Assessing and Using Genetic Diversity in the Agricultural Research Service Seed and Germplasm Collections

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USB UNITED SOYBEAN BOARD *Making Your Checkoff Pay Off.*

The Loss of Genetic Variation Resulting from Domestication and Crop Improvement

From: Tanksley and McCouch. 1997. *Science* 277:1063-1064.

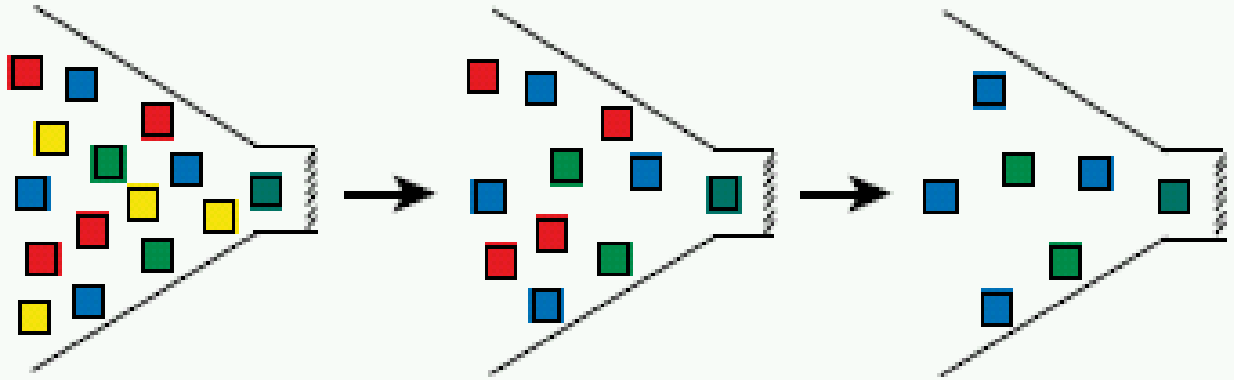


Fig. 1. Genetic bottlenecks imposed on crop plants during domestication and through modern plant-breeding practices. Boxes represent allelic variations of genes originally found in the wild, but gradually lost through domestication and breeding. Such lost alleles can be recovered only by going back to the wild ancestors of our crop species.

The Impacts of Human Intervention on Crop Genetic Diversity

- **Crop domestication resulted in rapid and radical changes in plant species**
  - **Non-shattering of seeds**
  - **Loss of germination inhibition**
  - **Erect growth habit**
  - **Seed size and composition**
- **Modern plant breeding**
  - **Limited number of ancestors i.e., a narrow genetic base**
  - **The parents of new cultivars are restricted to a few that produce superior progeny**
  - **Resistance to a given disease in currently grown varieties traces to a single source**

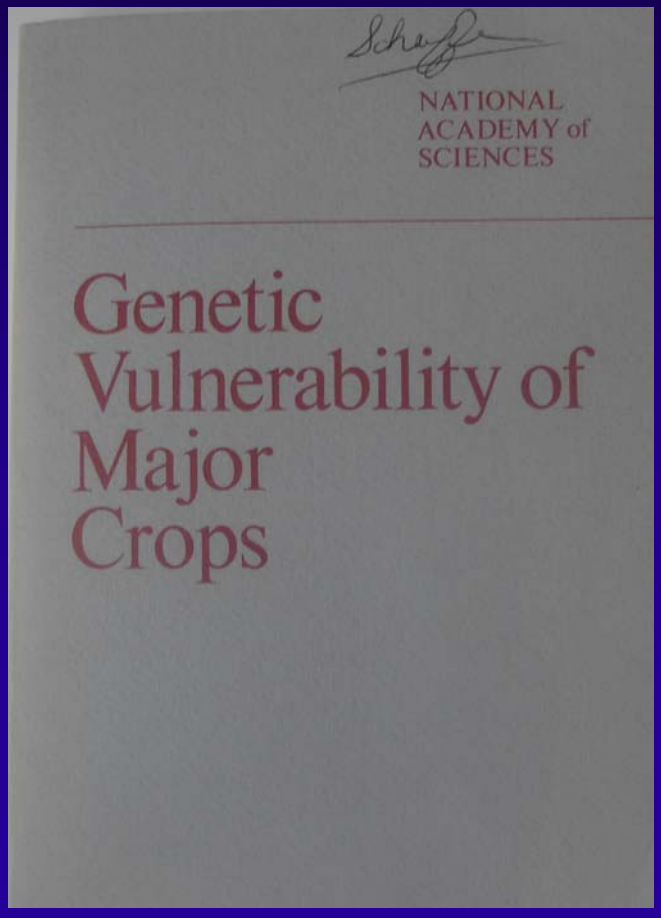
The Implications of Reduced Crop Genetic Diversity

- **Increased Genetic Vulnerability - The condition of being broadly susceptible to attack by a disease or insect pest**
- **Jeopardizes the potential for sustained genetic improvement over the long term**

GENETIC VULNERABILITY of Crop Plants

- **1970 – The "Southern Corn Leaf Blight" epidemic – Up to 50% yield losses in some Southern states and 15% nationwide**

The Agricultural Board, Division of Biology and Agriculture of the National Academy of Sciences appointed the "Committee on Genetic Vulnerability of Major Crops"



Committee on Genetic Vulnerability of Major Crops

- Conclusions -

- "Crops become genetically vulnerable because of the uniformity society demands of the plant breeder."
- "Uniformity of produce means uniformity in the genetics of the crop."
- "A genetically uniform crop is highly likely to pick up any mutant strain of organism that chances to have the capacity to attack it."

Committee on Genetic Vulnerability of Major Crops

- Conclusions Relating to Soybean -

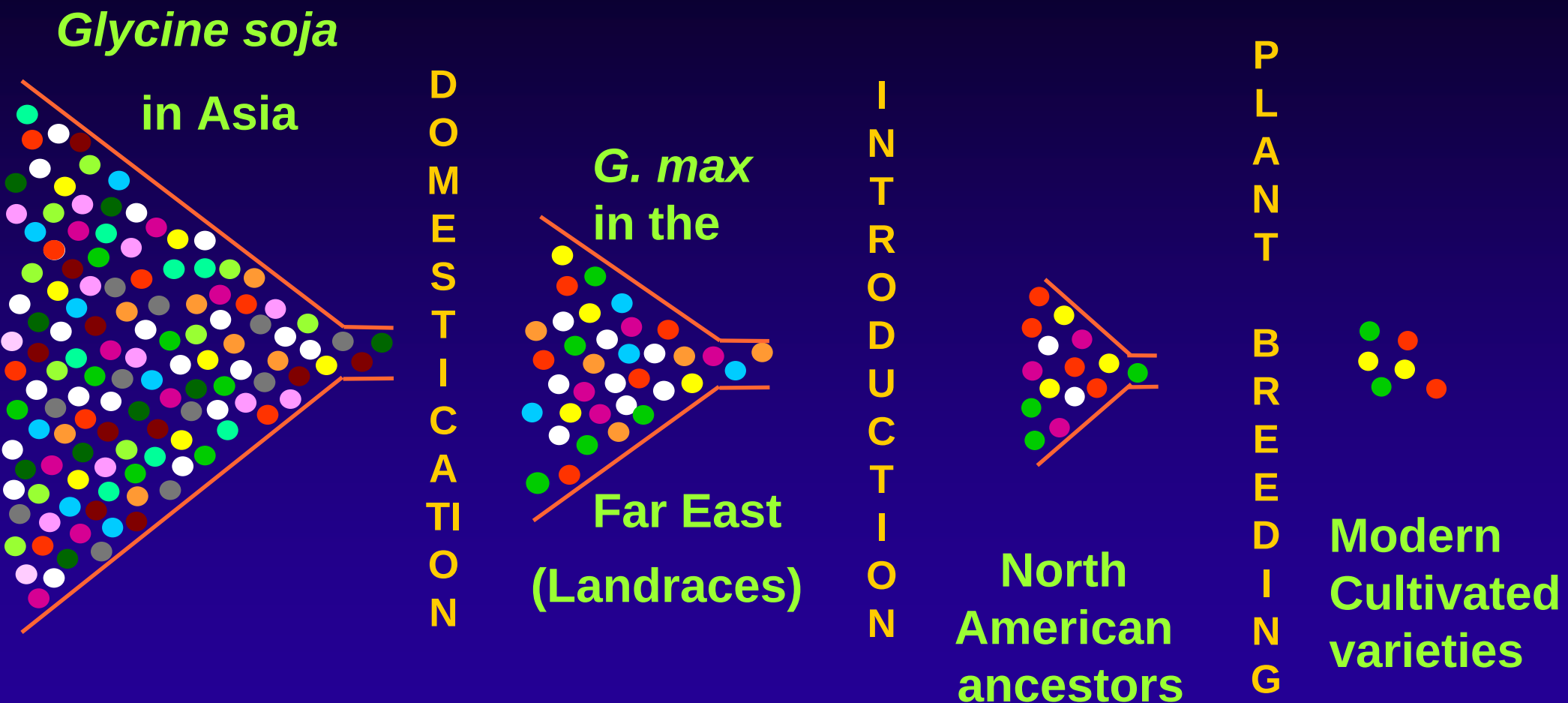
Analyzed the pedigrees of the 62 cultivars grown in the Northern and Southern U.S.

- Most cultivars were derived from 11 Asian introductions.
- Cytoplasmic diversity was extremely limited – 74% of Northern cultivars with identical cytoplasm
- Of the 62 cultivars, only 17 were grown on 1 percent or more of the U.S. acreage – 6 cultivars occupied 56% of the acreage

Relative Genetic Diversity in Three Plant Species vs. Humans

	Θ_w (x 10^3)
Soybean:	
Zhu *et al.* 2003. *Genetics* 163: 1123–1134	0.86
25 cultivated soybeans	
***Arabidopsis*:**	
Kawabe and Miyashita (1999) *Genetics* 153:1445-1453	11.2
Kuittinen and Aguade (2000) *Genetics* 155:863-872	5.3
Schmid et al. (2005) *Genetics* 169:1601-1615	7.1
Maize	
Tenaillon et al. (2001) PNAS 98:9161-9166	
Landraces (16) and inbreds (9)	9.6
Humans:	
Halushka *et al.* (1999) *Nat. Genet.* 22:239-247	0.83
Cargill *et al.* (1999) *Nat. Genet.* 22:231-238	0.53

Genetic Diversity in Soybean Before and After Genetic Bottlenecks Based Upon the Assumption of Severe Genetic Bottlenecks *



* *A la* Tanksley and McCouch (1997) *Science* 277:1063-1066

An Analysis DNA Sequence Variation in Wild and Cultivated Soybean

- Plant Materials -

- 26 Wild soybeans (*Glycine soja)* collected from across from China, Korea, Japan and Russia.
- 52 Asian cultivated soybean (*G. max)* "landraces" collected from 19 Chinese Provinces, 5 Korean provinces, 2 Japanese prefectures.
- 17 "Ancestral cultivars" of N. Am. cultivated soybean estimated to have contributed approx. 86.2% of the genes in currently grown N. American soybeans
- 25 "Modern U.S. cultivars" selected to maximize diversity based upon an analysis of N. Am. cultivated soybean

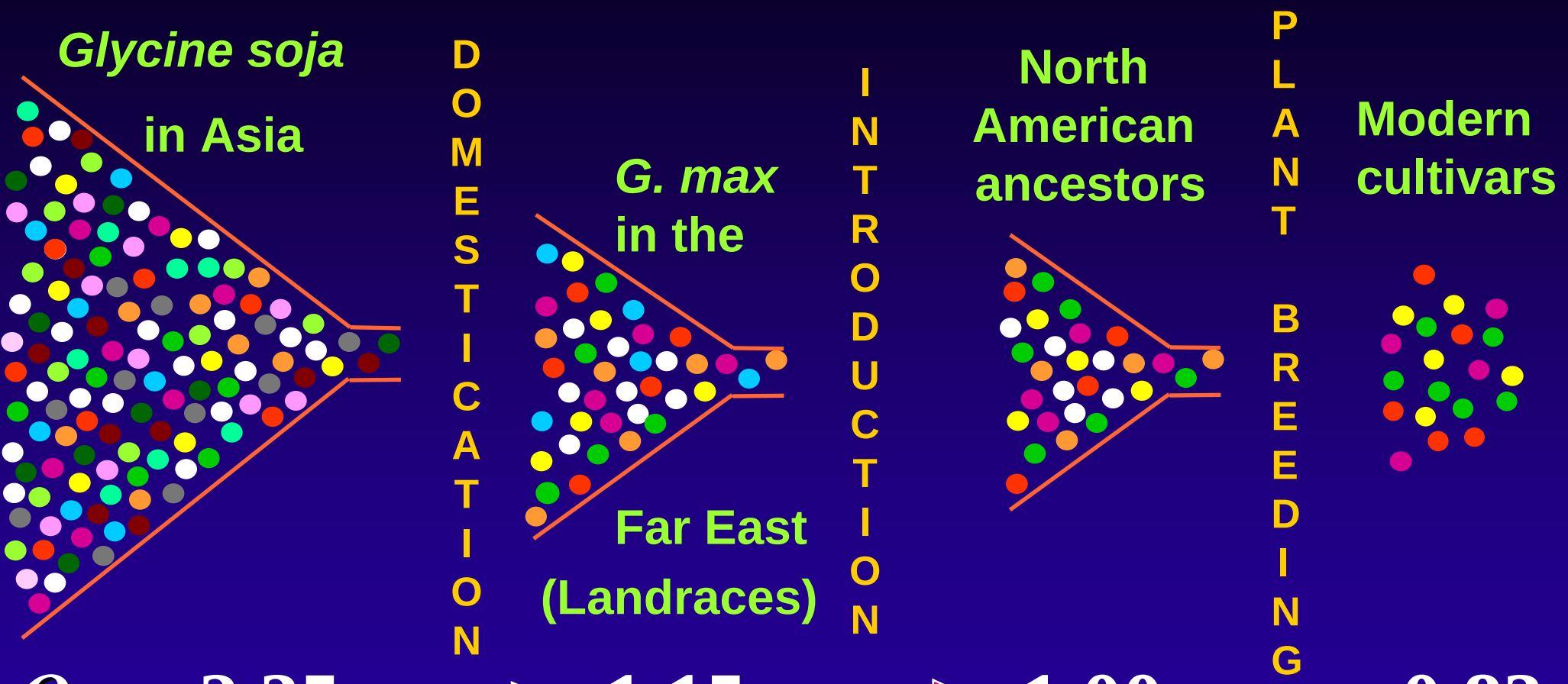
DNA Sequence Diversity (102 Genes) in Four Soybean Populations

Population	Θ_w (x 10^3)
Wild soybean	2.35
Asian landraces	1.15
Ancestors	1.00
Modern cultivars	0.83

Reported Estimates of θ_w in Non-cultivated Plant Species

	Θ_w (x 10^3)
● ***G. soja* - Wild Soybean:**	
53.1 kbp of genic sequence, 26 genotypes	2.35
● ***Arabidopsis*:**	
Schmid et al. (2005) Genetics 169:1601-1615	7.1
139 kbp genic sequence, 12 genotypes	
● ***Hordeum vulgare* ssp. *spontaneum* - Wild Barley**	
Morrell *et al.* (2003) PNAS 100:10812-10817	
12.5 kbp genic sequence, 25 genotypes	9.79
● **Teosinte (*Zea mays* ssp. *parviglumis*)**	
Tenaillon et al. (2004) Mol. Biol. Evol. 21:1214-1225	
11.3 kbp genic sequence, 16 accessions	13.4

Estimates of Genetic Diversity in Soybean Before and After Three Genetic Bottlenecks



Conclusions – Soybean Genetic Diversity

- Unusually low nucleotide diversity in *G. soja*
- Domestication had the greatest effect on diversity
  - 50% loss of nucleotide diversity
- The 5-7 cycles of hybridization and selection between 1935 and 1985 had minimum effect on genome diversity (estimated loss = 17%)

Is Genetic Uniformity a Problem?

Universal Susceptibility to Asian Soybean Rust !

YES !

Would greater diversity *per se* prevent universal susceptibility to rust or other "new" pest problems?

Resistance to Pests or Specific Races of Pests Occurs at Low Frequency

Brown Stem Rot: Chamberlain and Bernard (1968) Crop Sci. 8:728-729. Screened 2060 accessions and found only one with "a high proportion of disease–free plants" (< 0.05%)

Insect resistance: Van Duyn et al. (1971) Crop Sci. 11:572-573. Screened the all MG VII & VIII Plant Introductions and found three resistance genotypes (< 0.5%)

Soybean Rust: Bromfield and Hartwig (1980) Crop Sci. 20:254-255. Screened 1080 genotypes and rated nine as "moderately resistance" (less than 1%).

Soybean Cyst Nematode: Anand and Gallo (1984) Plant Disease 68:593-595: Screened 9153 genotypes for Race 3 resistance. Only 45 (< 0.5%) had even moderate resistance.

Root-Knot Nematode: Luzzi et al. (1987) Crop Sci. 27:258-262. Of 2370 genotypes screened 61 (2.6% were resistant)

The N. American Soybean Crop: Protection and Genetic Improvement

- **Genetic Vulnerability**
  - Will not be significantly decreased by broadening the germplasm base
  - Careful attention to potential pests and germplasm collection, characterization and deployment
- **Genetic Variability and Sustained Long Term Genetic Improvement**
  - Systematic approaches are needed to mine the diversity present in germplasm collections

Enhancing the Availability of Soybean Genetic Diversity

- *G. soja* is a major reservoir of allelic variation in annual soybean

Number of Accessions in Soybean Germplasm Collections

	Glycine soja	Glycine max
USDA Collection	1,114	16,566
Bejing, China	5,417	23,587
Nanjing, China	1,000	10,000
Japan	166	1,000

Thanks

Collaborators

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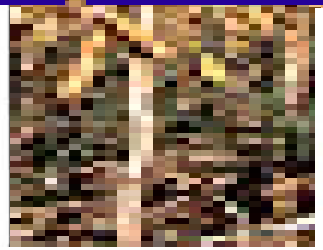
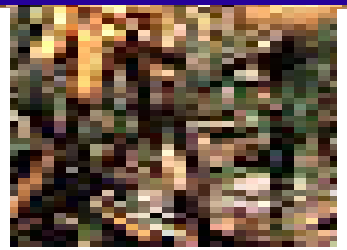


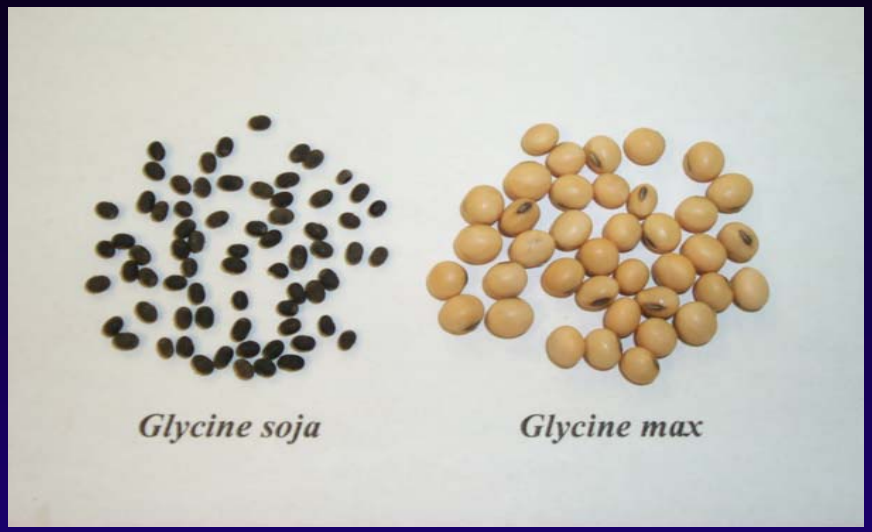


Genetic Diversity and Phenotype

Nature 438: 745

Dog has an average of 1 SNP per 1,000 bases which is close to the level of diversity in modern soybean cultivars.

Wild and Cultivated Soybeans



G. soja

G. max