Nutrient Accumulation Patterns in Soybean Cultivars Released Over 90 Years

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Introduction:

Soybean yield has increased 22.6 kg ha^{-1} year^{-1} from 1924 to 1998 (Specht et al., 1999). Fifteen soybean genotypes increased in total biomass from obsolete to modern lines (Cregan and Yaklich, 1986). Hanway and Weber (1971) partitioned eight soybean cultivars from maturity group (MG) II by leaves, petioles, stems, pods, and seeds throughout the season. The plant partitions were also analyzed for nitrogen, phosphorus, and potassium. Soybean breeding has released cultivars with greater yield potential, altered leaf arrangement (e.g., narrow, erect), and other physiological advancements in the following 40 years. Agronomic management (e.g., fertilization, tillage, planting date) has also changed.

Objectives were to determine:

(1) the seasonal uptake of nutrients by soybean cultivars within MG II and III released over the last 90 years and

(2) the allocation of nutrients to leaves, stems, pods, and seeds within these cultivars.

Materials & Methods:

Location, Year, and Soil Type: West Lafayette, IN in 2011. Toronto-Millbrook soil complex (Toronto series: fine-silty, mixed, superactive, mesic Udollic Epiaqualf) (Millbrook series: fine-silty, mixed, superactive, mesic Udollic Endoaqualf)

Cultivars: Twenty-six cultivars from each MG II and MG III were selected to total 52 cultivars from public and private breeding programs. Two to four cultivars were selected per decade within each MG set to represent the past 90 years. The release years range from 1928 to 2011 in MG II and from 1923 to 2011 in MG III.

Experimental Design: Cultivars from each MG were arranged in a RCBD with 3 replications to create two separate studies located in the same location.

Plots: 6.1 m wide (eight 76-cm rows) by 4.6 m long

Sampling: Plant samples were taken five times throughout the growing season at key growth stages: **V4** (4 trifoliates), **R2** (full bloom), **R4** (full pod), **R6** (full seed), and **R8** (physiological maturity) (Fehr and Caviness, 1977). The four in-season samples were partitioned into leaves, stems and pods (if available). The R8 sample was separated into seeds and stover without collecting fallen leaves.

Data Collection: Plants were cut from 1 m of row at the R2, R6, and R8 timings. The biomass of plant parts was less at V4 and R4, and thus, plants were cut from 2 m of row. Plant partitions were dried, weighed, and analyzed for nutrients.

Statistical Analysis: Cultivars were regressed over release years using PROC REG in SAS version 9.2 (SAS Inst., Cary, NC) to determine changes in biomass and nutrient accumulations within growth stages and plant parts.

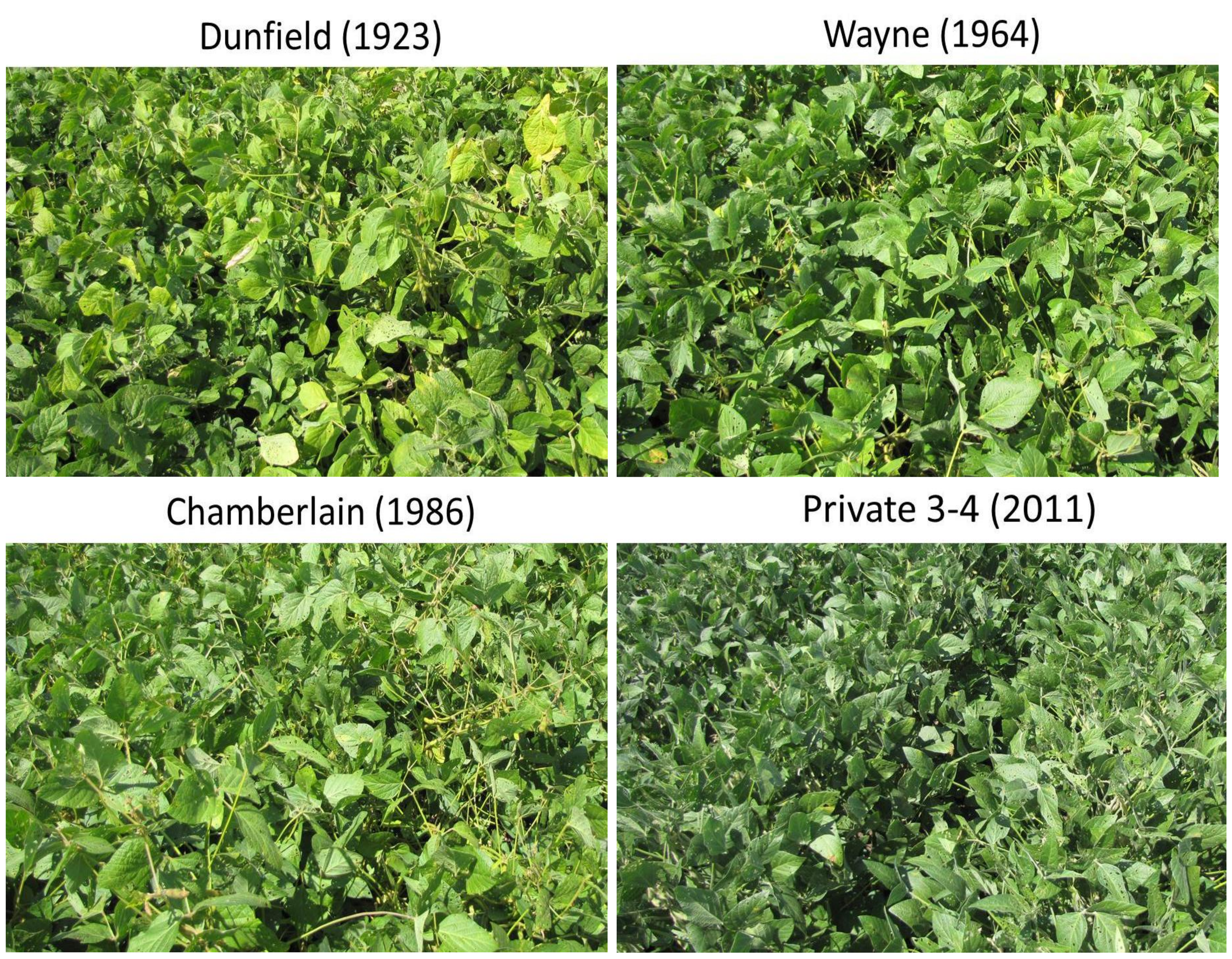
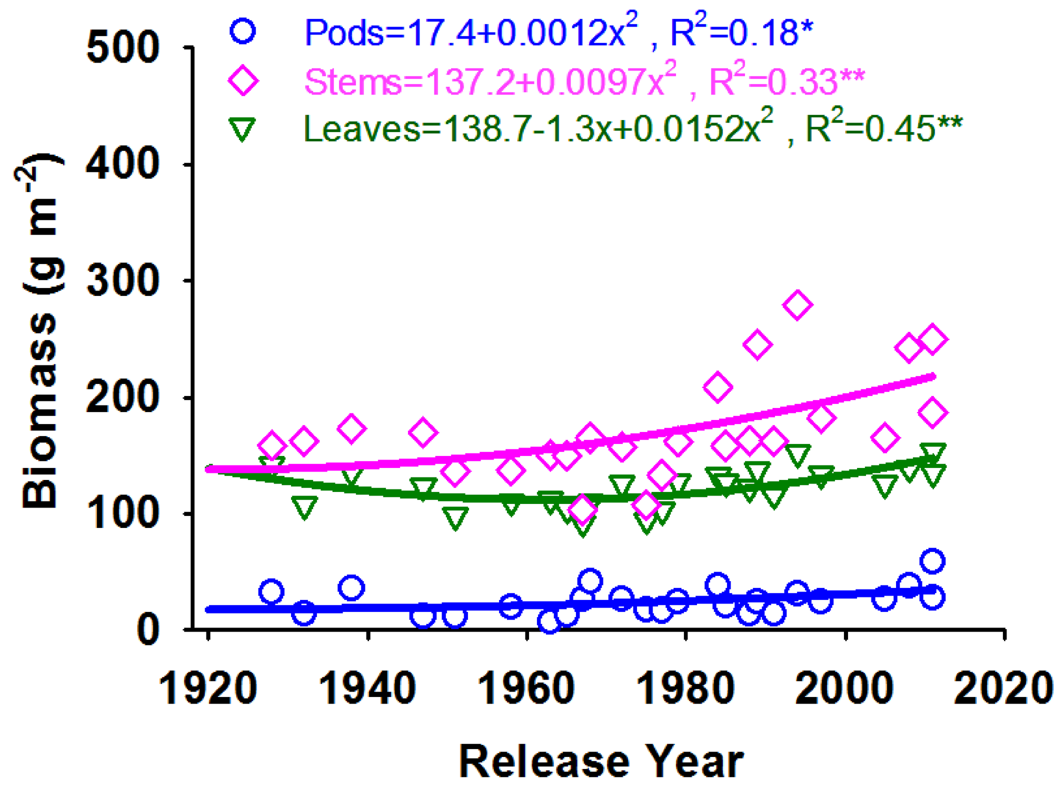


Figure 1. Example of MG III cultivars released over the past 90 years. Picture taken at R6 (full seed) on August 21. Note the differences in greenness, leaf shape, and plant stature.

Results: In-Season Biomass



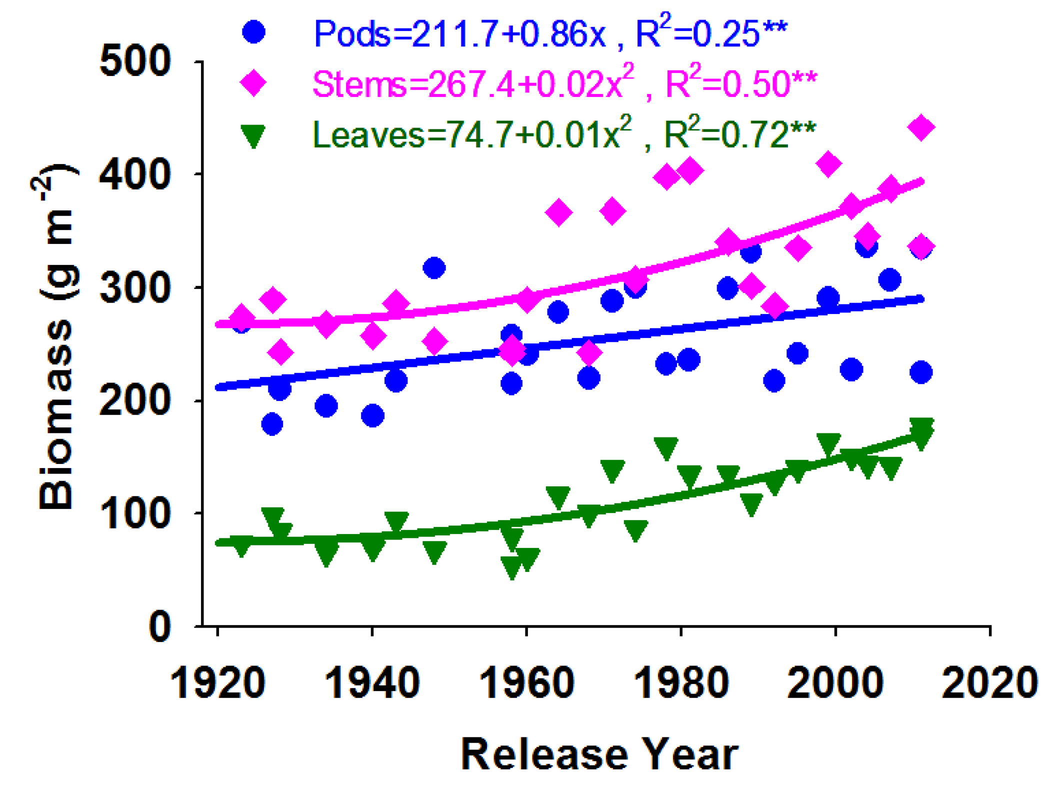
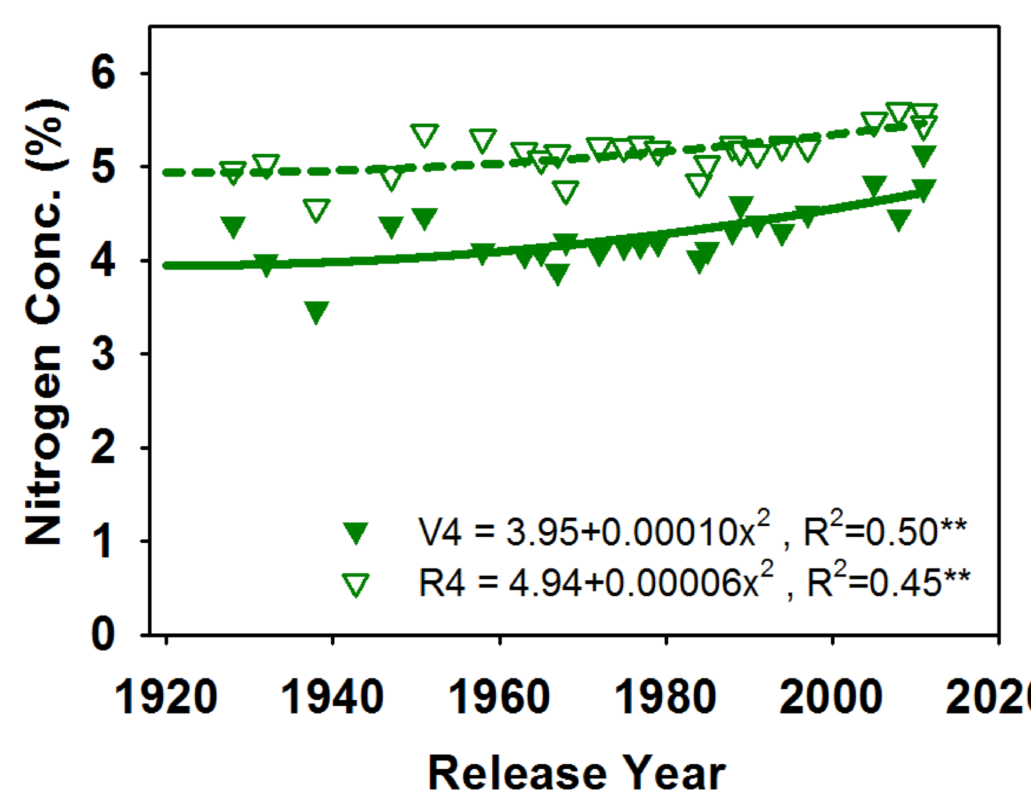


Figure 2. Biomass of MG II cultivars at R4 (full pod). **Figure 3.** Biomass of MG III cultivars at R6 (full seed).

- Biomass (total and plant partitions) of MG II cultivars increased across release years within V4, R2, and R4 (Fig. 2) growth stages. However, biomass of MG II cultivars did not differ at R6.
- Biomass (total and plant partitions) of MG III cultivars did not differ across release years at V4 or R2, however biomass of leaves at R4 and plant partitions at R6 (Fig. 3) increased across release years.
- Biomass distribution within plant parts did not change across release years. In MG II cultivars at R4, the biomass was partitioned into leaves (~40%), stems (~53%), and pods (~7%). In MG III cultivars at R6, the biomass was partitioned into leaves (~20%), stems (~40%), and pods (~40%).
- Yield increased 1000 to 2350 kg ha^{-1} in MG II and 1340 to 3020 kg ha^{-1} in MG III across release years.

Results: In-Season Nutrients



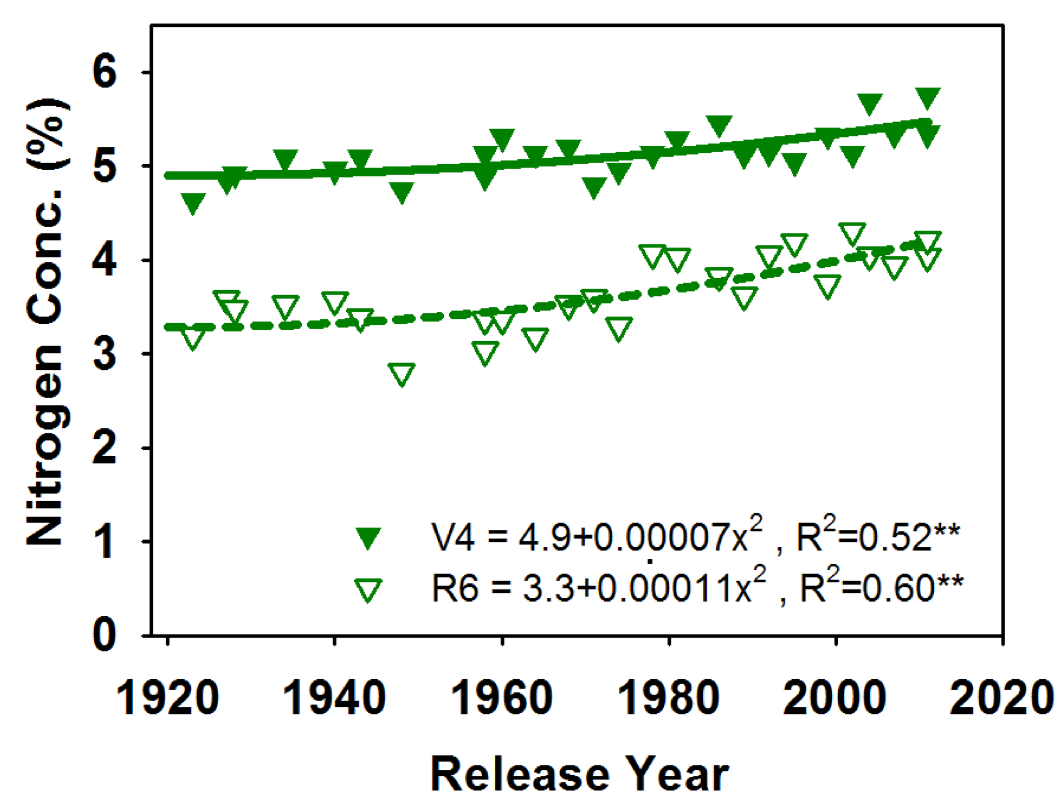


Figure 4. Leaf N Concentration of MG II at V4 & R4. **Figure 5.** Leaf N Concentration of MG III at V4 & R6.

- Leaf N concentrations of MG II and III increased across release years at V4, R2, R4, and R6, which suggested increasing chlorophyll content and photosynthetic capacity.
- Leaf P concentrations averaged 0.36% at V4 and decreased to ~0.23% at R6 in MG II and III.
- Leaf K concentrations averaged 2.2% at V4 and decreased to ~1.5% at R6 in MG II and III.
- Concentrations of N in the grain declined over 90 years of breeding in MG II, which is related to the protein trends documented in Wilcox and Guodong (1997) where soybean yield and protein (i.e., N) concentrations were inversely related.

Conclusions:

- Biomass accumulation increased across release years in both MGs. The increase occurred earlier in the growing season at R4 for MG II compared to the increase at R6 for MG III. These biomass differences were likely linked to the growth and development timelines of each MG.
- Modern cultivars accumulated more biomass throughout the season, which suggests more efficient photosynthetic rate and allocation of photosynthates (Morrison et al., 2000).
- Consistent increases in leaf biomass and leaf N concentrations suggests breeding efforts enhanced leaf retention, chlorophyll content, and plant development to supply more photosynthates to build plant biomass leading to higher yields.

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