Characterization of Maize Genetic Improvements over Time in Plant Density and Nitrogen Stress Tolerances

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Abstract

Modeling efforts attempting to predict maize yield responses to abiotic stress and climate change would be improved if they incorporated accurate phenotypic responses of modern maize hybrids to a variety of stress factors. In order to achieve this, hybrid era and technology trait variables were tested at three plant densities and two N rates in a two year (2012, 2013) study at two field sites in Indiana. Yield of recent (2005) commercial hybrids averaged 23% higher than a hybrid from 1975. New hybrids displayed a higher leaf to stem ratio (for both biomass and N uptake) and a shorter anthesis-silking interval (ASI) at flowering as well as better kernel establishment and delayed leaf senescence during grain fill. New hybrids demonstrated improved plant density and nitrogen stress tolerances.

Objective

- Understand the physiological foundations of phenotypic differences, and nitrogen dynamic difference in new hybrids and old hybrids in response to nitrogen and density stress.
- Understand genotype x environment x management interactions, associated with model improvement.

Methods

I. 3 hybrids (2012), 8 hybrids (2013) were planted at 3 plant densities (5.4,7.9,10.4 plants m^{-2}) and 2 nitrogen rates (55, 220 kg N ha^{-1}) on two Purdue farms, ACRE (West Lafayette, IN) and PPAC (Wanatah, IN). 6 replications per site. In this poster we focus on DKC61-69 and DKC61-72 (released at 2005), XL72AA (released at 1974) since they were used in both year.

II. We focused our phenotypic measurements on those indicators of plant development that will be used in maize modeling, such as LAI (leaf area index), green leaf number during reproductive stage, leaf tip and leaf ligule number, ASI (anthesis to silking interval), leaf chlorophyll status (SPAD), stem heights and diameters, and kernel milkline during maturity in both years.

III. In order to study differences in nitrogen partitioning and nitrogen remobilization in new and old hybrids, we harvested biomass at R1 (50% silking) and R6 (physiological maturity) stages and partitioned leaf, stem and ear/grain components at R1, R6 (2013) to determine their nitrogen concentrations (For R6 2012, we separated plants as stover and ear/grain).

ASI (anthesis-silking interval)

Recent hybrids (DKC61-69, DKC61-72) have a shorter LAI than XL72AA, especially in 2012 with drought and heat stress occurred during flowering (Fig.1). Interestingly, recent hybrids are prone to have tassels emerge and pollen shed being initiated ahead of silk emergence (Fig. 1). In addition, recent hybrids are more likely to flower earlier than XL72AA (Fig. 1), and that leads to a longer time of grain filling period (data not shown).

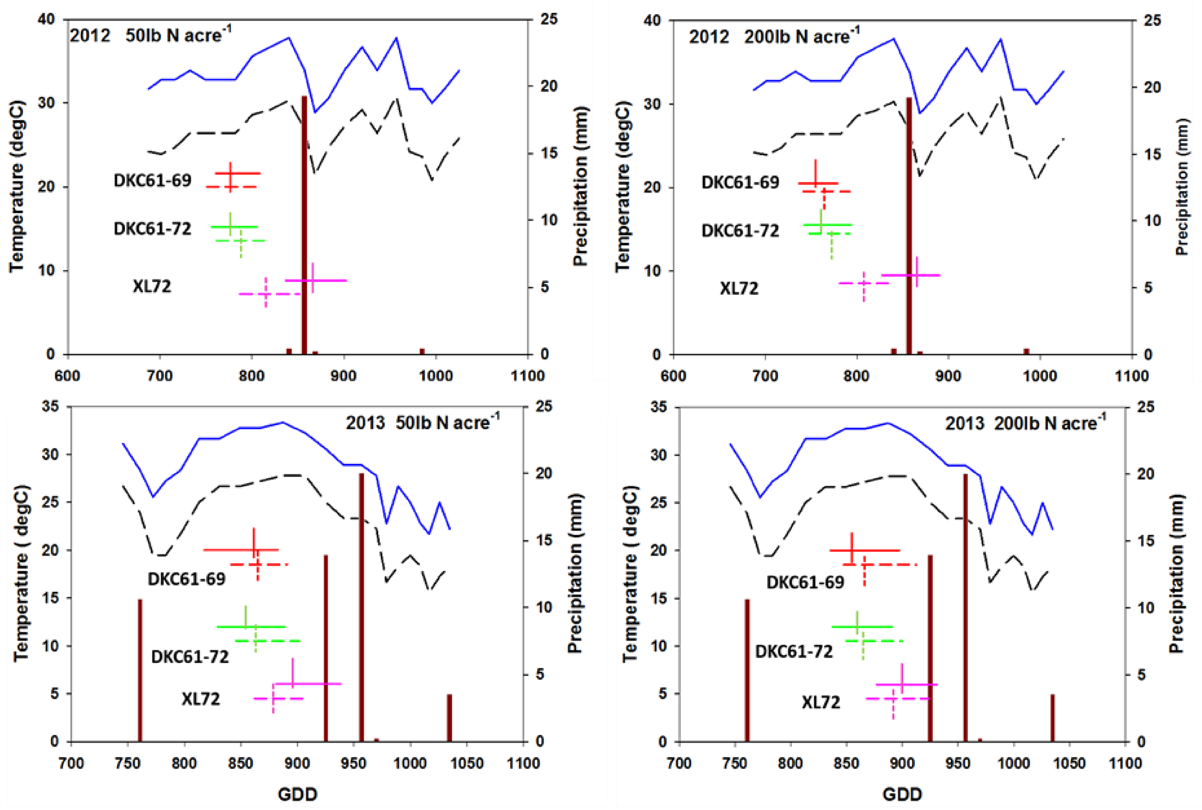

Fig.1 Flowering progress and ASI changes with accumulating GDD of three hybrids at 2 N rates (averaged for 3 plant densities) and in the context of short-term temperature and precipitation changes in 2012 and 2013. Solid vertical bar is 50% silk emergence, dashed vertical bar is 50% anthesis. Solid horizontal line is GDD interval of 10%-90% silk, dashed horizontal line is the GDD interval of 10%-90% anthesis. Data is from ACRE.

Leaf structure

Recent hybrids DKC61-69, DKC61-72 both have a more erect upper leaf structure compare to XL72AA (Fig.2, Fig.3). Erect upper leaves can allow more light penetration into the canopy leading to a greater radiation interception.

Fig.2 Comparison of XL72AA (left) and DKC61-72 (right), picture taken at 48 days after planting. Picture is from ACRE, 2013.

Fig.3 Comparison of XL72AA (left) and DKC61-69 (right), picture taken at 86 days after planting. Picture is from ACRE, 2013.

Visible Green leaf number

The newer hybrids retained green leaf number longer than the old-era hybrid XL72AA. Hybrid differences were especially apparent in 2012, the year with drought and heat stress. Both plant density and N rate factors significantly affected green leaf number. The advantage of DKC61-69 was particularly obvious at all densities in 2012 and at the highest density in 2013 (Fig.4).

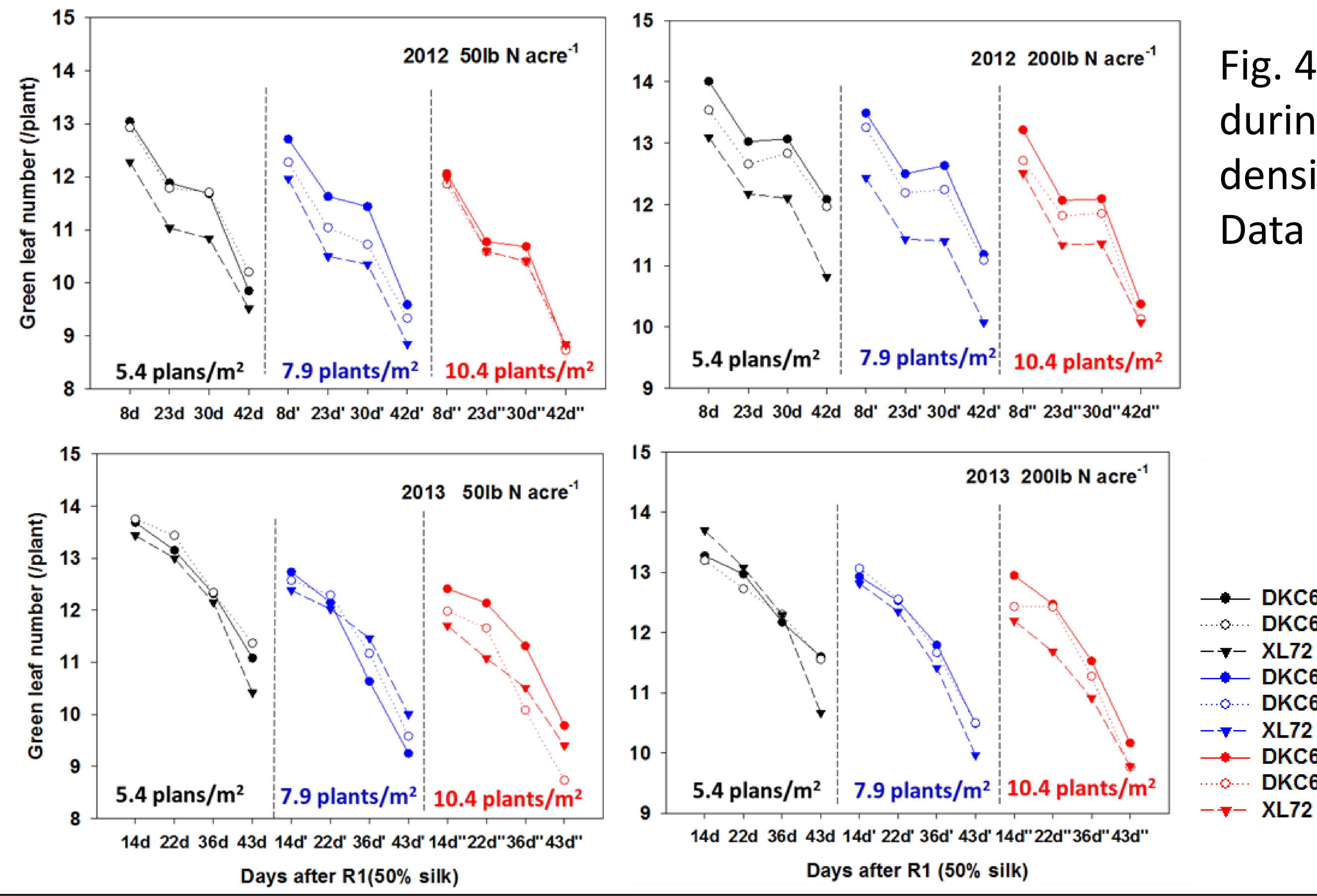

Fig. 4 Green leaf number of three hybrids during reproductive development at 3 plant densities and 2 N rates in 2012 and 2013. Data are from ACRE.

Stem/leaf biomass at R1 and Grain Yield at R6

Although overall whole-plant biomass at the R1 stage was not different among these three hybrids in both 2012 and 2013, it is interesting that the old-era hybrid (XL72AA) had considerably more stem and less leaf biomass than the two hybrids from 2005 (DKC61-69 and DKC61-72) (Fig.5). The 2005 hybrids had higher dry matter accumulation after flowering (data not shown), better kernel formation (Fig.6), and substantially higher grain yields (Fig. 7).

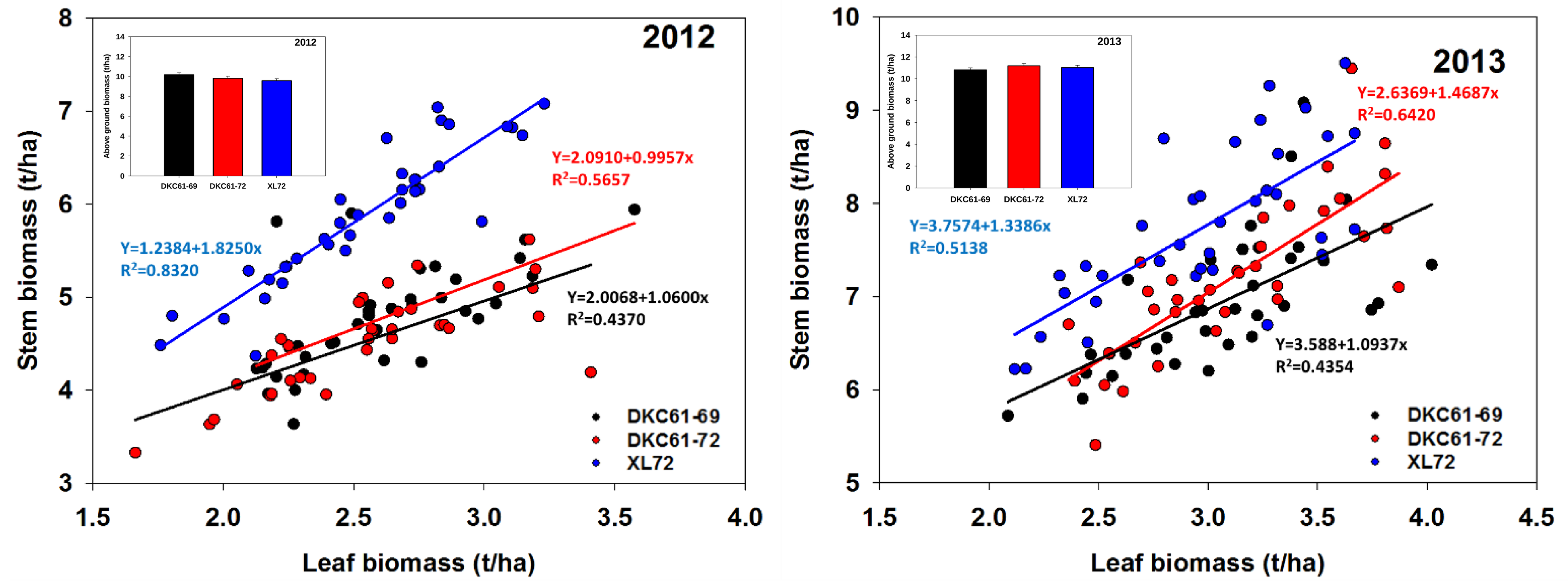

Fig.5 Regression between stem biomass and leaf biomass in 3 hybrids at R1 stage in 2012 and 2013. The inset vertical bar graph is total biomass at R1 (means + SE). Means are the average of 3 plant densities and 2 nitrogen rates. All the data is from ACRE.

Fig.6 Ear formation for 3 hybrids at ACRE, 2013. Pictures are taken at 220kg N ha^{-1} and 5.4 plants m^{-2}, 86 days after planting. Pictures for 3 hybrids are originally at same height standard level.

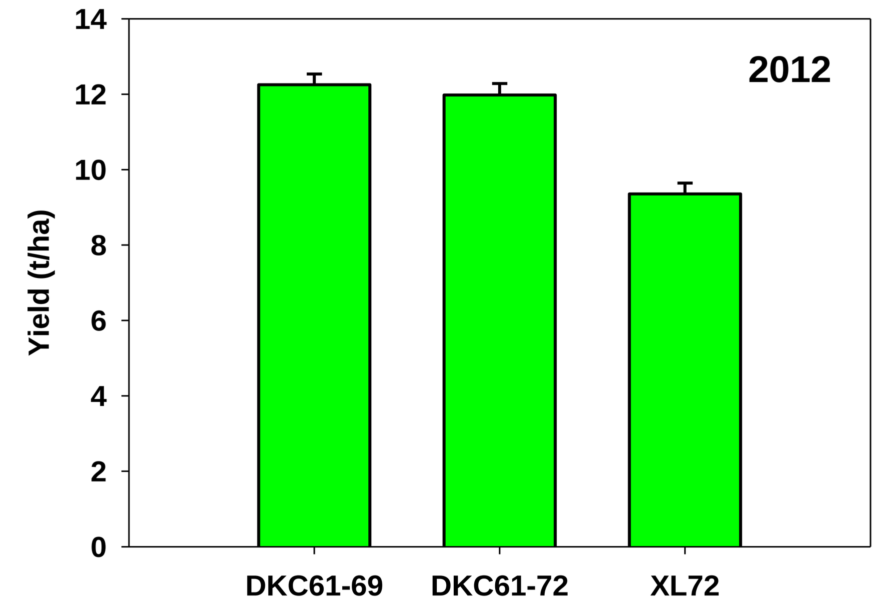

Fig.7 Grain yields of 2012 of two hybrids from 2005 versus a single hybrid from 1975 (means + SE). Means are the average of 3 plant densities and 2 nitrogen rates. Data is from ACRE.

Conclusion

- Recent hybrids had a shorter ASI, delayed leaf senescence and higher leaf/stem biomass compared to old hybrids, especially under stress conditions.
- Density and N rate had a significant effect on phenotype traits of all hybrids, which can be used in future model improvement.