

Nutrient Management for High Yield Soybeans

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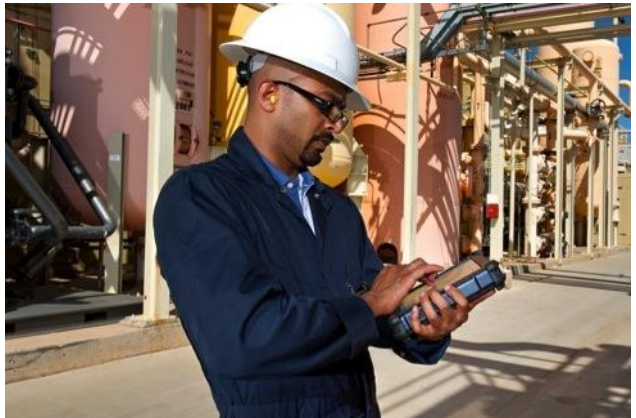


Soybean Nutritional Needs

Higher Yields Mean Higher Nutrient Needs

Grain	Lb/bu	50 bu	75 bu	100 bu
N	3.30	165	248	330
P_2O_5	0.73	37	55	73
K_2O	1.20	60	90	120
S	0.18	9	14	18
Total S	**0.35**	**18**	**26**	**35**

International Plant Nutrition Institute, 2014

Nutrient Uptake and Removal by 60 Bushel Soybean

(In pounds/acre, except for Zn and B, which are in ounces/acre)

Nutrient	Required	Removed	Harvest Index (%)
N	245	179	73
P_2O_5	43	35	81
K_2O	170	70	41
S	17	10	61
Zn	4.8 oz	2.0 oz	44
B	4.6 oz	1.6 oz	34

Agron. J. 107:563-573 (2015)

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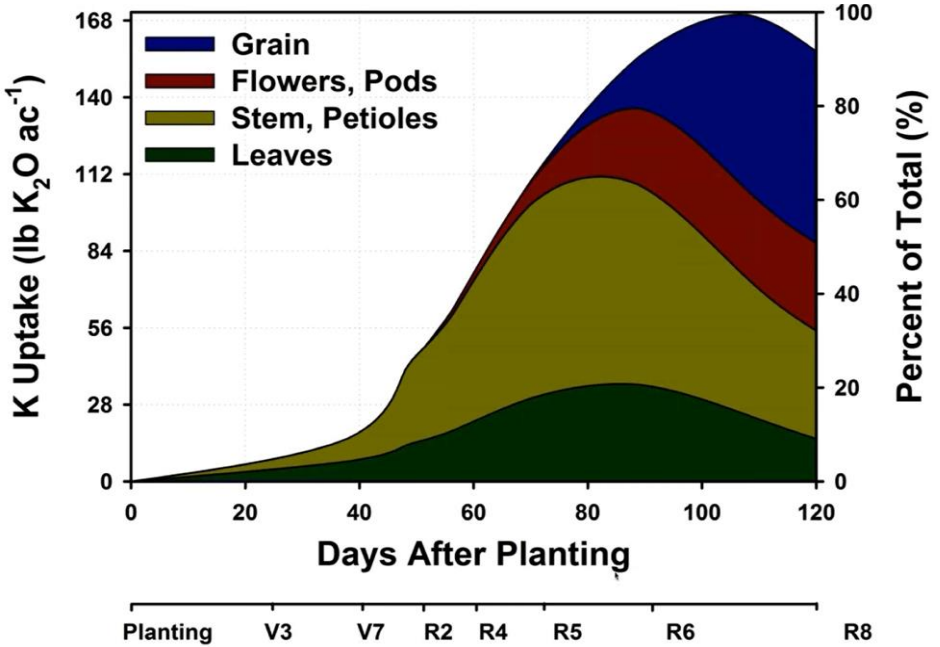
Potassium Uptake & Partitioning – 60 Bu/Acre Soybeans

Reservoir of K in Stem and Leaf Petioles

- Maximum uptake rate of 3.5 lb K_2O per acre per day for 50 days
- Most (50%) K accumulation is in the stem and leaf petioles
- Only 41% of total removed with grain, rest returned to soil



Data averaged across two varieties, two fertility regimes, and three site-years during 2012 and 2013 -- Agron. J. 107:563-573 (2015)

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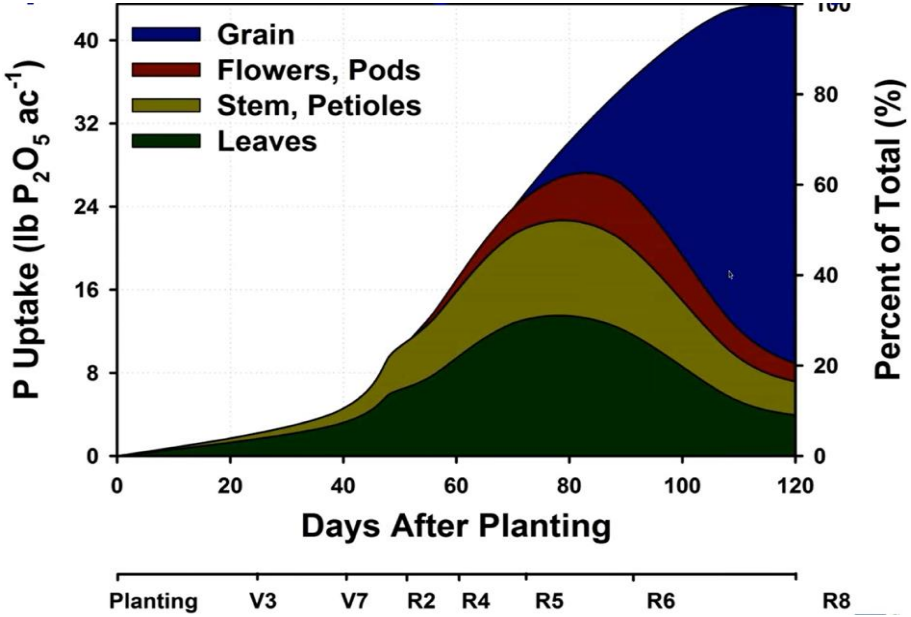
Phosphorus Uptake & Partitioning – 60 Bu/Acre Soybeans

High Seed Needs Must Come from Soil

- Rapid uptake for 70 days, 45% P uptake during seed fill
- No reservoir of P in the stem and leaf petioles
- Extensive grain removal (80%)



Data averaged across two varieties, two fertility regimes, and three site-years during 2012 and 2013 -- Agron. J. 107:563-573 (2015)

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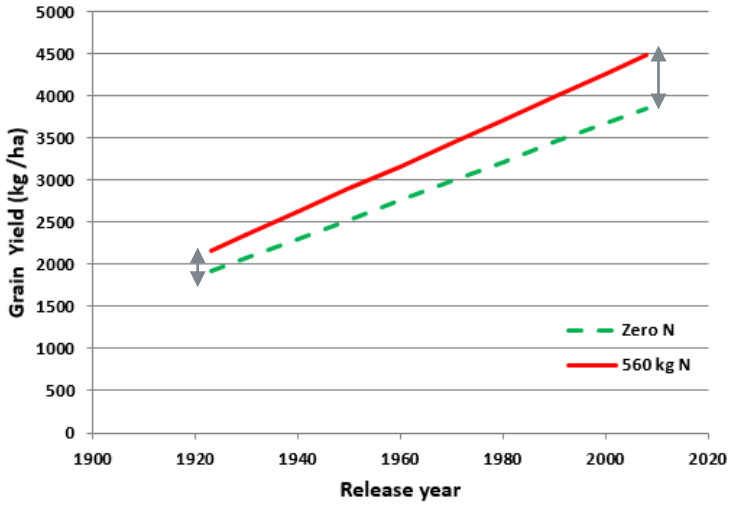
Modern Vs. Older Soybean Varieties Study

N Supply from Soil And Biological N Fixation was Insufficient to Maximize Yield

- Study in IL and IN tested 57 cultivars released between 1928 and 2008
- Grain yield increased with release year
- Grain yield (and protein) also increased with N fertilization
- The yield (and protein) response to N was higher with the modern varieties
- They yield response to N occur despite high soil fertility (OM levels of 2.9 to 4.1%)

Grain yield of cultivars released from 1923 to 2008 (MG3)



Crop Science, 54:340-348 (2014)

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Modern Soybeans Differ from Older Cultivars

Traditional Fertilizer Recommendations are Based on 50+ Year-Old Research

- Greater leaf N concentration and N accumulation throughout the season in modern varieties
  - Increased leaf retention, less leaf senescence in lower canopy
  - Increased photosynthetic activity
- Increased nutrient allocation at full seed (R6) in modern varieties
  - 21% leaf N allocation in 1923 Vs. 32% in 2011
  - 64% total N removal in 1923 Vs. 75% total N removal in 2011

Pictures taken 8/26/12 ©2019 Casteel, Purdue University

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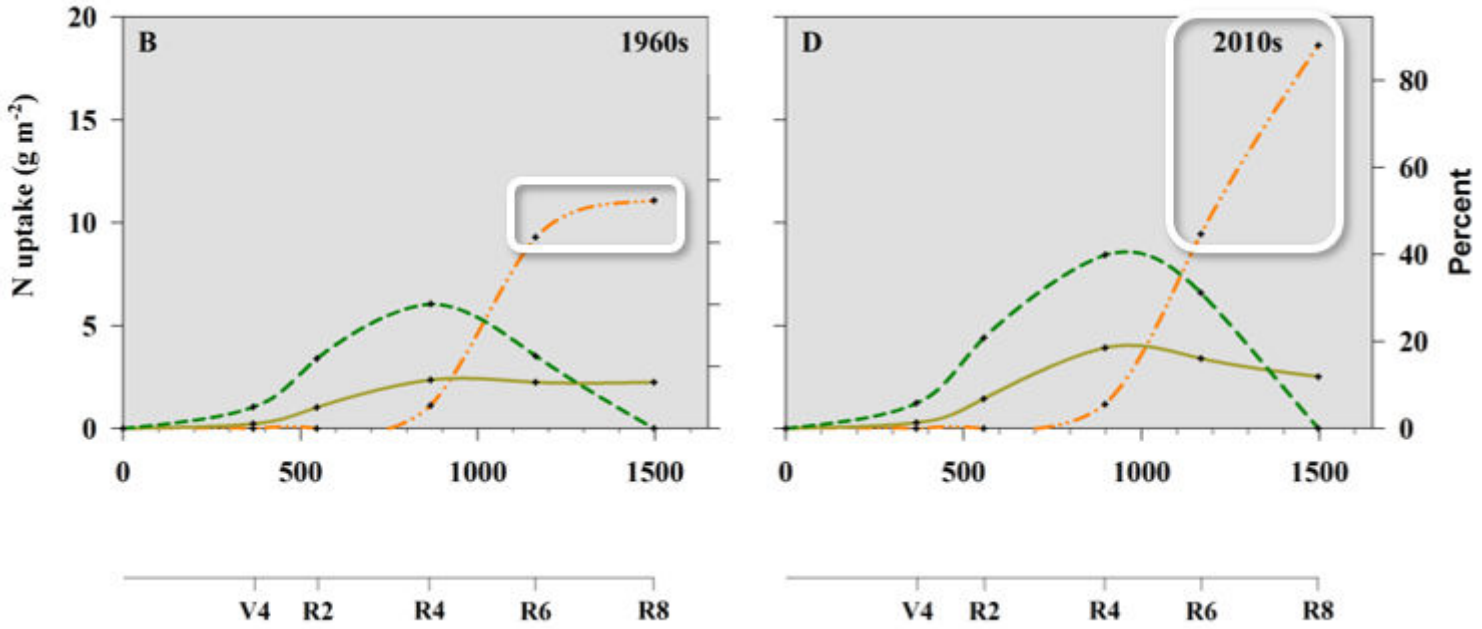
Nitrogen Accumulation: 1960s vs. 2010s

In Modern Varieties N Accumulation Continues Through the End of the Season



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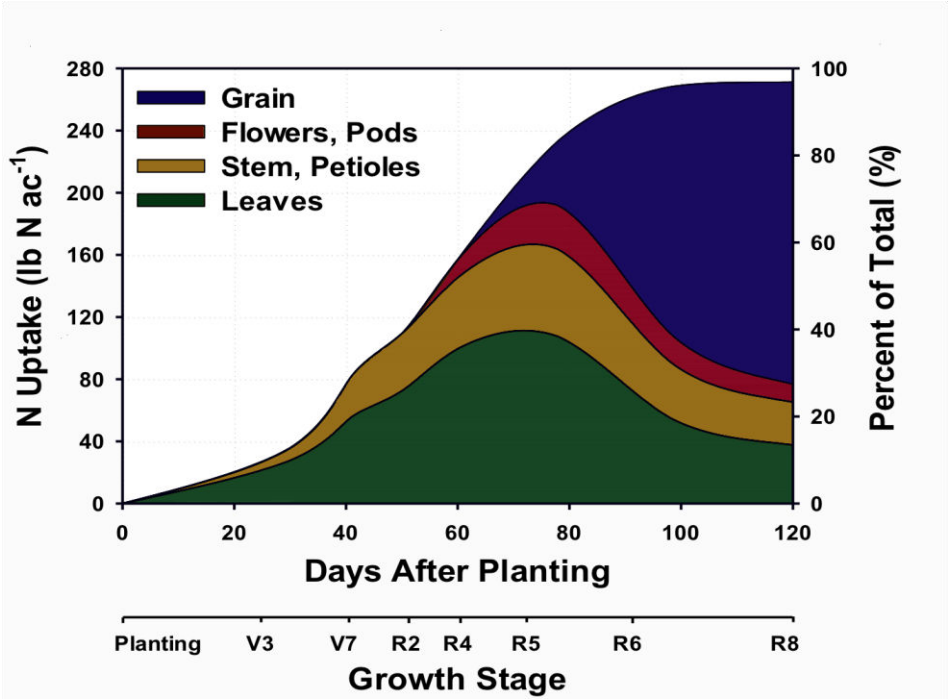
Nitrogen Uptake & Partitioning – 60 Bu/Acre Soybeans

Late-Season Nitrogen is Key

- Small amount N needed before N-fixation kicks in
- Only about half of the N accumulated in grain comes from N in other parts of the plant
- The other half of N accumulated in grain is taken up after flowering (R2)



Data averaged across two varieties, two fertility regimes, and three site-years during 2012 and 2013 -- Agron. J. 107:563-573 (2015)

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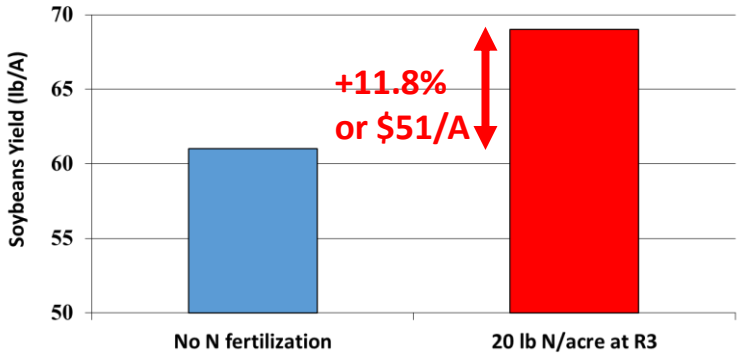
Late-Season N Fertilization

High-Yielding Soybeans Benefit from Late-Season N

- Study on irrigated soybeans in Kansas
- No N at planting
- 0, 20, and 40 lb N /acre at early pod (R3)
- Average yield increase of 6.9 bu/acre or 11.8%
- Benefit assumptions:
  - $9/bu soybean, so 6.9 bu/A grosses…… $62/A
  - $0.25/lb N; $6/A spreading cost, so 20 lb N/A cost ($11/A)
  - Net benefit …… $51/A



Lamond et al. (Journal Production Agriculture, 1998)

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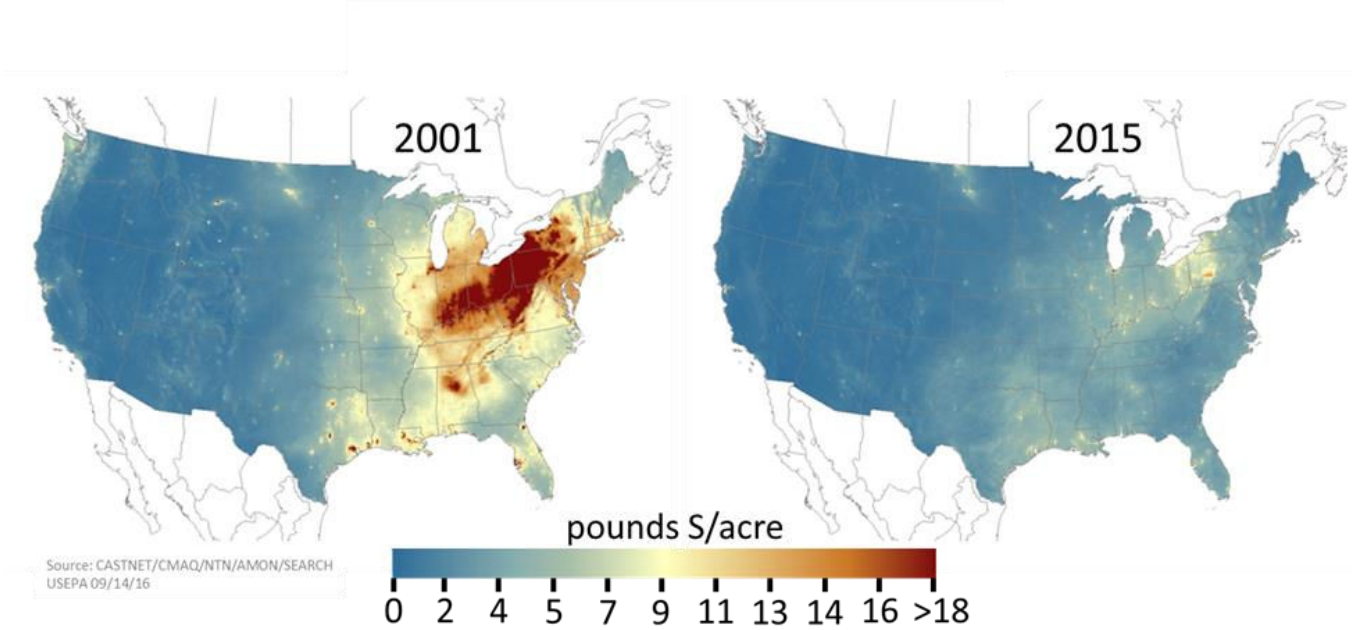
Reduction in Total Sulfur Deposition

Less Acid Rain Means Less “Free” Sulfur Received by Cropland



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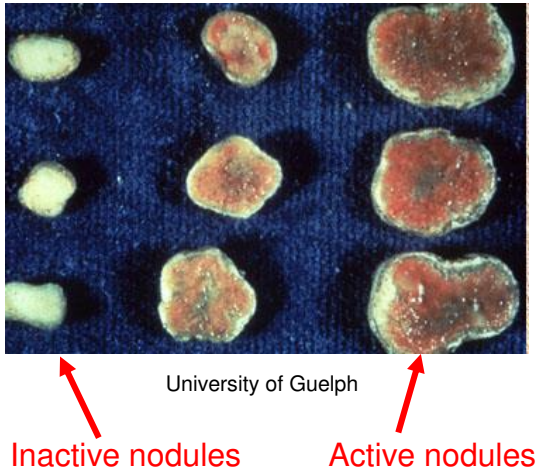
Early-Season N and S on Soybeans

Ammonium Sulfate Provides an Effective Starter Boost

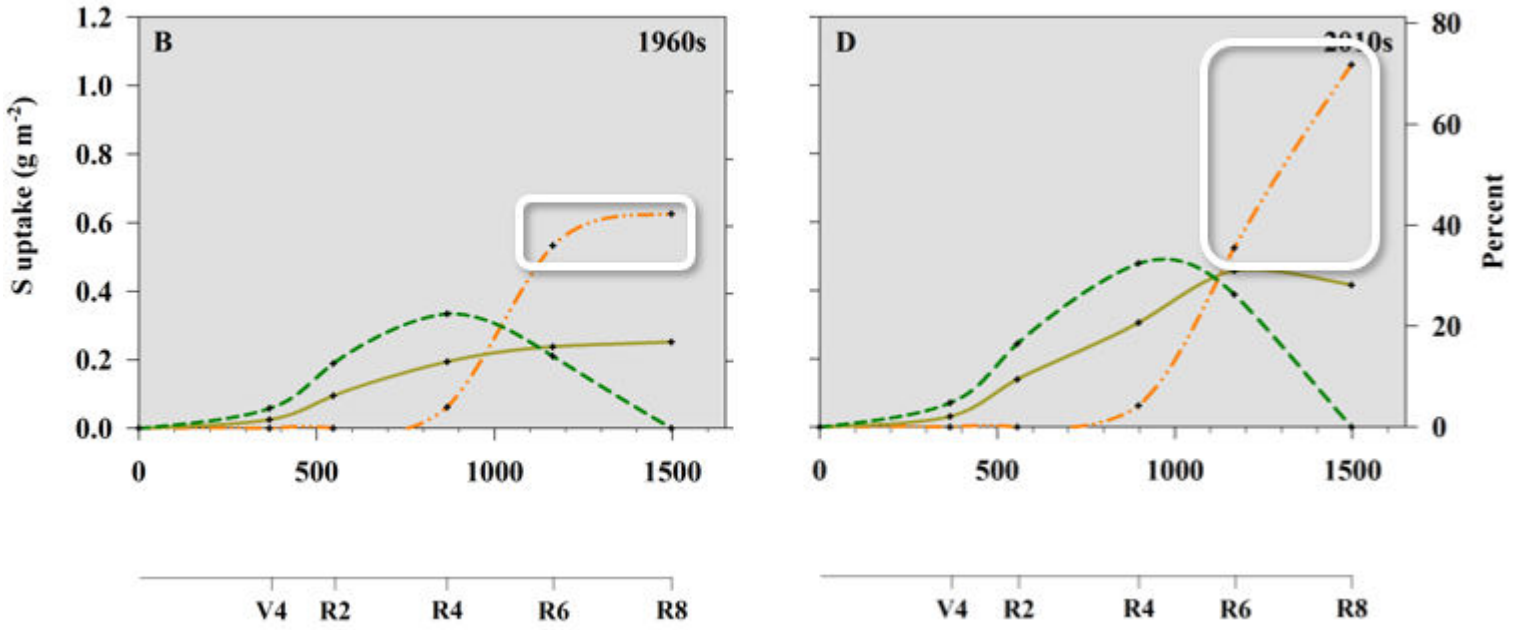
- Sulfur is required for the nodulation process
- 20 – 25 lb N/acre are often recommended since it takes a couple of weeks for nodules to be actively fixing atmospheric N
- The ammonium form of N can improve P and micronutrient (B, Zn, Mn) availability

Cross section of soybean nodules



Sulfur Accumulation: 1960s vs. 2010s

In Modern Varieties S Accumulation Continues Through the End of the Season



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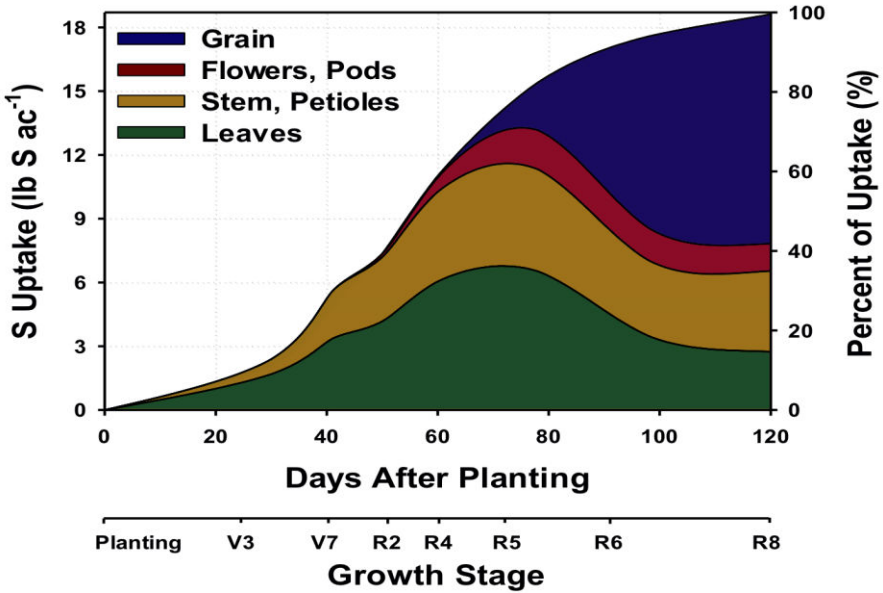
Sulfur Uptake & Partitioning – 60 Bu/Acre Soybeans

Sulfate-Sulfur is Also Key in the Reproductive Stages

- Similar to N, only about half the S accumulation in soybeans grain comes from other parts of the plant
- The other half of the S accumulated in the grain is taken up after flowering (R2)
- Late season availability of sulfate-S (pod and seed stages, or R4 to R6) in the soil profile is critical



Data averaged across two varieties, two fertility regimes, and three site-years during 2012 and 2013 -- Agron. J. 107:563-573 (2015)

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Sulfur Needs: Rough Mass Balance

Also Consider “Situational" S-Deficiencies (i.e. early planting cold temperatures)

Yield	Need	Sky	O.M.			
			1%	2%	3%	4%
bu/A	lb S/A					
			≈4	≈8	≈12	≈16
50	18	≈5	9	5	1	+3
75	26	≈5	17	13	9	5
100	35	≈5	26	23	18	14

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Maximizing Soybean Yields

Bigger Size, Greener color and Better Canopy Closure with Sulfate

No S

Sulf-N @ 20 lb S/acre

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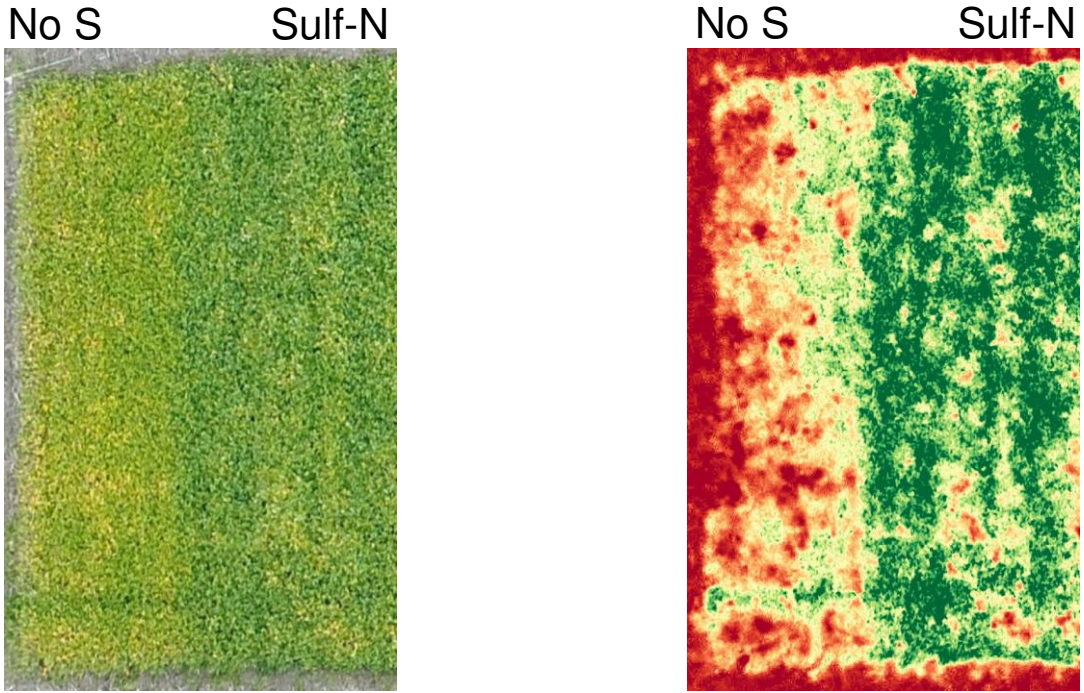
Aerial Photo and Normalized Difference Vegetation Index Map

Better Canopy Closure with Sulfate Fertilization



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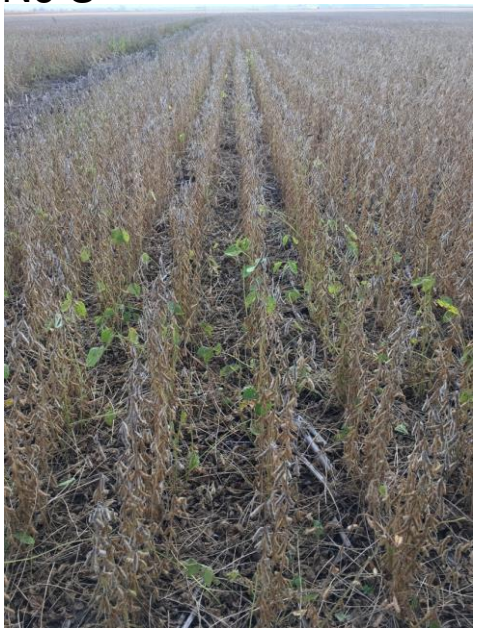
Maximizing Soybean Yields

Less Weed Intrusion, More Pod Retention and Branching with Sulfate Fertilization

No S



Sulf-N @ 20 lb S/acre

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Maximizing Soybean Yields

More Pods, Nods, and Branches with Sulfate Fertilization

No S

31 pods,
17 nodes,
1 branch

Sulf-N @ 20 lb S/acre

45 pods,
18 nodes,
2 branches

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Sulf-N Ammonium Sulfate on Soybeans

Split-Application of Non-Volatile, Readily-Available N and S

- Right time is about assuring nutrients are available when the crop needs them, as well as minimizing loss to the environment
  - Readily-available N and S early in the season are key to boost early growth and promote nodulation
  - Non-volatile N and readily-available S supplementation may be needed in the reproductive stages to ensure these elements don't become limiting in high yielding environments
    - High clearance, high-capacity spreaders have made it possible to top-dress ammonium sulfate at bloom to fulfill this need

How About Elemental Sulfur Sources?

Granular Elemental Sulfur (ES) Shows Inadequate Oxidation

- Sulfur must be in the sulfate form in order to be taken up by plant roots
- Powder ES oxidizes to sulfate due to a wide surface area in contact with soil particles
- Granular ES limits the contact between the ES and soil particles because the fine particles still cluster around the granule site even after disintegration and release of the micronized ES particles

Bentonite-ES 90 days after application

Bentonite-ES after granule disintegration

Chien et al., 2009; photos by Flore, Western Cooperative Fertilizers, Canada

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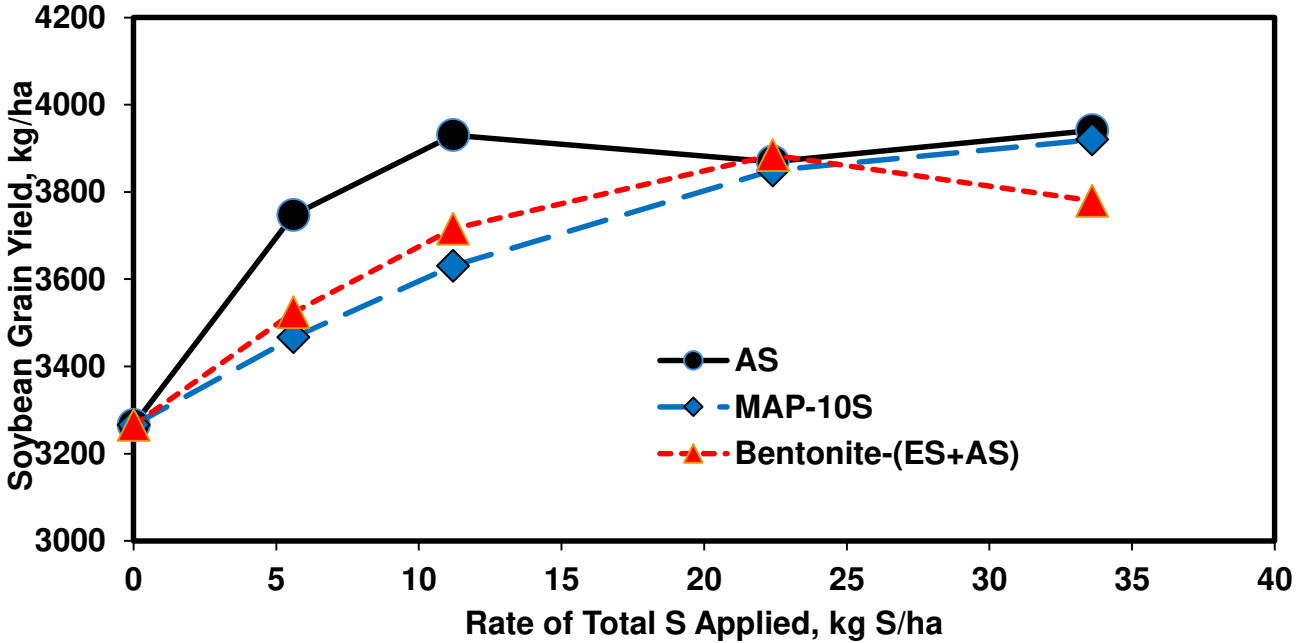
Soybean Response to Different Sulfur Sources

Ammonium Sulfate was Twice as Effective than Elemental-S Granular Products

- Field study with three different S sources:
  - Ammonium sulfate (24%AS-S)
  - MAP-10S (5%ES+5%AS-S)
  - Bentonite-(ES+AS) (25%ES+25%AS-S)
- AS achieved maximum yields at half the total S rate than the mixed-S granular sources



Communications in Soil Science and Plant Analysis, 50:22, 2941-2947

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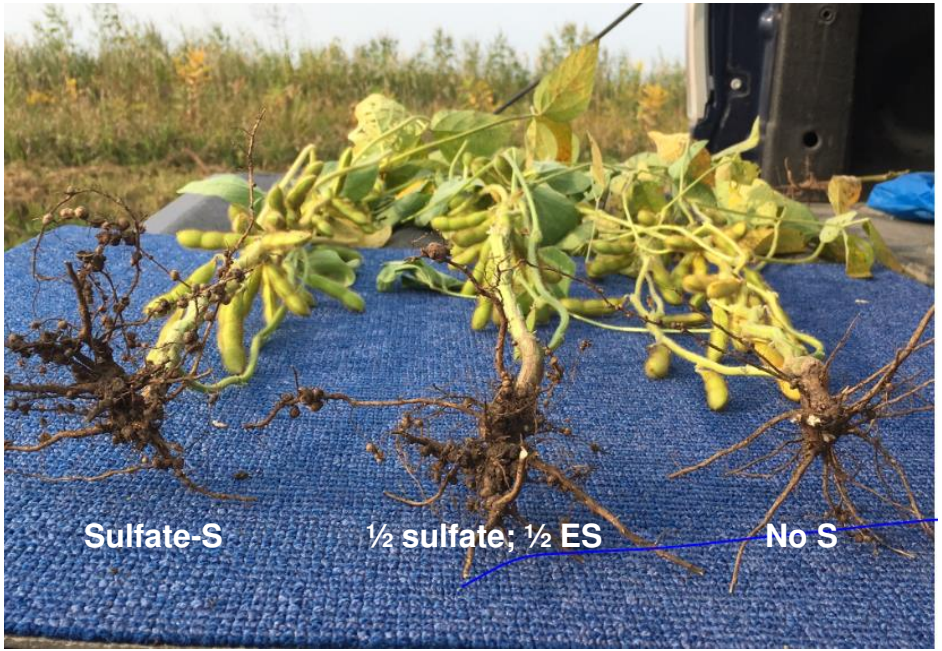
Sulfate-S

Key to Nodulation

- Samples were randomly picked from each fertilizer treatment at the 20 lb S/acre rate to compare nodulation
- Nodulation was higher when ammonium sulfate was applied
- Number of internodes per plant, and thus pods per plant, were also higher for the ammonium sulfate treatment



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Sulf-N® Ammonium Sulfate

Research-Supported, Field-Tested, Time-Proven

- 21 – 0 – 0 – 24S
- 100% ammonium-N
- 100% sulfate-S

Sulfur Availability To Plants

100% Of Sulfur In Ammonium Sulfate Is Immediately Plant-Available

Sulfate Sulfur > Powder ES > Granular Micronized ES
Roots only take up sulfate sulfur
ES must oxidize to sulfate first
Granular ES also suffers locality effect

ES = elemental sulfur

Agron. J. 2016; 108: 1-11