# Oxygen, Carbon and Nitrogen Isotope Signatures of Cultivated and Wild Soybean

H. Zakeri[1*], A. Scaboo[2] and F. Fritschi[2]

1- Department of Plant and Soil Sciences, California State University, Chico, 2- Division of Plant Science, University of Missouri

# Introduction

Biological and physical processes influence the isotopic composition of plants. Carbon and O isotope discrimination have been used in efforts to select and breed for crop cultivars with greater water use efficiency (WUE) and drought tolerance, and N isotope signatures is used to assess biological N fixation.

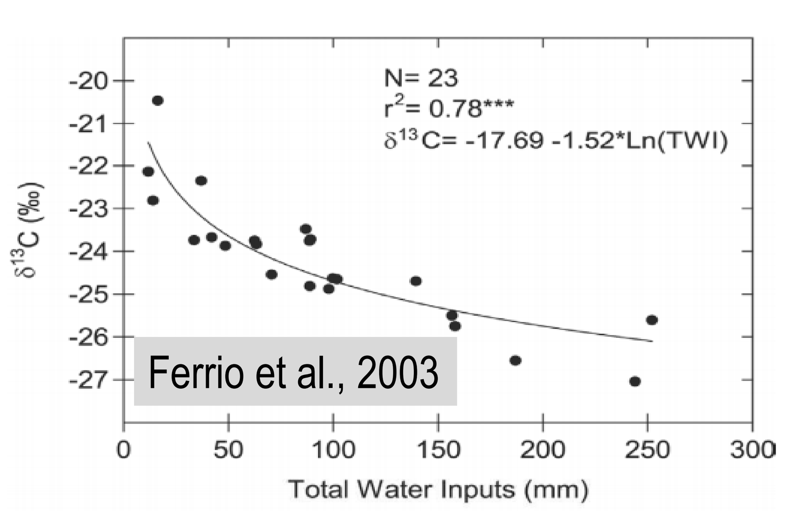
## Plant Isotopes Studies

The absolute isotopic composition of materials is not easy to measure, directly. Therefore, the deviation of a sample isotopic composition from a standard is measured. This value is expressed using delta denotation in parts per thousand (‰):

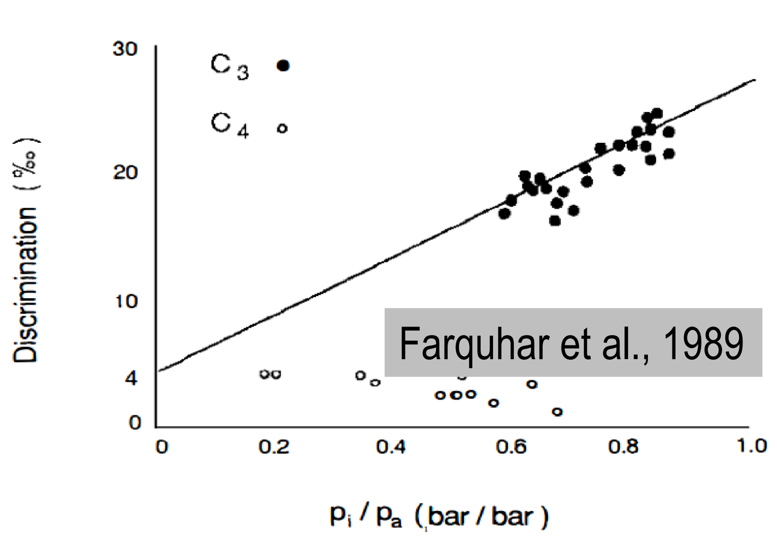
$$\delta = \left[\frac{R_{sample}}{R_{Standard}} - 1\right] \times 1000$$

In which, R = $^{13}C/^{14}C$ ratio (for C), $^{18}O/^{16}O$ ratio (for O), and $^{15}N/^{14}N$ ratio (for N). The standards are Vienna Pee Dee Belemnite (VPDB) for C, Vienna Standard Mean Ocean Water (VSMOW) for O, and Air for N.

**$\delta^{13}$C:** Plant discriminates against the heavy C isotope ($^{13}C$) during C uptake and assimilation. Therefore, plant materials are depleted in $\delta^{13}C$ compared to the atmosphere. Stomata control due to stress or plant genetic increases the $\delta^{13}C$ discrimination rate, further depletes plant $\delta^{13}C$ and results in negative $\delta^{13}C$ values compared to the atmosphere. Associations have been established between plant $\delta^{13}C$ and plant water use efficiency (WUE) and drought resistance for most $C_3$ field crops.




Ferrio et al., 2003



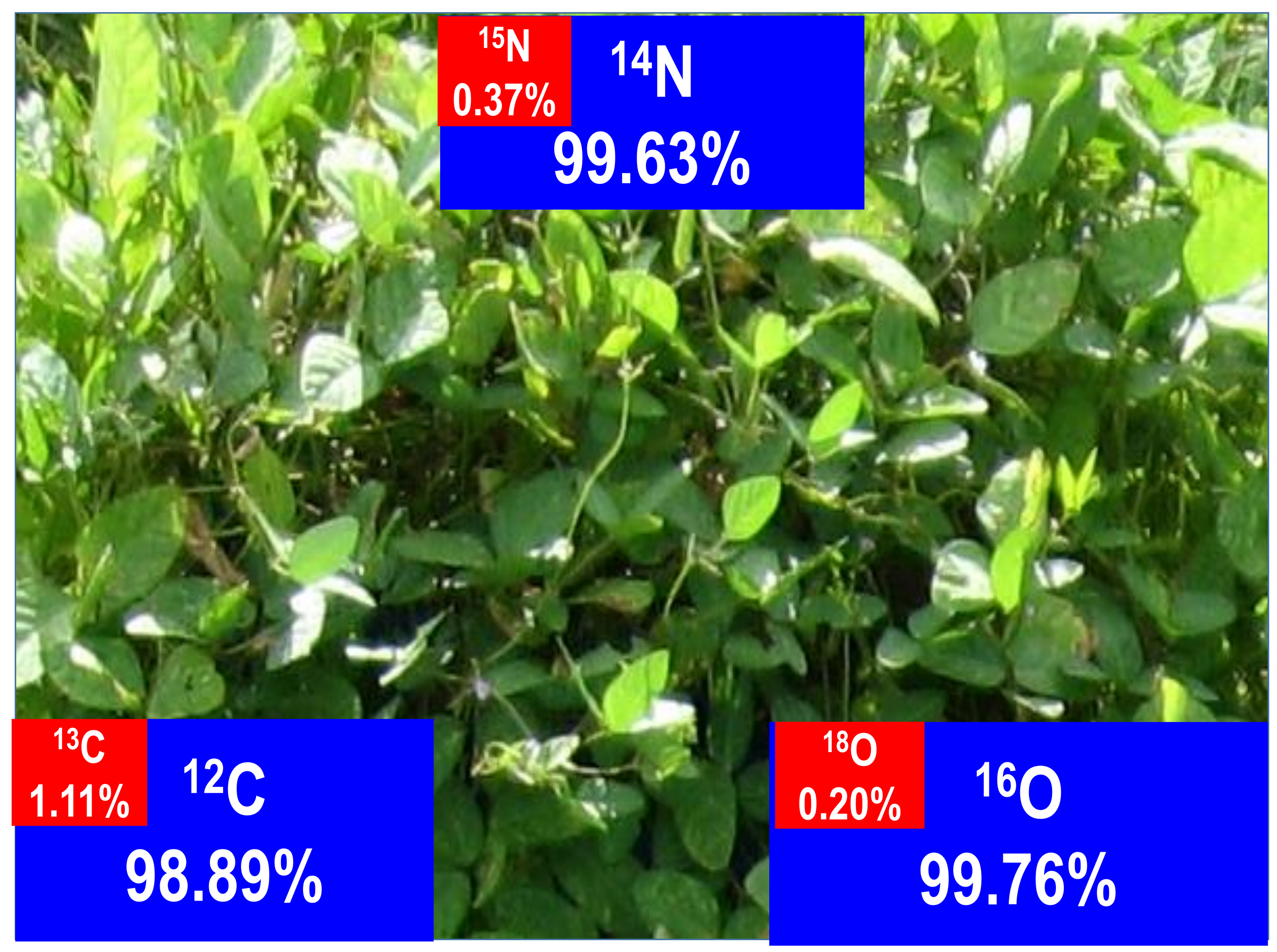

Farquhar et al., 1989

**$\delta^{18}$O:** Higher transpiration rates of $^{16}O$ than the heavy O isotope ($^{18}O$) enriches plant materials $^{18}O$ over time. Stomata control due to environmental stresses limits plant transpiration and alters the plant $\delta^{18}O$. Such variation can be used to screen for genotypes with more stomatal control during water stress.

**$\delta^{15}$N:** Legumes obtain most of their N from the atmosphere, where $^{15}N/^{14}N$ ratio ($\delta^{15}N$) is significantly depleted compared to soil. Therefore, legumes $\delta^{15}N$ is similar to the atmospheric composition (0 ‰, air). Comparison of the $\delta^{15}N$ signature of N-fixing and a non-N fixing plants determines the proportion of plant N derived from atmosphere (%Ndfa).

# Field trials:

- Diversity panels of 83 cultivated soybean (*Glycine max*) plant introductions (PIs) and 83 wild soybean (*G. soja*) genotypes were grown in field experiments in 2013 and 2014 in Columbia, MO.
- Aboveground biomass was sampled at R5 and shoot tissue triple isotopes (C, O, N) was determined by a Mass Spectrometer.
- Genotypes with extreme C isotopic signature values are crossed with high-yielding commercial cultivars, and $\delta^{13}C$ of the progenies will be assessed.



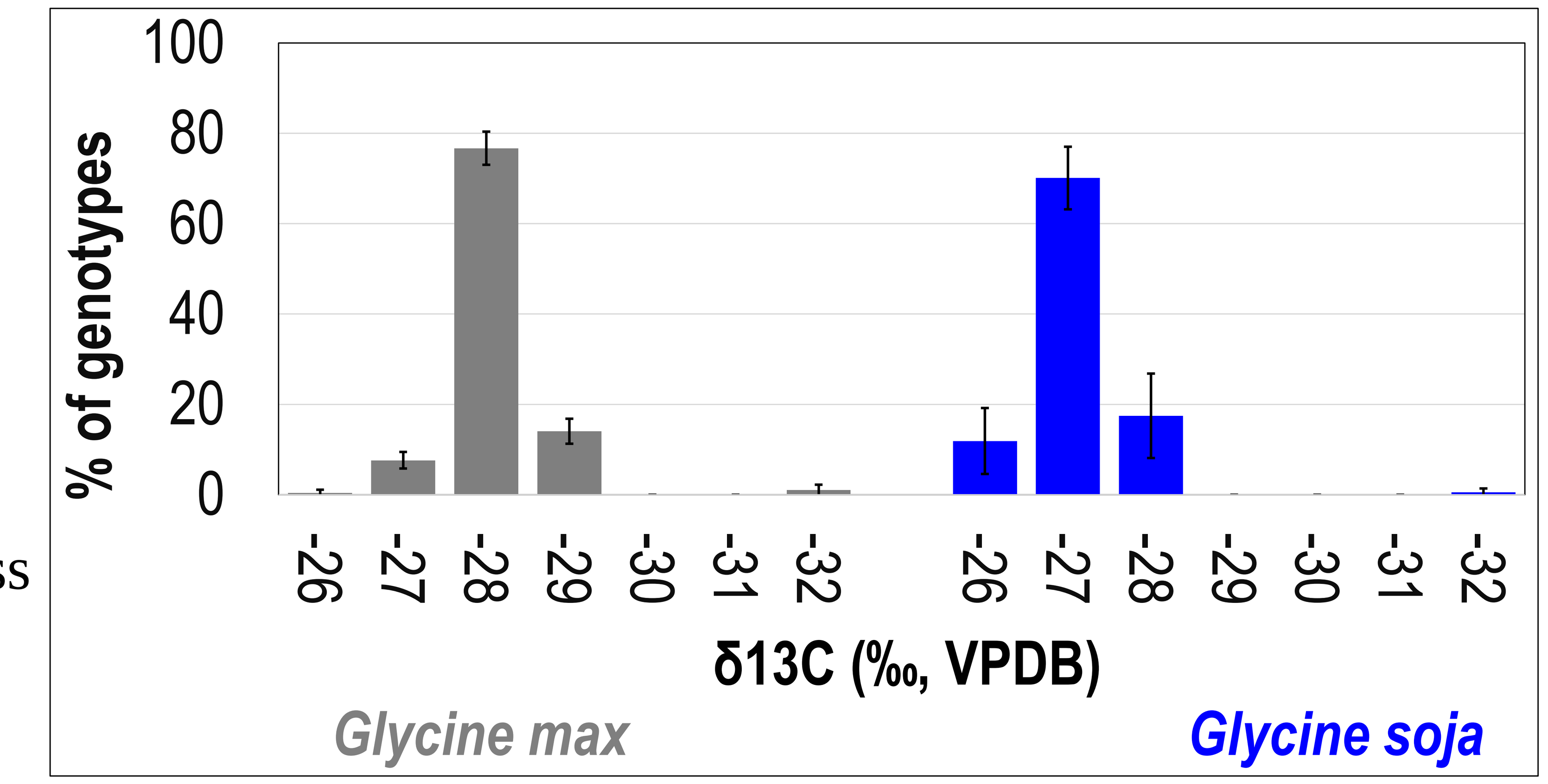

# Preliminary Results (2013):

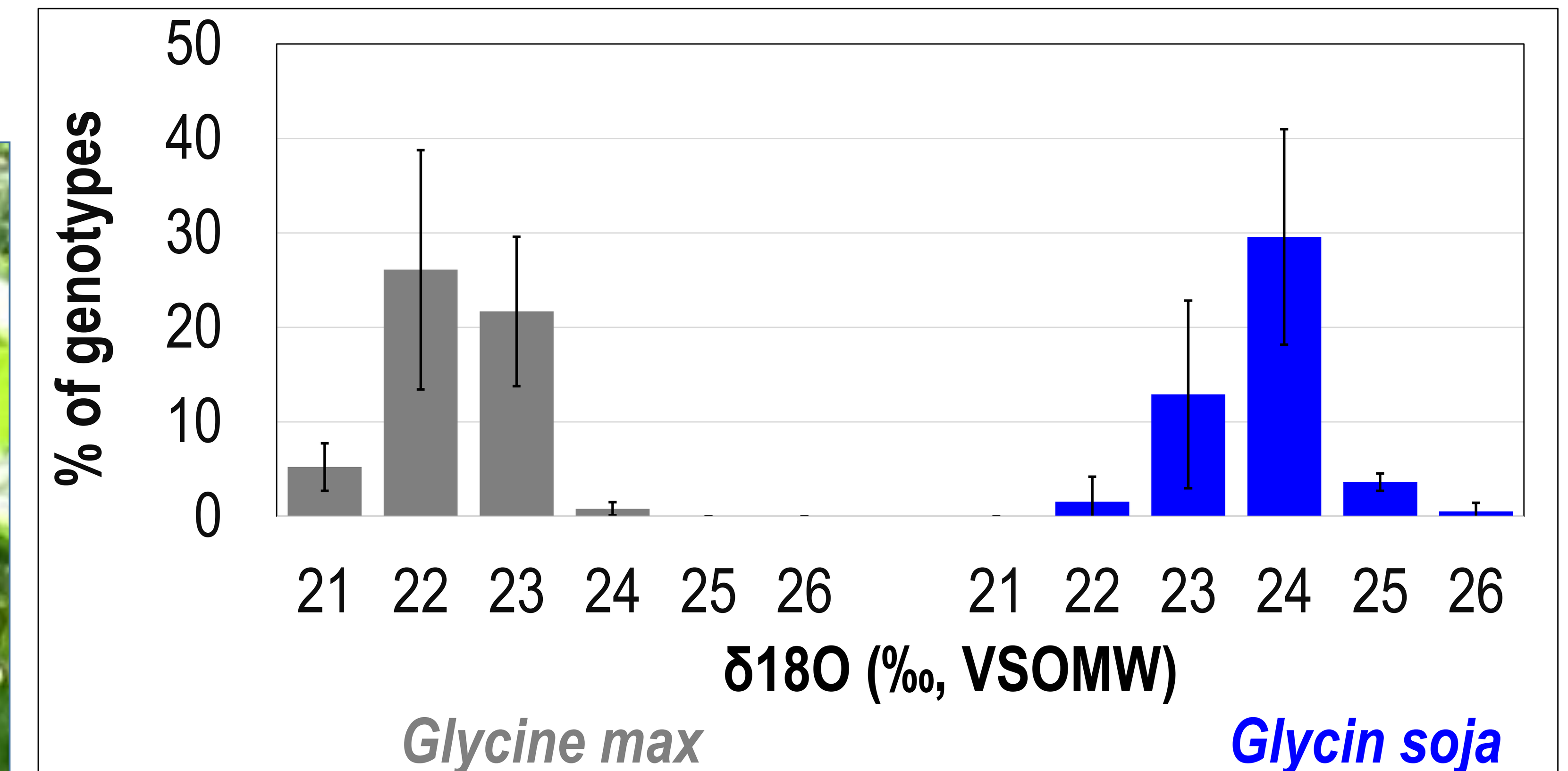
✓ Domesticated and wild soybean had similar $\delta^{13}C$ ranges. With a few exceptions, the majority of lines $\delta^{13}C$ fell into the -26 to -28 ‰ category.

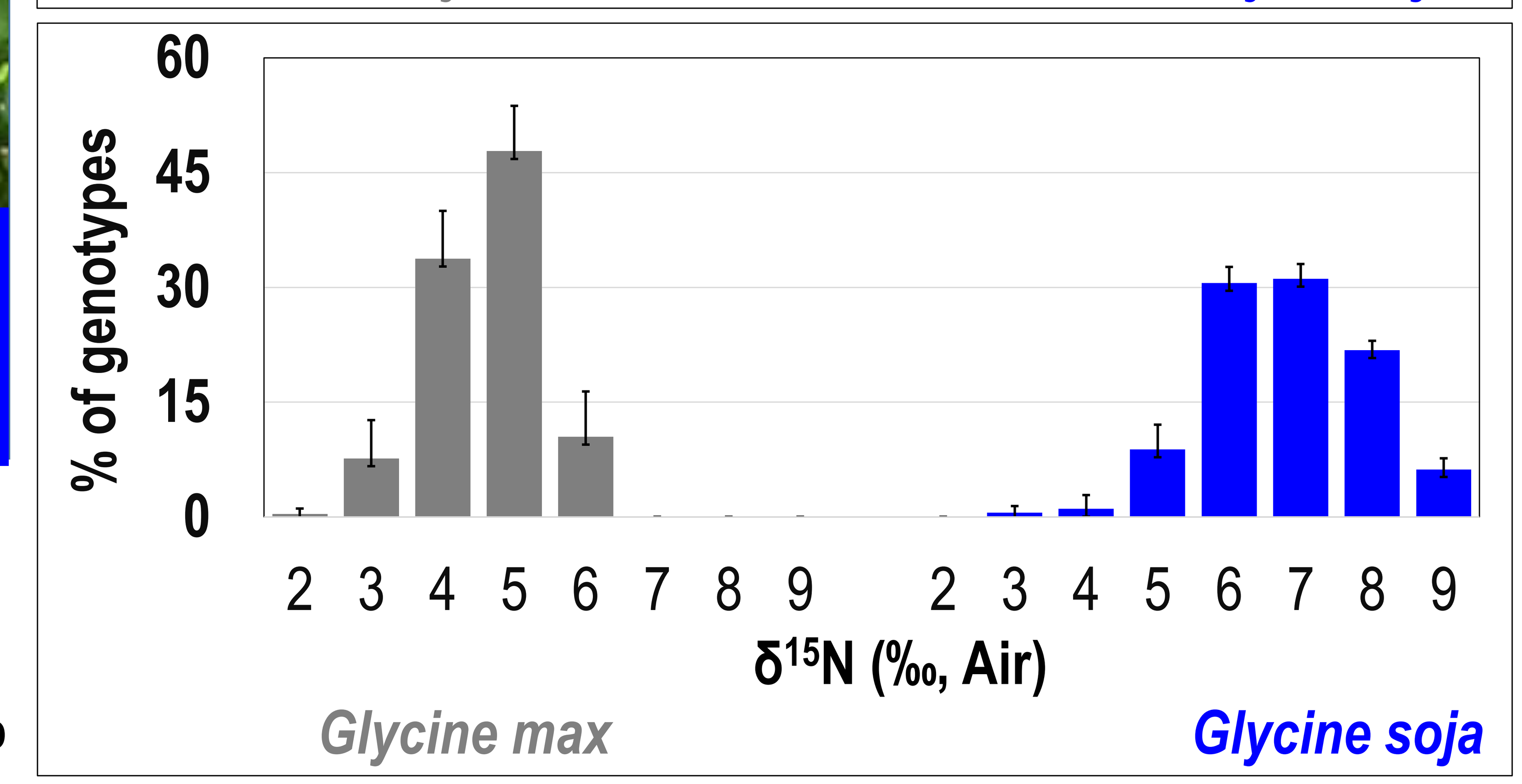
✓ Plant $\delta^{18}O$ did not differ between two plant groups and the majority of lines $\delta^{18}O$ were between 21 to 24 ‰.

✓ Despite having similar C and O signature values, plant $\delta^{15}N$ was depleted in the *G. max* compared to the *G. soja* population. Averaged over the genotypes and replications, $\delta^{15}N$ of *G. max* and *G. soja* was 4.1 ± 0.8 and 6.33 ± 1.1, respectively. Two groups had similar average N concentrations.

✓ Enriched $\delta^{15}N$ of the *G. soja* lines is most likely associated with low %Ndfa. However, root structure, rooting depth and soil $\delta^{15}N$ signature could affect the plants $\delta^{15}N$.




**Distribution of *G. max* and *G. soja* genotypes for $\delta^{13}C$ (top), $\delta^{18}O$ (middle) and $\delta^{15}N$ (bottom).**

**Acknowledgment:**
Funding by the Missouri Soybean Board is appreciated.

## Contacts:

**H. Zakeri:** hzakeri@csuchico.edu

**F. Fritschi** fritschif@missouri.edu

**References:**

❖ Farquhar, et al. 1989. Annual Review Plant Physiology. 40:503-537
❖ Ferrio et al. 2003. Management of Environmental Quality. 14:82-98
❖ Lawrence et al. 2013.Plant, Cell & Environment. 37: 425–438
❖ Condon et al. 2004. Experimental Botany. 55:2447-2460