

In 2012, your Illinois Soybean Association (ISA) checkoff program established a goal of utilizing (producing and selling) 600 million bushels of Illinois soybeans by 2020 — a 25% increase over typical soybean levels of that time. While many felt soybean yields had plateaued, the ISA Board believed our farmers could increase yields and generate better profits with smarter, more intensive management and the latest technology.

To help accomplish that goal, ISA started funding a first-of-its-kind study to look more holistically at intensive soybean management — to identify if better management leads to better yields and determine which of those practices are most critical to success.

**After five years of research, we're pleased to share this summary of the Six Secrets of Soybean Success.**



## Secrets of Soybean Success

### WHAT FIVE YEARS OF RESEARCH HAS TAUGHT US

Fred E. Below, Ph.D., is a professor of crop physiology in the Department of Crop Sciences at the University of Illinois. His research is focused on understanding factors limiting crop productivity, particularly corn and soybeans. He is author or co-author on more than 85 peer-reviewed manuscripts, numerous abstracts, book and proceedings chapters, and he has advised more than 65 graduate

and postdoctoral students. He developed the “Seven Wonders of The Corn Yield World” and the “Six Secrets of Soybean Success” as tools to teach farmers and agricultural professionals the value of their individual crop management decisions, and he has been actively using these concepts to develop cropping systems capable of sustainably producing high corn and soybean yields.



FRED E. BELOW, PH.D.

Professor of Crop Physiology, University of Illinois



#### WEATHER:

The number one influence on soybean yields, but beyond our control



#### FERTILITY:

Proactive fertilization can boost yields over 60 bushels



#### FOLIAR PROTECTION:

Fungicides and insecticides protect foliage and prevent yield loss



#### GENETICS:

The fullest maturities for the region produce the greatest yield increases



#### ROW SPACING:

Narrower, 15- or 20-inch rows increase yield and respond better to more intense management



#### SEED TREATMENT:

Early season protection protects yield potential

## Relearning Soybean's Fertility Needs

A grower's typical fertilization practice was to fertilize corn and add in extra for soybeans or let soybean scavenge for leftover nutrients in the soil. When growers expected low yields of 40 to 60 bushels per acre, this practice was acceptable.

But today, growers are pushing yields to 60 to 80 bushels and even higher. That requires fertilizing soybeans separate from corn and following a program unique to soybeans. Most high-yield soybean producers are following a broad-ranging fertility program that includes all the macros and micros.

## Potassium (K) vs. Phosphorus (P) Paradox

Growers are advised to pay attention to potassium (K). A 60-bushel soybean crop requires 170 lbs. of  $K_2O$  (equal to 280 lbs. of Muriate of Potash fertilizer). The plant takes up 3.5 lbs. of  $K_2O$  per day over a 50-day period beginning at pod set, and banks K in stems and petioles so it's readily available to fill pods. However, only 40% is removed with the grain and the rest stays with the stover and is returned to the soil.

Phosphorus however, responds quite differently — uptake continues over a longer 70-day period beginning at pod set. The plant doesn't store available P in the stem, and the majority of its supply must come directly from the soil. And 80% is removed with the grain with very little remaining in the stover.

**NUTRIENT UPTAKE, REMOVAL AND HARVEST INDEX FOR 60-BUSHEL CROP**

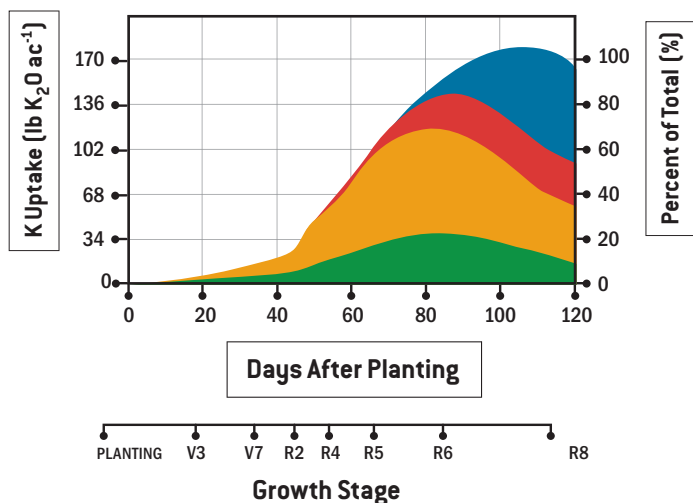
Nutrient	Required to Produce	Removed with Grain	Harvest Index
POUNDS PER ACRE			%
<b>N</b>	<b>245</b>	<b>179</b>	<b>73</b>
<b>P<sub>2</sub>O<sub>5</sub></b>	<b>43</b>	<b>35</b>	<b>81</b>
<b>K<sub>2</sub>O</b>	<b>170</b>	<b>70</b>	<b>41</b>
<b>S</b>	<b>17</b>	<b>10</b>	<b>61</b>
<b>Zn (OZ)</b>	<b>4.8</b>	<b>2.0</b>	<b>44</b>
<b>B (OZ)</b>	<b>4.6</b>	<b>1.6</b>	<b>34</b>

SOURCE: AGRONOMY JOURNAL: 107:563-573 (2015)

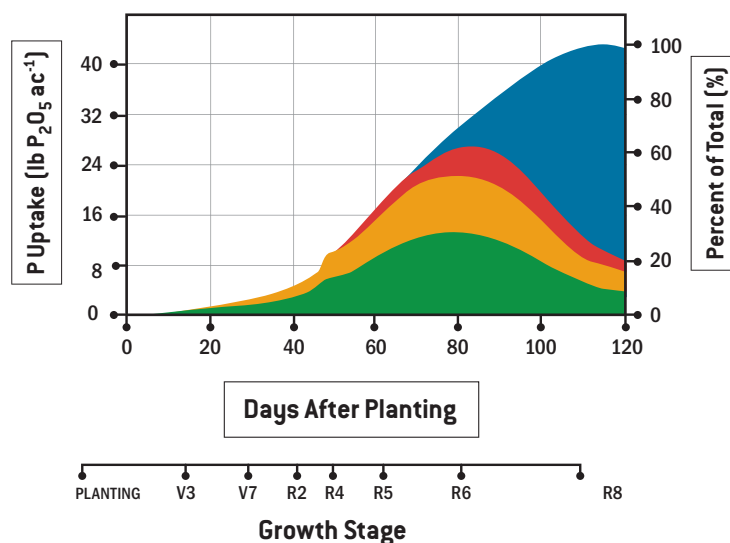
Soybeans require ample amounts of nutrients and particularly nitrogen (N), potassium (K) and phosphorus (P). Soybeans need about 4 to 4.5 lbs. of N per bushel produced with about half coming from their own nitrogen fixing nodules and the rest from the soil. A 60-bushel crop removes significant amounts of nutrients with the grain, particularly N, P and sulfur (S).

### K AND P UPTAKE AND PARTITIONING FOR 60-BUSHEL SOYBEAN CROP

GRAIN FLOWERS, PODS STEM, PETIOLES LEAVES



Source: Agronomy Journal: 107:563-573 (2015)



Based on University of Illinois field trials, extra fertility — especially P (not K as long thought) has the most significant impact on yield. This is because soybeans get most of the K needed from the residue of the previous corn crop. Today's higher crop yields remove more nutrients while fertilizer rates are remaining relatively stable, so growers need to pay more attention to when and how much they apply.

## N ON BEANS



PHOTO BY FRED BELOW

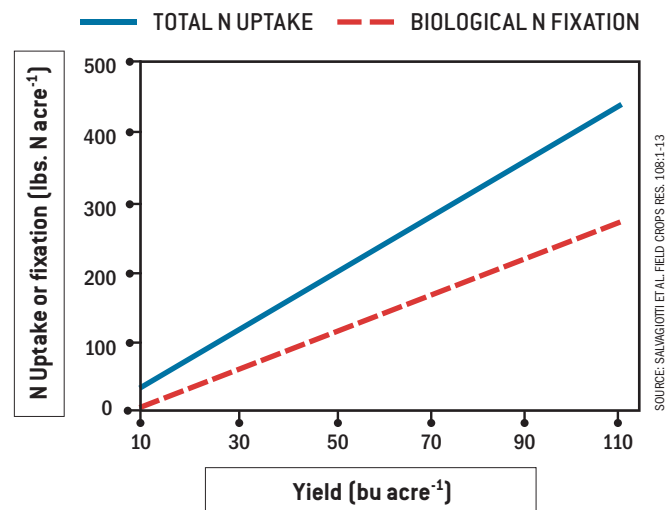
## Do Soybeans Respond to Fertilizer N?

Soybeans need 4 to 5 lbs. of nitrogen (N) per bushel with about half coming from their nitrogen-fixing nodules and the rest from the soil. By R5/pod fill stage, N-fixation begins to

slow and plants cannibalize internal N sources if the soil can't provide enough to meet demand.

Soybean needs more N than it can get from nodules. Research has shown that when yield potential exceeds 50 to 60 bushels, the crop increasingly relies on soil reserves of nitrate and mineralized N.

As growers push yields to 70 bushels or greater, the gap between how much N soybeans need and what can be provided by the nodules gets wider. As such, farmers may need to apply additional nitrogen to supplement what the soil can provide.



Recent university research has shown that supplemental nitrogen, and particularly nitrate, doesn't suppress N-fixation as long-believed.

### RESPONSE TO N ON SOYBEANS - 2015

Average 3 Locations (100 lbs. of N applied)

Source	Pre-plant	V3	R1	R3
changes in bushels acre <sup>-1</sup>				
<b>AN</b>	<b>4.0*</b>	<b>4.2*</b>	<b>5.3*</b>	<b>5.7*</b>
<b>AMS</b>	<b>2.7*</b>	<b>1.6</b>	<b>3.5*</b>	<b>3.2*</b>
<b>UAN</b>	<b>3.5*</b>	<b>4.1*</b>	<b>3.8*</b>	<b>3.1*</b>
<b>Urea</b>	<b>2.3</b>	<b>2.9*</b>	<b>3.2*</b>	<b>3.1*</b>
<b>Urea + Limus</b>	<b>1.6</b>	<b>3.3*</b>	<b>3.7*</b>	<b>4.2*</b>
<b>AN + KN + AMS</b>	<b>2.6*</b>	<b>1.4</b>	<b>4.5*</b>	<b>3.6*</b>
<b>ESN</b>	<b>3.2*</b>	<b>2.7*</b>	<b>4.3*</b>	<b>3.1*</b>

Control = 71.7 bu acre<sup>-1</sup>

\* Significantly different than control

SOURCE: UNIVERSITY OF ILLINOIS CROP PHYSIOLOGY LAB

Data from 2015 show that most supplemental N sources provide a positive yield response.

## What N Sources, Rates and Timing are Optimal?

**TIMING:** Nitrogen can be applied pre-plant to supply the plant until N-fixation kicks in at V2-V3 (20 to 30 days after planting). An early pre-plant application also will compensate if nodule development is hindered by wet June weather.

By the R4 growth stage, soybeans increasingly begin to move N from vegetative tissues to the pods. The most recommended application timing is at R3 or beginning pod set.

**SOURCE:** There are many N sources available from organic to commercial. Organic forms like compost, litter and manure are slow release and are available later in the season as demand increases with pod fill.

University of Illinois studies evaluated ammonium nitrate (AN), ammonium sulfate (AMS), urea ammonium nitrate (UAN), urea, potassium nitrate (KN), Agrium's Environmentally Smart Nitrogen (ESN) and the addition of stabilizers (BASF's Limus) to urea.

However, nitrate containing and controlled release sources (ESN) were the most effective and consistent at all stages of application.

**RATE:** Nitrogen can be applied pre-plant or in-season

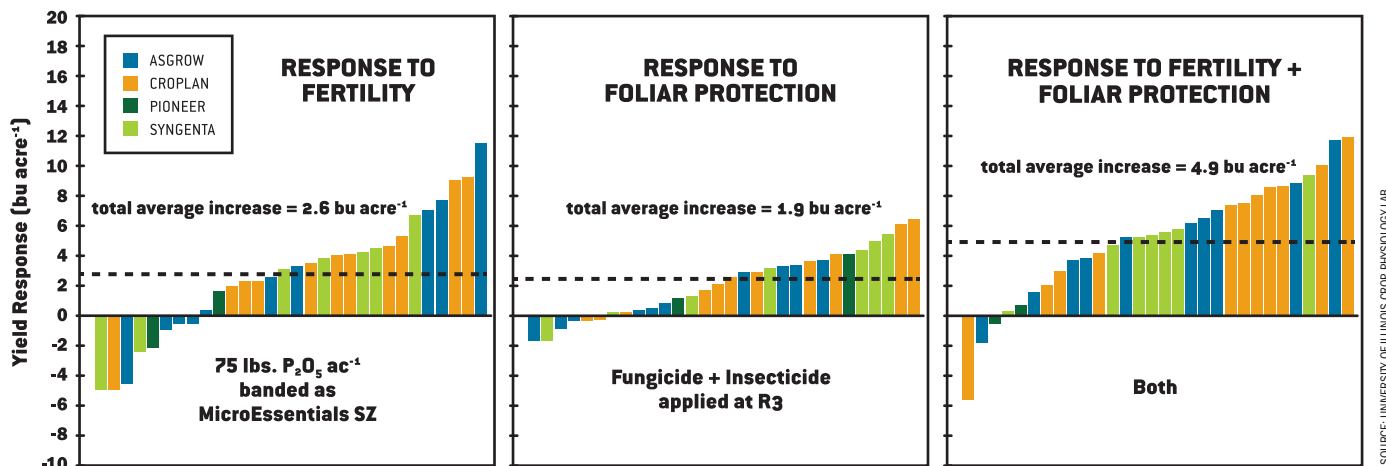
- Pre-plant at a rate of 30 to 50 lbs. per acre
- In-season at a rate of 50 to 100 lbs. per acre

## Variety Selection

Growers are constantly reminded that their first production decision is the variety they plant. Always select a variety that is high yielding, has the necessary agronomic and defensive package and is adapted to the field and soil where you will plant it.

However, soybean varieties differ in their response to

management. In 2016, the University of Illinois compared the yield response of 28 commercially available varieties to different management at Yorkville, Champaign and Harrisburg, Ill., with maturity ranging from 2.3 to 4.8. Champaign results are shown below.



The piano graphs above ranked the varieties from the lowest to highest performing in response to fertility, foliar protection or the combination of the two. Some varieties showed a negative response to adding technology. However, in most cases, there was a positive and additive yield response with the greatest response coming from fertility (2.6 bushels) and foliar protection (1.9 bushels). When applied together there was a 4.9-bushel increase. And when there was a positive response to management, it ranged by as much as 12 bushels.

### Variety matters

- Variety makes a big difference in yield, and the fullest maturity usually produces the highest yield.

- In the Champaign trial, yield ranged from 76 to 93.6 bushels, so varieties aren't created equal.
- Soybean varieties differ in their response to fertility and foliar protection, so if deploying a high management approach, plant an offensive variety that is known to respond.

## Row Spacing

Since the introduction of Roundup Ready soybeans, many growers returned to planting soybeans in 30-inch rows. Today many growers have one or more planters that plant both corn and soybeans. But by doing so, have they given up yield?

The University of Illinois examined the effects of row spacing on yield with standard practices and high management techniques. Standard practices included fertilizer before corn only; no-, or minimal- seed treatment; and no foliar protection. High management included P, sulfur, and zinc banded below the row; K broadcast and incorporated; complete seed treatment with fungicide, insecticide and nematicide; and foliar fungicide and insecticide applied at R3.

Narrower rows (20- vs. 30-inch) can have a big impact on final yield, and narrow row soybeans are more responsive when adding more intensive management factors.

### EFFECT OF ROW SPACING ON YIELD WITH AND WITHOUT HIGH MANAGEMENT

row spacing	30-INCH	20-INCH	GAIN
standard practice	70.0	74.2	+4.2
high technology	75.7	84.2	+8.5

Narrow rows increased yield by 4.2 bushels with standard management and 8.5 bushels under a high management system.



## FUNGICIDES, INSECTICIDES AND SEED TREATMENTS

## Seed Treatments

Your goal as a soybean grower is to produce a good stand that emerges evenly and is well distributed. That means getting as many seeds as possible to germinate and emerge without succumbing to cold and wet conditions or soil pathogens.

Many seed companies and growers have adopted seed treatments as a standard practice, and today you can't buy some brands or varieties without treatment. The array of active ingredients you can apply to seed is mind-boggling, including fungicides, insecticides, nematicides and biological inoculants.

UNTREATED SEED



FUNGICIDE, INSECTICIDE, NEMATICIDE



PHOTOS BY A.J. WOODWARD

Treated seed is more vigorous in its early growth pattern, outgrowing untreated seedlings.

UNTREATED SEED

[R2 growth stage, Champaign, Ill., 2012]



PHOTOS BY UNIVERSITY OF ILLINOIS CROP PHYSIOLOGY LAB

Make it a goal to add more pods. Adding one more pod to each soybean plant is worth two bushels per acre in final yield.

## Foliar Protection

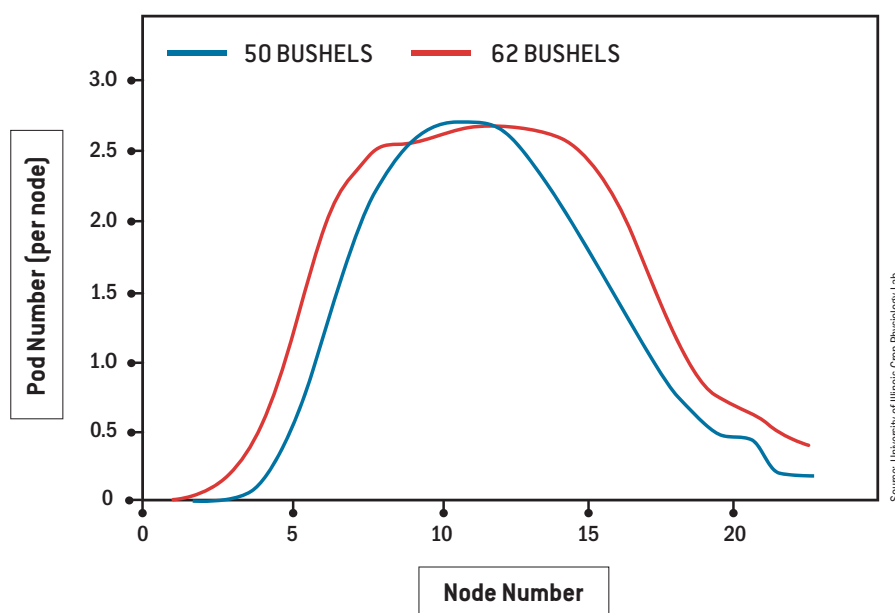
Soybean yield is influenced by pod number per plant. The difference between a 50- and 62-bushel yield is largely the number of pods in the middle portion of the plant.

About 60% of soybean yield comes from the middle nodes (nodes 7 to 13) of a plant. It is important to protect leaves at those nodes. The closest leaves provide most of the energy for pods at those nodes.

FUNGICIDE, INSECTICIDE, NEMATICIDE



Research at the University of Illinois showed that a complete seed treatment adds on average 1.5 bushels per acre in a standard system and 2.5 bushels in a high management system.



Source: University of Illinois Crop Physiology Lab

Research at the University of Illinois showed that a foliar fungicide plus insecticide applied at R3 adds on average 2.5 bushels per acre in a standard system and 3.5 bushels in a high management system.

## OMISSION PLOTS/SUMMARY

Below and his team conducted field research using an omission/addition plot design. With this approach you test each production factor either alone or in various combinations for one up to six treatments. Treatments included P, K, P and K combined, fungicide and insecticide combined, seed treatment and row spacing. The standard plot was a check to which individual practices were bumped up to the high-tech level for comparison. The high management plot included all six practices with individual practices set to the standard level for comparison.

The standard plot had a yield of 70 bushels per acre. The greatest yield increases (over 4 bushels) came from including P, P and K combined, or narrowing rows to 20-inches. Surprisingly, adding potassium didn't show a response, which is contrary to popular

belief. Seed treatments added 1.4 bushels alone and foliar protection added 2.6 bushels. As a grower, if you are conservative and want to limit your cost, phosphate application is your best investment. Row spacing is also an excellent investment if you already have a planter that can seed in 15 or 20-inch rows.

The high management plot had a yield of 84.2 bushels per acre, 14.2 more bushels than the standard plot. The greatest drop in yield, 8.5 bushels, occurred when soybeans were planted in 30-inch rows compared to 20-inch. Soybeans are more responsive to technology investments in a narrower row configuration. Removing P from the high management package had the second biggest impact on yield with a loss of 5 to 6 bushels followed by foliar protection and seed treatments at 3.2 and 2.4 bushels, respectively.

STANDARD VS. HIGH-TECH SYSTEMS 2014-15		
FACTOR	STANDARD SYSTEMS	HIGH-TECH SYSTEMS
<b>PHOSPHORUS</b>	P applied the year before to corn	75 lbs. P <sub>2</sub> O <sub>5</sub> as MicroEssentials-SZ (23 N 19 S, & 1.9 Zn) Banded 4-6" under row planting
<b>POTASSIUM</b>	K applied the year before to corn	75 lbs. K <sub>2</sub> O as Aspire (0.6 B) Broadcast Incorporated
<b>P &amp; K</b>	P & K applied the year before to corn	MESZ and Aspire applied as to the left
<b>FOLIAR PROTECTION</b>	No foliar protection	Fungicide and Insecticide applied at R3
<b>SEED TREATMENT</b>	Untreated or Fungicide only	Fungicide, Insecticide, Nematicide
<b>ROW SPACING</b>	30-inch row spacing	20-inch row spacing

SOYBEAN OMISSION PLOTS - AVERAGE OF 2014 & 2015 TRIALS				
FACTOR	STANDARD		HIGH-TECH	
	YIELD	ADD FACTOR	YIELD	OMIT FACTOR
	BUSHEL ACRE <sup>-1</sup>			
<b>NONE OR ALL</b>	<b>70.0</b>		<b>84.2</b>	
<b>PHOSPHATE</b>	<b>74.7</b>	<b>+4.7*</b>	<b>78.8</b>	<b>-5.4*</b>
<b>POTASSIUM</b>	<b>69.6</b>	<b>-0.4</b>	<b>84.8</b>	<b>+0.6</b>
<b>P &amp; K</b>	<b>74.4</b>	<b>+4.4*</b>	<b>78.2</b>	<b>-6.0*</b>
<b>FUNGICIDE + INSECTICIDE</b>	<b>72.6</b>	<b>+2.6*</b>	<b>81.0</b>	<b>-3.2*</b>
<b>SEED TREATMENT</b>	<b>71.4</b>	<b>+1.4</b>	<b>81.8</b>	<b>-2.4*</b>
<b>ROW SPACING</b>	<b>74.2</b>	<b>+4.2*</b>	<b>75.5</b>	<b>-8.5*</b>

\* Significantly different at P ≤ 0.05  
Average of 10 trials over 2014 and 2015 with two varieties in each trial

Soil fertility, particularly phosphorus, and narrowing row spacing, are the two most important management factors for increasing soybean yields.

SOURCE: UNIVERSITY OF ILLINOIS CROP PHYSIOLOGY LAB

## SUMMARY

## Conclusions

Soybean yield can be increased through better crop management and adoption of the right practices and technologies that optimize the system.

The high management research produced nearly a 15-bushel acre yield gain. At \$10 per bushel, that is a net increase of \$150 per acre. Managing soybeans can pay.

SOYBEAN OMISSION PLOTS 2014			
LOCATION	STANDARD	HIGH-TECH	Δ
	BUSHEL ACRE <sup>-1</sup>		
DEKALB	69.6	79.1	+9.5*
CHAMPAIGN	76.7	97.4	+20.7*
HARRISBURG	61.6	71.2	+9.6*
AVERAGE	69.3	83.0	+13.7*

SOYBEAN OMISSION PLOTS 2015			
LOCATION	STANDARD	HIGH-TECH	Δ
	BUSHEL ACRE <sup>-1</sup>		
DEKALB	56.5	73.6	+17.1*
CHAMPAIGN	80.1	98.9	+18.8*
HARRISBURG	75.1	83.2	+8.1*
AVERAGE	70.6	85.3	+14.7*

\* Significantly different at  $P \leq 0.05$   
Average of 10 trials over 2014 and 2015 with two varieties in each trial

SOURCE: UNIVERSITY OF ILLINOIS CROP PHYSIOLOGY LAB

Each of the six secrets independently can increase yield and when combined into a system they act synergistically. Identify the factors limiting your soybean yield and select the “secrets” and practices that work together to optimize yield and profitability.

## KEY POINTS TO REMEMBER

1

- Early planting and planting fuller maturities increases yield.

2

- Phosphorus increasingly is becoming the limiting nutrient to yield.

3

- Protect the foliage — about 60% of soybean yield comes from nodes 7 to 13, so protect leaves at or close to those nodes.

4

- Adding one more pod to each soybean plant adds 2 bushels per acre to yield.
- Planting in narrower rows increases yield, and the crop is more responsive to high yield management.

5

- Soybean varieties greatly differ in their response to high management practices, so select wisely.

6

**For more information, visit:**  
**<http://cropphysiology.cropsci.illinois.edu>**

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THANK  
YOU

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## ISA is here for our soybean farmers

Six Secrets is just one way your checkoff works for you. From ILSoyAdvisor.com, our soybean management hub, to the ISA Yield Challenge, double-crop initiative, local events, profitability radio and much more, ISA has the tools and resources to help you break your yield barriers and boost your bottom line, sustainably. Visit us at [ilsoy.org](http://ilsoy.org) or [ILSoyAdvisor.com](http://ILSoyAdvisor.com) – and be sure to sign up for the ILSoyAdvisor and Yield Challenge newsletters to stay informed.

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