# Agronomic Management Innovations Improve Soybean Yield by Lengthening Seed-Filling Duration at Different Canopy Regions


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**Question:** ***Can yield of soybean be improved with agronomic management by targeting different regions of the soybean canopy?***

**Objective:** ***Quantify soybean yield distribution and how agronomic management influences seed development at specific canopy regions.***

## Introduction:

- Soybean seed yield is comprised of yield components including pod number area$^{-1}$, seed number pod$^{-1}$, and individual seed weight. Agronomic management commonly used to improve yield is thought to influence multiple yield components simultaneously.
- Although research has documented nodal variation throughout the soybean canopy for some yield components, there has been no known research which documents how agronomic management influences nodal yield distribution and seed development.
- Seed-filling and final seed weight, the relationship between cumulative photoassimilation and dry weight partitioning, is often expressed as a function of time: *Effective Filling Period (EFP) = Seed-Filling Rate (SFR) x Seed-Filling Duration (SFD)*
- Therefore, it is believed that agronomic management can also be used as a strategy to improve final seed weight at different canopy locations.

## Research approach:

- Two field experiments were planted at Champaign and DeKalb, IL during 2012 and 2013.
- Three agronomic factors were selected to evaluate the effect of crop management on the yield distribution and EFP of soybean:
  1) **Variety:** 2.8 vs 3.4 RM variety (Study 1); 3.4 vs 3.6 RM variety (Study 2).
  2) **Fertilization regime:** Untreated control vs preplant banded phosphorus at 84 kg $P_2O_5$ ha$^{-1}$ as Mosaic's MicroEssentials® SZ™ (12-40-0-10S-1Zn).
  3) **Foliar Protection:** Untreated control vs a foliar insecticide and fungicide applied at R3 (Study 2).
- Plots were planted to achieve an approximate final stand of 358,000 plants ha$^{-1}$ (145,000 plants Ac$^{-1}$).
- Using weekly time intervals beginning after R4, five plants plot$^{-1}$ were sampled and the number of pods and the number and weight of beans were determined.
- Measurements were conducted at specific nodal positions to represent precise canopy regions: node 4 to 6 (bottom third of canopy), node 10 to 12 (middle third), and node 15 to 17 (upper third).
- Seed growth was described using a nonlinear beta growth regression function as described by Yin et al. (2003).

## Effective filling period of soybean – What is it?

- **In study 2, the effective filling period (EFP) was quantified and was limited to an approximate 8-week period during 2013 (Figure 2).**
- **Nearly 65% of final seed weight was produced between weeks 3 to 6 at a rate of 4.51 mg seed$^{-1}$ day$^{-1}$.**

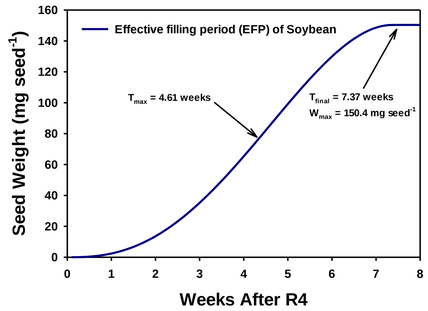


**Figure 2.** Mean EFP averaged across two varieties, three agronomic treatments, and three canopy regions at Champaign, IL during 2013. The EFP was described using a beta growth function to predict the time at which maximum seed growth occurs ($T_{max}$), the time at which final seed weight is achieved ($T_{final}$), and the seed weight at maturity ($W_{final}$). Seed weight is shown on a dry weight basis (i.e., 0% moisture concentration).

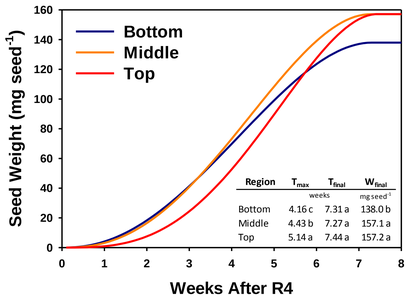


**Figure 3.** Effect of canopy region on the EFP of soybean measured at Champaign, IL during 2013. Similar letters within a column are not statistically different at α = 0.05.

- **Seed growth varied markedly throughout the soybean canopy (Figure 3).**
- **Compared to the bottom, the greater final seed weight associated with the middle region was achieved through a greater seed filling rate during weeks 4 to 6.**
- **Seed development in the top region was initially delayed, though rapidly reached a final seed weight equivalent to the middle region.**

## Soybean yield potential - Where is it located?

- **Study 1 was conducted over three site-years to quantify the effect of variety selection and fertility management on the nodal distribution of pods and beans.**
- **Exploratory data analysis (EDA) suggested inherent differences in yield potential (e.g., pod and bean number) depending on the canopy region (Figure 1). These results were used to create distinct canopy subsections for the bottom (nodes 1-7), middle (nodes 8-14), top (nodes 15+), and branch regions (Table 1).**

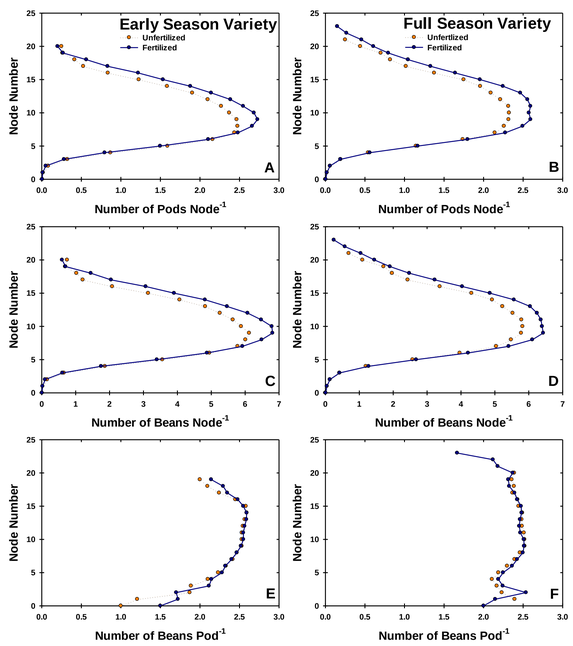


**Figure 1.** Pod number (A, B), bean number (C, D), and pod capacity (E, F) at each nodal position for early season (2.8 RM) and full season (3.4 RM) varieties with and without fertilization. The fertilization treatment consisted of 84 kg $P_2O_5$ ha$^{-1}$ as Mosaic's MicroEssentials® SZ™ (12-40-0-10S-1Zn) banded before planting. Means were generated using exploratory data analysis and averaged across three environments which included DeKalb (2012 and 2013) and Champaign, IL (2013). Branch information is provided in Table 1.

**Table 1.** Pod number, bean number, and pod capacity distribution throughout the soybean canopy as influenced by different variety-fertility treatment combinations measured at DeKalb (2012 and 2013) and at Champaign (2013). Mean separation letters (lower case) compare treatments within an individual subsection for each parameter. Upper case letters compare the main effect of canopy subsection within a parameter. Similar letters are not statistically different at α = 0.05.

| | Subsection (*corresponding nodes*) | | | |
|---|---|---|---|---|
| **Variety RM (Fertility Treatment)** | **Bottom (*1-7*)** | **Middle (*8-14*)** | **Top (*15+*)** | **Branches** |
| **Pod Number** | pod number subsection$^{-1}$ | | | |
| Early Maturity (Unfertilized) | 5.1 a | 15.6 c | 3.5 c | 5.3 bc |
| Early Maturity (Fertilized) | 4.6 ab | 16.6 b | 4.4 c | 4.6 c |
| Full Maturity (Unfertilized) | 4.0 b | 15.5 c | 5.6 b | 5.8 ab |
| Full Maturity (Fertilized) | 4.1 b | 18.0 a | 6.7 a | 6.8 a |
| Subsection Mean | 4.5 C | 16.4 A | 5.0 C | 5.6 B |
| **Bean Number** | bean number subsection$^{-1}$ | | | |
| Early Maturity (Unfertilized) | 11.4 a | 39.7 b | 9.1 b | 11.6 ab |
| Early Maturity (Fertilized) | 10.4 ab | 43.9 a | 11.4 b | 10.3 b |
| Full Maturity (Unfertilized) | 9.0 b | 37.9 b | 14.0 a | 11.9 ab |
| Full Maturity (Fertilized) | 9.6 ab | 44.2 a | 16.4 a | 14.4 a |
| Subsection Mean | 10.1 C | 41.4 A | 12.7 B | 12.1 B |
| **Pod Capacity** | bean number pod$^{-1}$ | | | |
| Early Maturity (Unfertilized) | 2.24 a | 2.45 a | 2.60 a | 2.10 ab |
| Early Maturity (Fertilized) | 2.25 a | 2.47 a | 2.55 ab | 2.18 a |
| Full Maturity (Unfertilized) | 2.25 a | 2.45 a | 2.48 b | 2.04 b |
| Full Maturity (Fertilized) | 2.29 a | 2.44 a | 2.48 b | 2.10 ab |
| Subsection Mean | 2.26 C | 2.45 B | 2.53 A | 2.10 D |

- **Approximately 52% of pods and 55% of beans were positioned in the middle region of the canopy (Table 1). Therefore, only seven nodes constituted between 50% - 60% of soybean yield.**
- **The yield improvement associated with supplemental fertility was a consequence of improved pod and bean number in the middle and top canopy regions (Figure 1, Table 1).**
- **Relative to the early season variety, the full season variety was able to more effectively capture yield potential in the top canopy region by setting additional pods (Table 1).**
- **Pod capacity (i.e., bean number pod$^{-1}$) gradually increased from the bottom to the top of the soybean canopy (Figure 1, Table 1) and was potentially the result of greater light interception.**

## Can agronomic management enhance the EFP of soybean?

- **In study 2, yield increases due to the fertility treatment (+173 kg ha$^{-1}$, 5%) and foliar protection (+179 kg ha$^{-1}$, 5%) were associated with seed weight and not seed number (data not shown).**
- **Agronomic management resulted in differential seed weight responses depending on canopy region (Figure 4).**
- **The fertility treatment increased seed weight by 10%, 9%, 6%, in the bottom, middle, and top regions, respectively.**
- **Foliar protection increased seed weight by 6%, 6%, 8%, in the bottom, middle, and top regions, respectively.**
- **Seed weight increases were generally associated with prolonged seed filling duration near maturity.**

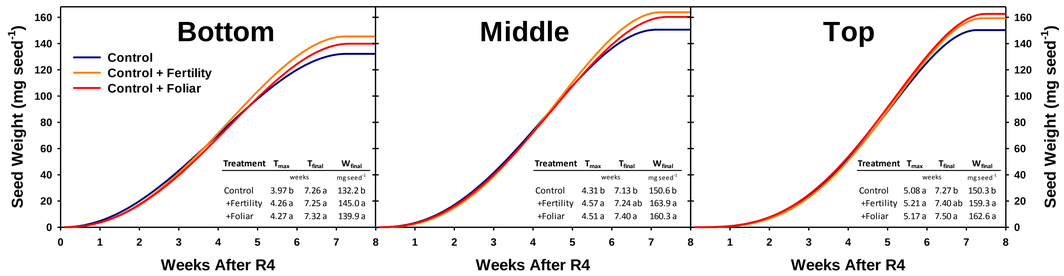


**Figure 4.** Effect of agronomic management on the EFP in the bottom, middle, and top canopy regions of the soybean canopy at Champaign, IL during 2013. The fertilization treatment consisted of 84 kg $P_2O_5$ ha$^{-1}$ as Mosaic's MicroEssentials® SZ™ (12-40-0-10S-1Zn) applied before planting. Foliar protection included a fungicide and insecticide applied at R3. Similar letters within a column are not statistically different at α = 0.05.

## Agronomic implications:

**1. Do canopy regions vary in their ability to generate yield?**

✓ **Yes, the middle region of the soybean canopy was responsible for approximately 50% – 60% of final yield compared to the bottom, top, and branch regions (10 – 20% each).**

**2. Can specific regions be targeted with agronomic management for a multifaceted approach to improved yield?**

✓ **Yes, fertilization improved pod set (middle and top canopy regions) and enhanced seed weight (especially in the bottom and middle regions). Foliar protection lengthened the EFP of soybean which improved yield through increased seed weight (especially in the top region).**


*ASA, CSSA, and SSSA 2014 International Annual Meetings, Nov. 2-5, Long Beach, CA.*