Nutrient Use Efficiencies in Soybean: A review

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Introduction

From a physiological standpoint, a synthesis-analysis on potassium (K) and nitrogen (N) content, utilization, interaction with other nutrients and impact on yield is relevant for properly understanding scientific knowledge gaps on this nutrient.

Objective

Summarizing, interpreting, and increasing the understanding of soybean yield and N-K uptake associations from both historical and geographical perspectives.

Material & Methods

- Numerous data sources (Refereed Journals) and unpublished selected theses (MS and PhD). – Since 1920's.
- A total of ~500 treatment means for grain yield and plant nutrient uptake at maturity were collected.
- The database was divided into geographical clusters: USA vs the World (excluding USA) and Eras (1920-60; 1961-75; 1976-95; 1996-05; 2006-12).
- Plant density values were gathered for each individual data point, and all variables were normally distributed.
- The term for Nutrient Internal efficiency (N-K) was calculated as: $\frac{\text{Grain yield (Mg ha}^{-1})}{\text{N} - \text{K uptake (kg ha}^{-1})}$

Results

Yield and Plant K Uptake Association

Main outcomes: **1)** Historical soybean yields followed country-level (USDA) evolution (Fig.1A); **2)** Historical world yield trend was stagnant relative to USA yield (Fig.1C); **3)** Aboveground-K uptake increased in parallel with yield until 1960's for USA; while, the World presented a similar pattern relative to the yield factor (Fig. 1D).

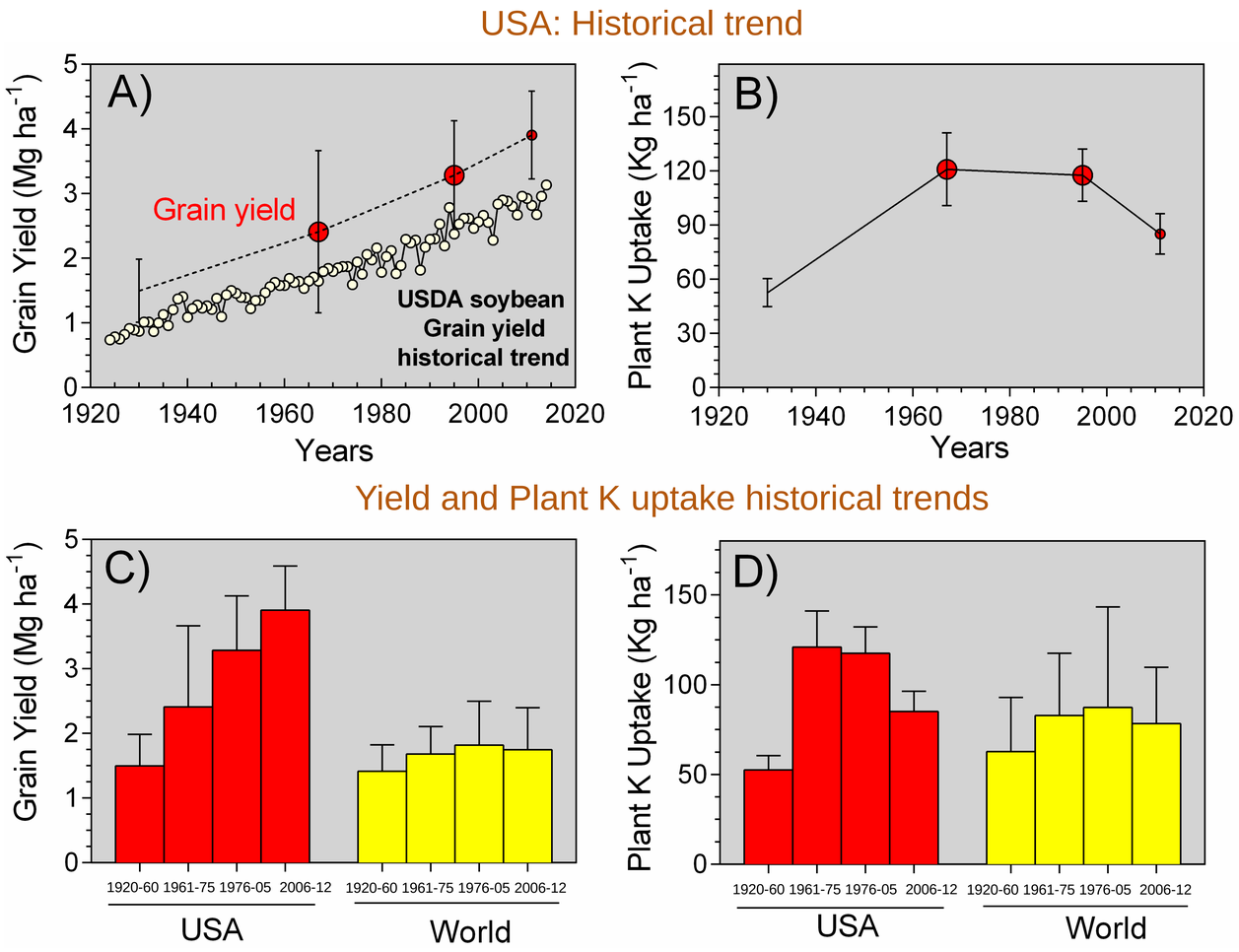


Figure 1. Soybean historical yield research database **(A)** and plant K uptake **(B)**, geographical yield **(C)** and whole-plant K uptake **(D)** histograms (USA vs. the World). Bubble sizes represent number of data gathered for each Era evaluated (panel A & B). Error bars represent the standard error.

Yield to Plant Uptake (K and N) and Nutrient balance: NK ratio

Main outcomes: **1)** USA showed more variability with a trend to higher NIE (Fig. 2A) and KIE (Fig. 2B) relative to the World (Fig. 2A,B). **2)** Overall NK ratio was 2:1 at maturity but ranged from 1:1 (maximum K concentration) to 6:1 (maximum K dilution) (Fig. 2C).

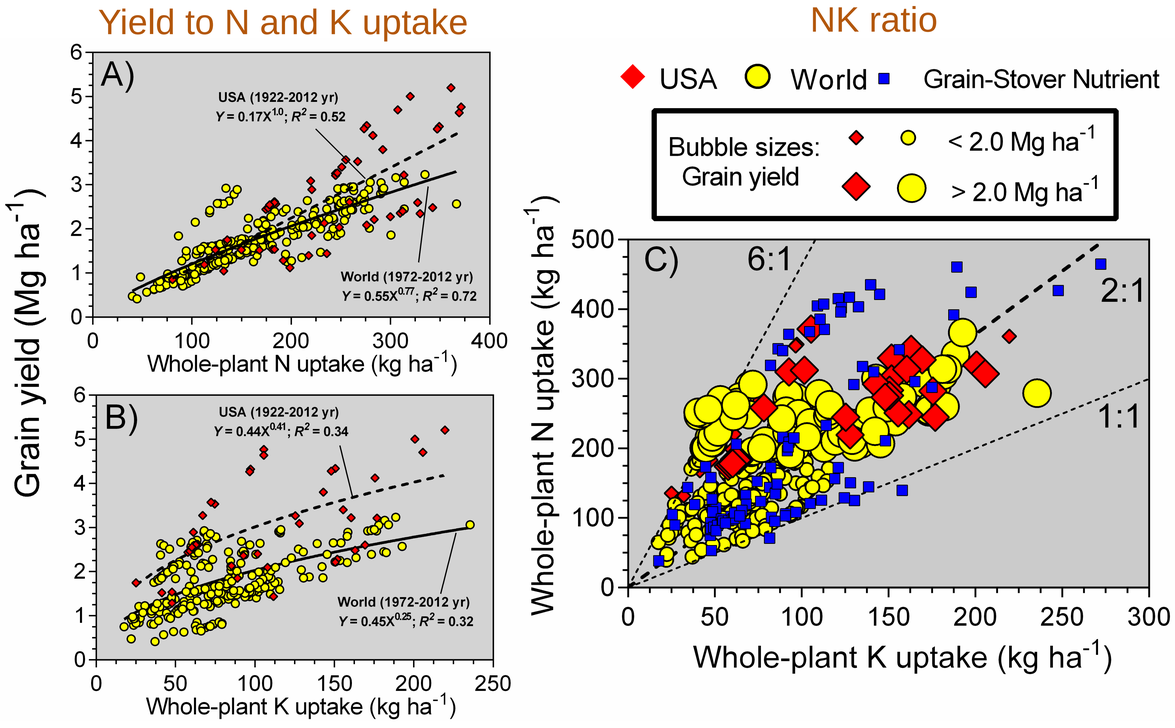
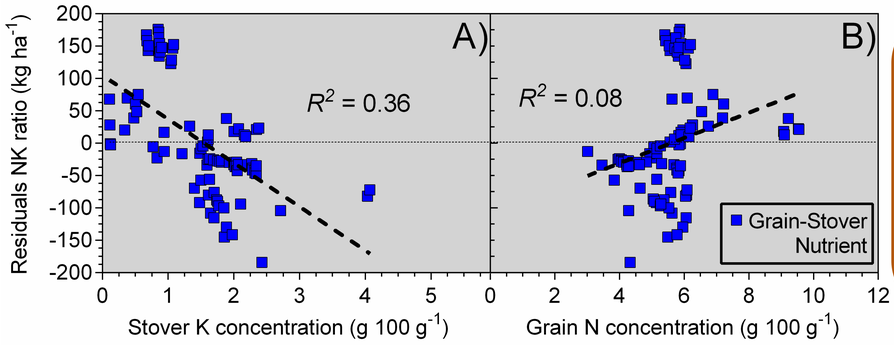


Figure 2. Data summary for the association yield vs. whole plant N **(A)**, K **(B)** uptake, and plant NK uptake ratio at maturity **(C)** for all historical and geographical division (USA vs. World).

NK ratio residuals

Main outcomes: **1)** Observed variation in the NK ratio (Fig. 2B) was largely accounted (R^2=0.36) by changes in stover K concentration (%) rather than grain %N (R^2 = 0.08) (Fig. 3).



What are residuals?
Difference between the observed value of the dependent variable (y) and it is the predicted value ($\hat{y}$).

Why is it important?
To understand and explain the variability observed in the regression model adjusted for the NK ratio.

Figure 3. Residuals for the NK ratio vs. stover K concentration **(A)** and grain N concentration **(B)**.

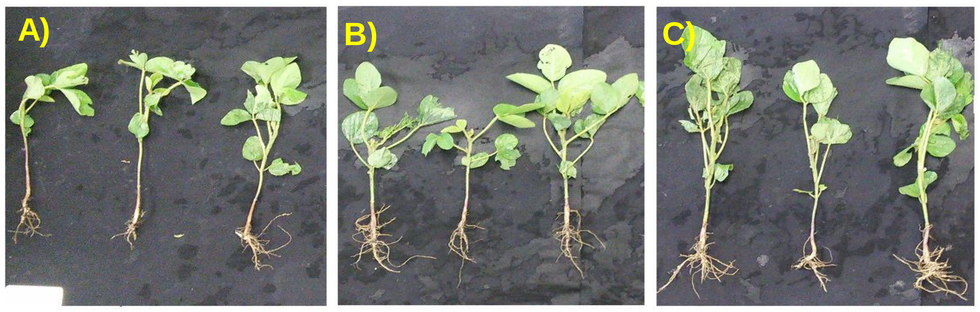


Figure 4. Illustration of different soybean Eras: Non-RR **(A)**, RR-1 **(B)** and RR-2 **(C)**, corresponding to 1997, 2006 and 2014 release year, respectively.

Conclusions

- Historical USA soybean yield research trend mimicked a similar pattern as portrayed by the USDA (1920-2012) yield database.
- The historical yield trend depicted a parallel K uptake pattern [except for the last years (2012 season, drought stress)].
- High-yielding data points were closely related with balanced N/K ratio close to 2:1.
- Stover %K largely influenced the NK variation as compared to the grain %N.