Top-Soil Root Architecture Characteristics of Obsolete and Modern Soybean Cultivars and Their Shoot and Seed Nutrient Contents

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Introduction

- Soybean is one of the most important crops globally and is produced for food, feed, fuel, and industrial uses.
- Soybean breeding efforts have led to continuous increases in yield.
- Breeding has improved soybean resistance to nematodes, diseases, and insects, and has changed shoot architecture and reduced the propensity for lodging.
- The increase in soybean seed yield has been attributed primarily to increased efficiencies in light interception, conversion of light energy to biomass, and resource allocation to seeds when water is abundant (Koester et al., 2014)
- Better understanding and focus on root system characteristics holds promise for maintaining agricultural productivity under drought stress and other environmental constraints (Den Herder et al., 2010)
- The impact of breeding on root system characteristics of US soybean cultivars has not been studied.
- Although above-ground changes associated with soybean yield increases have been documented, the relationship between the root architecture, nutrient uptake and allocation, and yield as a function of year of cultivar release is unclear.

Objectives

1) To examine the relationship between soybean root architecture and year of cultivar release.
2) To investigate the relationship of root system characteristics and nutrient uptake and accumulation in shoot tissue and in seeds.

Materials & Methods

- Experiments were conducted in 2016 at two field sites differing in soil type near Columbia, MO.
- Soil samples were collected and analyzed to assess the nutrient availability at both sites.
- 24 MG IV cultivars were selected to represent the genetic improvement of soybean over the course of 75 years (1930 – 2005).
- Soil moisture sensors were installed to monitor water availability.
- At seed filling (R5), five plants were excavated (20 cm diameter circle, 20 cm depth). After washing, root architecture traits were assessed (Table 1).
- Shoot biomass was measured at the same time. Five plants were randomly harvested for each plot, dried in an oven at 65ºC and weighed.
- At physiological maturity (R8) plants were harvested manually and threshed.
- Shoot tissue (R5) and seed samples (R8) were ground and nutrient concentrations determined by IPC-OES.
- Tissue and seed nutrient concentrations and their weights were used to calculate nutrient content.

Table 1. Root architecture traits and measurements

Traits	Stage	Description
Root complexity	R5	Visual scale from 1 (very simple) to 5 (very complex)
Taproot diameter	R5	Diameter of root at 5 cm from the uppermost lateral root
Lateral root angles	R5	Protractor board - 0° represents the lateral roots that are parallel to the soil surface and 90° vertical lateral roots
Lateral root No.	R5	Number of first order lateral roots in upper and lower portions of the root system
Lateral root density	R5	# of second order lateral roots along 2 cm of a randomly selected first order lateral root
Nodule size	R5	Visual scale from 1 (very small) to 4 (very big)
Nodule density	R5	Visual scale from 0 (no nodules) to 4 (very dense)

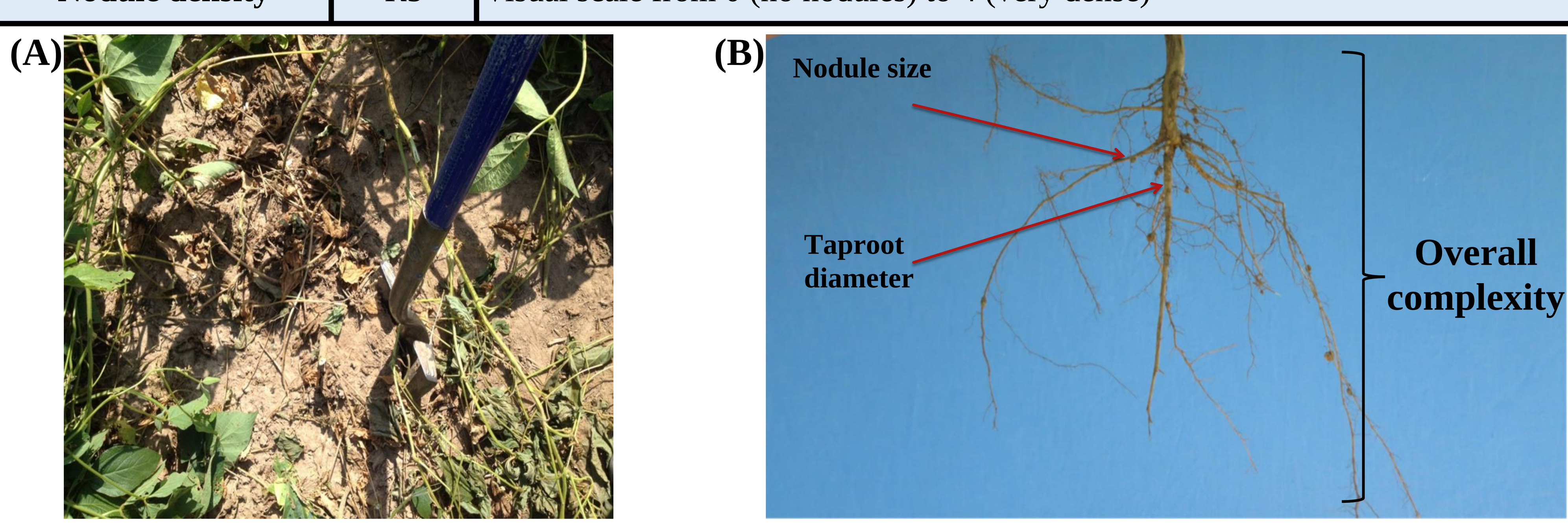

Figure 1. Shoots were cut prior to root system excavation (A) and top-soil root characteristics were assessed (B)

Results

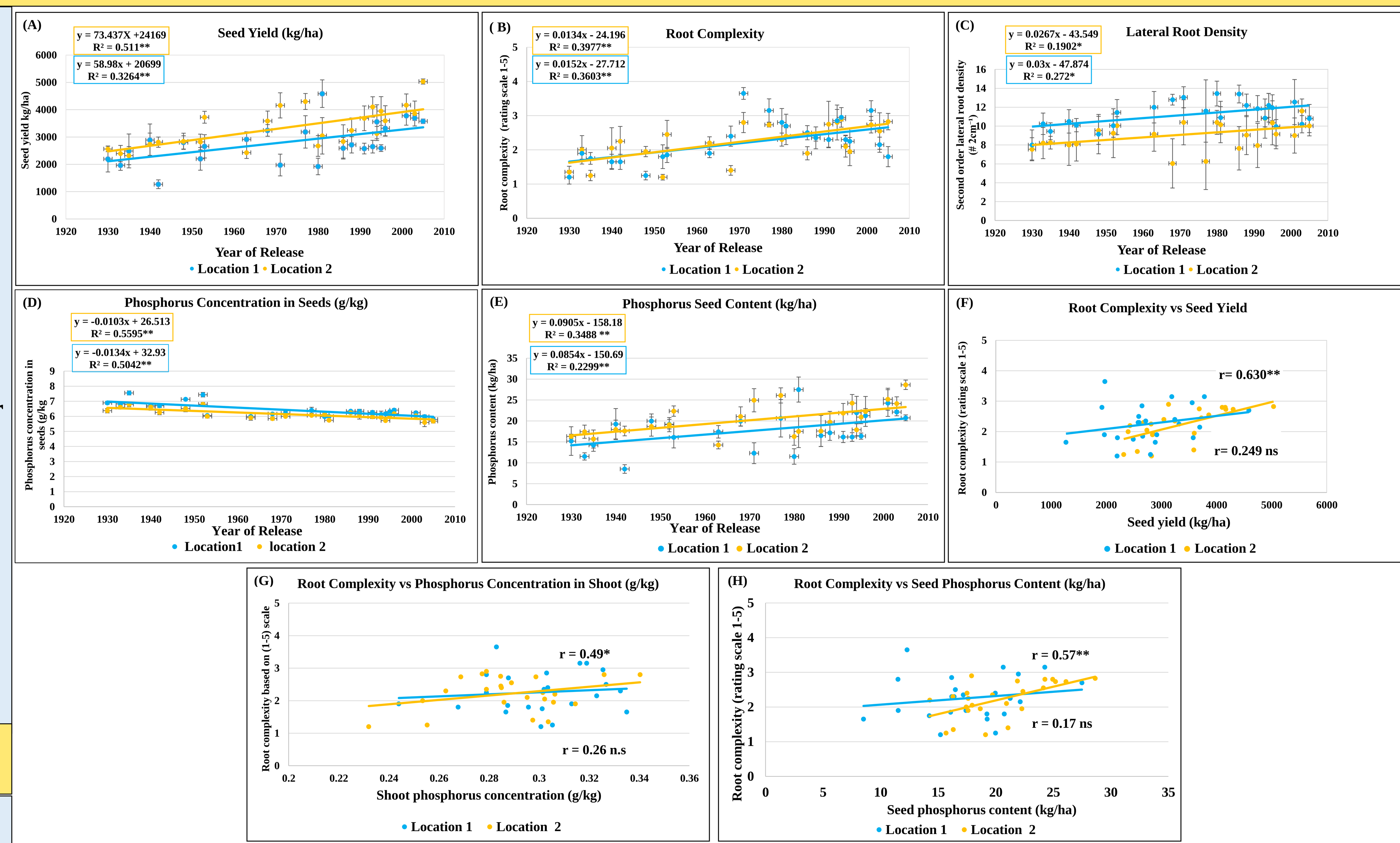

Figure 2. Selected root architecture characteristics, yield, and phosphorus concentrations and contents in response to year of release of MGIV soybean cultivars grown at two field sites differing in soil type. Seed yield (kg/ha) **(A),** overall root complexity **(B),** second order lateral root density **(C),** phosphorus concentration in seed (g/kg)**(D),** phosphorus content in seed (kg/ha) **(E),** relationship between root complexity and seed yield (kg/ha)**(F),** relationship between root complexity and phosphorus concentration in shoot (g/kg) **(G),** relationship between root complexity and seed phosphorus content (kg/ha) **(H)**. Lines represent least squares regression **(*p < 0.05, ** p < 0.01).**

- Significant changes in several root and shoot traits were observed with respect to year of cultivar release (YOR).
- Seed yield increased with YOR, with yearly gain estimated at 73 kg ha^{-1} yr^{-1} and 59 kg ha^{-1} yr^{-1} for the two locations, respectively (Fig.2A).
- A significant positive correlation between root complexity and YOR was found (Fig. 2B).
- The density of second order lateral roots increased with respect to YOR (Fig. 2C).
- Seed phosphorus concentration decreased with YOR (Fig. 2D). Similar trends were observed for almost all macro- and micronutrients in respect to YOR (data not shown).
- Phosphorus removal from the field in seeds increased with YOR (Fig. 2E). The same trend was found for other nutrients (data not shown).
- The relationship between root complexity and seed yield was positive at one of the two locations (*r* =0.63**, Location 2), but was not significant at the other location (Fig. 2F).
- Root complexity was positively correlated to shoot phosphorus concentration at one of the two locations (*r* = 49*, location 2)(Fig.2G).
- Root complexity was positively correlated to seed phosphorus content at one of the two locations (*r* = 57*, location 2)(Fig.2H).

Conclusion

- Breeding for high yield has altered root architecture in MGIV soybean cultivars.
- Most modern cultivars had more complex root architecture compared to older cultivars.
- Nutrient concentrations in seeds of most modern cultivars were lower than in obsolete cultivars.
- Overall root complexity scores were positively correlated with the phosphorus concentration in shoot tissues and with the contents of macro- and micronutrients in seeds.
- Overall, this study indicates that breeding for higher yield altered soybean top soil root architecture and nutrient uptake of soybean cultivars; however, the extent to which changes in root system architecture may underlie greater yields of modern cultivars requires further investigation.

References

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