common bean phenotypic, genotypic, and molecular marker data** with other emerging legume genomic resources into **breeder-friendly bioinformatic tools**.

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Project objectives (cont.)

Objective 4: Launch the **"Nutritional Genetics and Genomics: Healthy Foods from the Field to the Table" WWW presence** that uses **high-quality animations** and other **multimedia** to **highlight** the **biology** and **technology** associated with the **genomic-based improvement of nutritional traits**.

Objective 5. Initiate a **modern plant breeding training program** that focuses on **early career recruitment** and provides **practical training** that illustrates how the **integration of genomic and phenotypic data** can be used to **improve nutritional traits in plants**.

Project Deliverables

Objective 1: Marker tools

Year 1:

- **SNP diversity data** for a collection of 196 common bean genotypes. **Solexa sequence** data for **two genotypes** from each of the following market classes: **pinto, navy, black, Great Northern, kidney, and snap** beans. (Hyten/Cregan)
- **SNPs** defined for **each race** and **OPA (1536 SNPs)** set developed (Hyten/Cregan)
- **66 CAP loci developed**; two per chromosome for each common bean race (McClean)

Objective 1: Marker tools (cont.)

Year 2:

- **SNP data** for ~2000 genotypes nominated by **breeder** and **geneticists**
- **66 CAP loci developed**; two per chromosome for each common bean race

Genotyping examples

- Entire NPGS core collection
- Association mapping population
- Bi-parental populations
- Breeding program specific genotypes

Objective 2: Association mapping of nutritional traits

Year 1: (Kelly, Brick, Osorno, Urrea)

- **Nutritional and agronomic performance data** for **~300 dry bean** and **~150 snap bean lines** grown under controlled **greenhouse conditions**
- Grow out lines for association mapping

Year 2:

- **Nutritional and agronomic performance data** for **~300 dry bean lines** (grown at four locations) and **~150 snap bean** (grown at one location)
- **Nutritional and agronomic performance data** for **~100 dry bean lines** grown at four locations under **water stress conditions**

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Objective 2: Association mapping of nutritional traits (cont.)

Trait examples:

- **Grusak/USDA/Houston**
  - 16 minerals
  - Nutritional availability (CaCo-2 cells)
- **Brick/Thompson/Ryan, CSU**
  - Antioxidants, phenolics, and anthocyanins
  - Soluble/insoluble carbohydrates
- **Tulmek, NDSU**
  - Protein, oil, fiber
- **Cichy, USDA/East Lansing**
  - Phytate
- **Myers, OSU**
  - Carotenoid, vitamin C, fiber

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Objective 3: Breeder-friendly bioinformatics tools

Year 1: (Gepts)

- Establish the **Phaseolus Genes** database; **link** it
- through the **BIC WWW** site
- Add **historical mapping** and **QTL data** to the **Phaseolus Genes database**
- Where possible, **link historical marker data** to available **common bean sequence data**
- **Establish relationships** with other **legume databases** to determine feasibility of **interoperability**

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Objective 3: Breeder-friendly bioinformatics tools (cont.)

***Year 2*:**

- Begin **incorporating genome sequence** data into **Phaseolus Genes**
- **Complete** incorporating **historical mapping and QTL data** into **Phaseolus Genes**
- Establish **principles** that enable **breeders** to **select** appropriate **markers** for **genetic** and **breeding** purposes.

Objective 4: Nutritional genomics and Genetics WWW presence

Year 1: (Garden-Robinson, Kelly, McClean)

- BeanCAP **WWW site**
- **Ning** learning community
  - Facebook like tool
- **Animations**
  - Root biology and mineral uptake
- **Moodle** learning site
- **Advertise** BeanCAP

Objective 4: Nutritional genomics and Genetics WWW presence (cont.)

Year 2

- **FAQs**
- **Animations**
  - Mineral metabolism in humans
  - Effects of mineral deficiency on human health
- **Plant breeding principles**
  - Powerpoint presentations
- **Moodle** learning modules focused on **plant breeding**
- **Advertise** project materials through **Ning site**

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Objective 5: Plant breeding training Program

Year 1: (Osorno, Urrea, Brick, Kelly)

- **Promotional materials** for the **high school audience**.
- **Collating** and **deliver advanced learning materials** from **other CAP projects**
- **Develop curriculum** for **summer** and **year-round internships**
  - Offer **summer** and **year-round internships**
- **Intern program database**
- **Contacts** established with **local high schools**.
  - **Leaders** make **High school visits**
  - **Visits** to **breeding programs** by **local high school students**.
- **Leaders** attend **national ag conferences**
  - **Promote** BeanCAP **education program**

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Objective 5: Plant breeding training Program

Year 2:

- **Summer** and **year-round internships**
- **Intern program database**
- **Leaders** make **High school visits**
- Visits to **breeding programs** by **local high school students**.
- **Leaders** attend **national ag conferences**
    - **Promote** BeanCAP **education program**

Leadership Teams

Advisory Committee

- **Fred Bliss**
  - Bean geneticist
  - Seminis: former head of plant improvement
- **Charlie Brummer**
  - Forage molecular geneticist, Noble Foundation
- **Chuck Hibberd**
  - Director, Purdue Extension Service
- **David Sleper**
  - Plant breeder, University of Missouri
  - Author: “Breeding Field Crops”
- **Steven Goff**
  - iPlant Collaborative, Project Director
- **Scott Jackson**
  - Common bean sequencing project

Leadership Teams (cont.)

Executive Committee

- **Phil McClean**
  - Project Director
- **Julie Garden-Robinson**
  - Nutrition
- **Paul Gepts**
  - Databases
- **Mike Grusak**
  - Nutrition
- **Jim Kelly**
  - Breeding and education
- **Phil Miklas**
  - Genetics and breeding
- **Jim Myers**
  - Snap beans
- **Juan Osorno**
  - Breeding and education

Stakeholder Committees

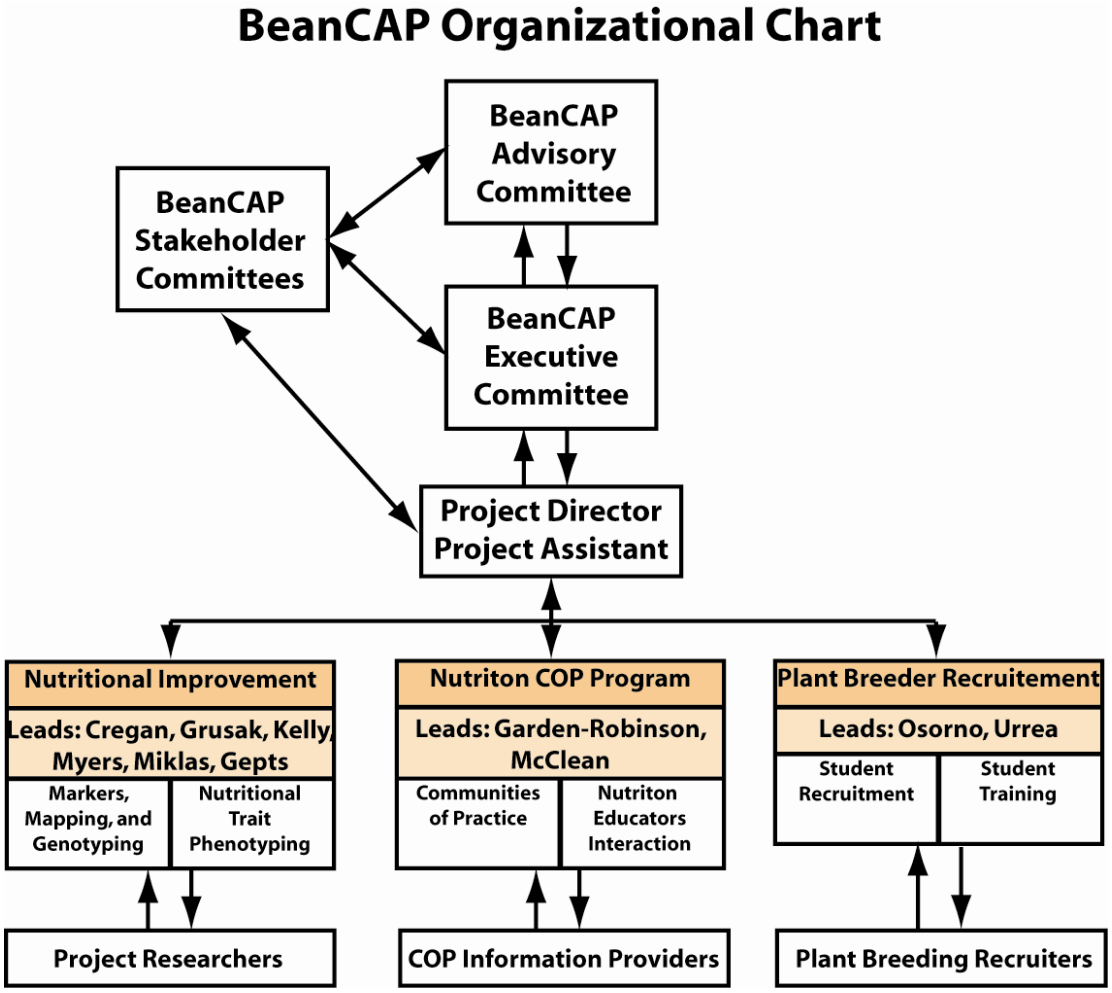
International Stakeholders

- **Kirsten Bett**
  - Univ of Saskatchewan
- **Horacio Guzman**
  - INIFAP, Mexico
- **Susan Nchimbi Msolla**
  - Tanzania
- **Federico Sanchez**
  - UNAM, Mexico
- **Joe Tohme**
  - CIAT, Colombia
- **Rajeev Varshney**
  - ICRISAT, India

Industry Stakeholders

- **Tom Grebb**
  - US DBC
- **Ken Kmecik**
  - Seminis
- **John Ryapati**
  - ADM

Project Management



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Genome-wide Association Mapping Example

- Species and trait
  - Soybean iron deficiency chlorosis
- Phenotyping experimental design
  - Four locations, five replications each
  - Two years
- Genotyping
  - 1536 SNP Illumina Golden Gate OPA
- Population structure control
  - Principal component analysis
  - Kinship
- Statistical analysis
  - Mixed linear model
- Declaring significant loci
  - False discovery rate

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Display

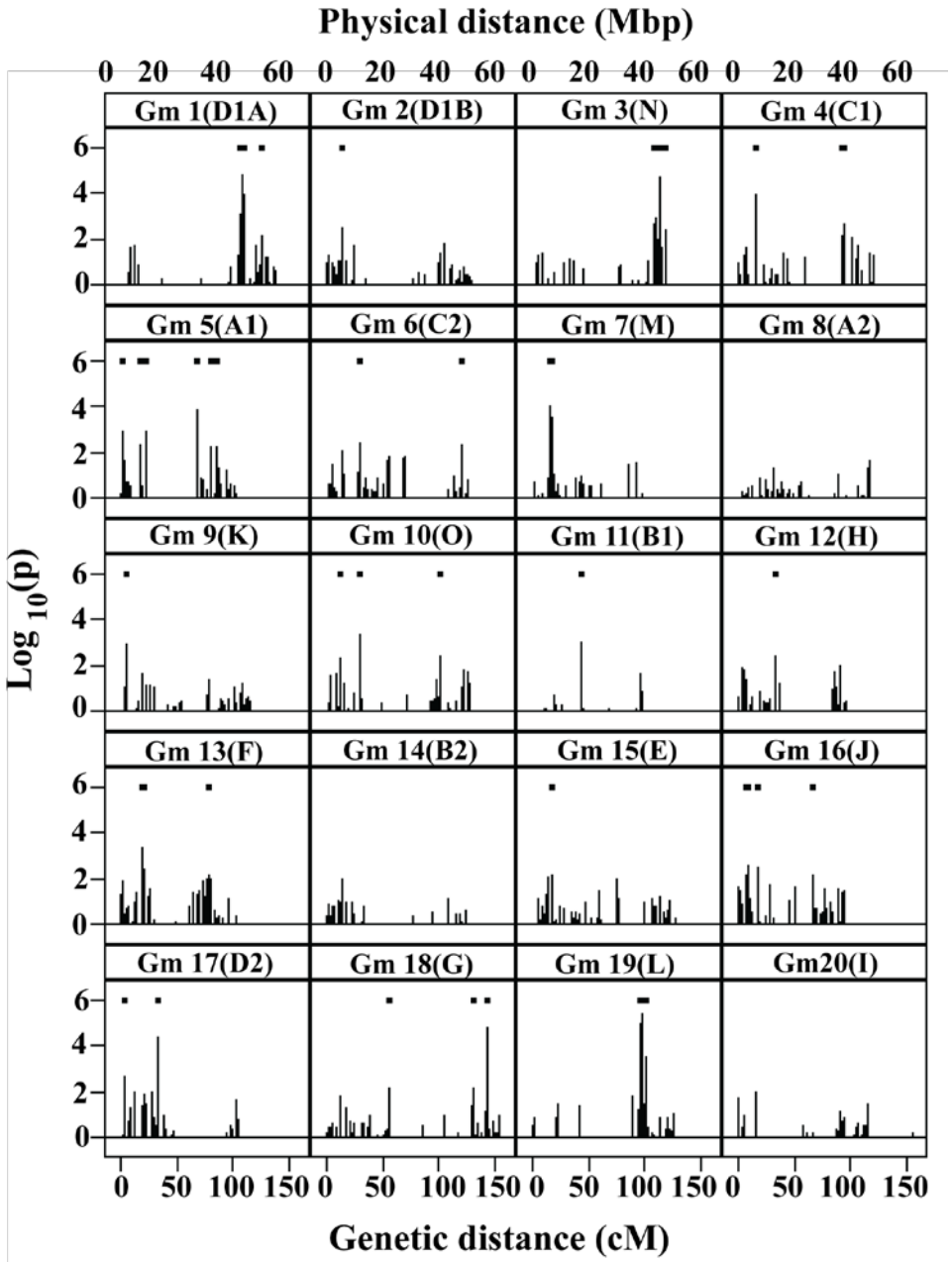
- Genome-wide associations

Bars designate

- Significant loci
  - FDR

Peaks

  - P value significance level



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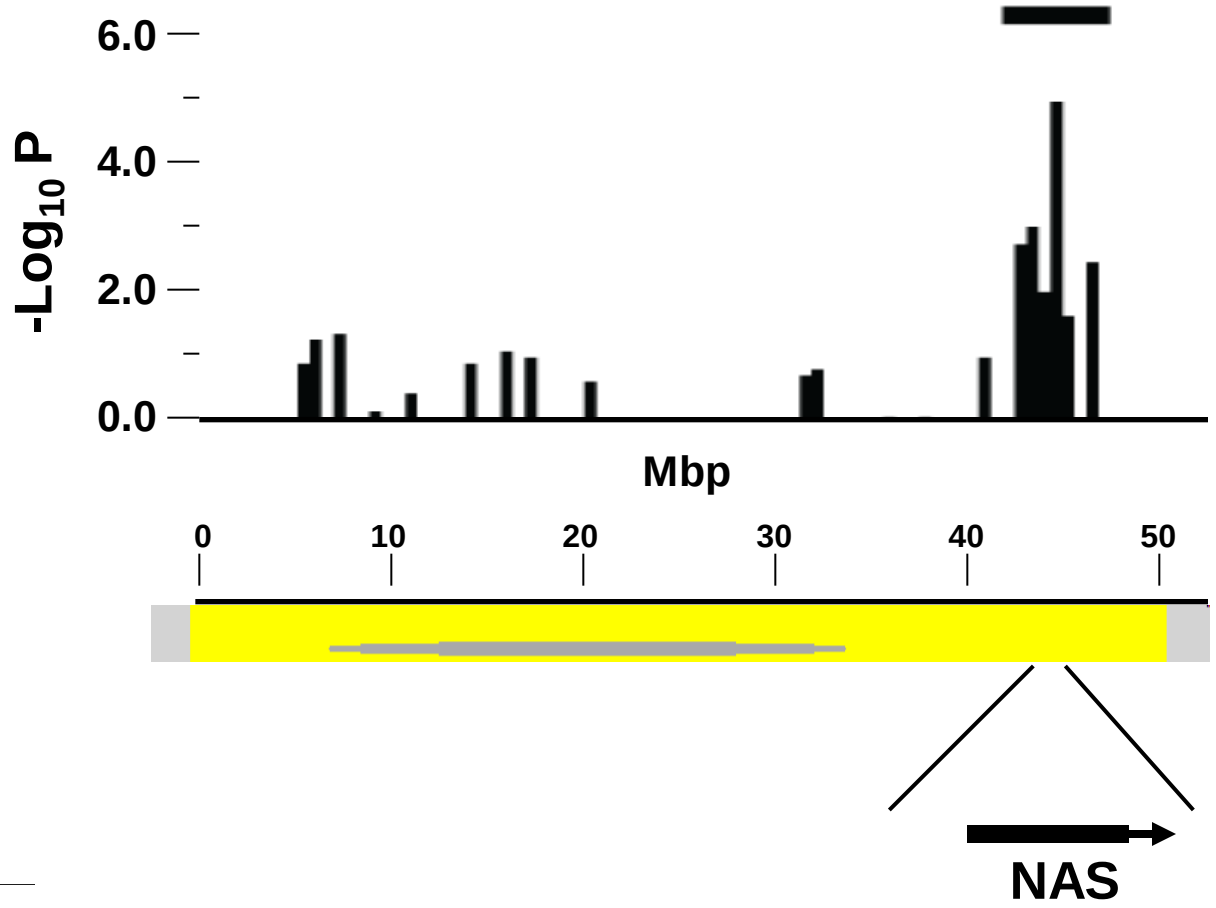
Research of: Shireen Chikara, Sujan Mamidi, Jay Goos, Phil McClean (NDSU)
David Hyten, Perry Cregan (USDA/Beltsville)

From Association Analysis to Candidate Gene

Gm3 associations



Long-distance xylem transport

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Association Mapping in Bean: Looking Forward

- **Marker/trait associations** will be **discovered** in the **project**
- **Sequenced genome** essential for
  - **Candidate gene selection**
- **Candidate genes** will be suggested by **inference** based on
  - **Physiology**
  - **Biochemistry**
  - **Developmental biology**
  - **Biotic and abiotic stress response**
- It is essential to **discover causative SNPs**
  - But this is **quite difficult**

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