Final Technical Report

Project Title:	**Systems that Improve Nutrient Efficiency, Foliar Protection, and Yield of Soybean: 2022 Summary (Year 2)**
Principle Investigator(s):	Dr. Shaun N. Casteel – Purdue Agronomy, Extension Soybean Agronomist **S22-03**
Date:	August 2023
Specify Quarter (Q.1, Q.2, Q.3, Q.4)	Final
Current Project Period:	
Date Final Report Due:	4/30/23

1. Outputs - Explain what you did, what was discovered, and what was learned as a result of the research project.

- Report outputs completed during the reporting period that contribute to the goals and objectives of the project (do not include publications here, they are to be reported separately in the block below).
- Do not include findings or conclusions that have been reached; these are to be reported separately as changes in knowledge in the outcomes section.
- Include a description of how the results have been disseminated to communities of interest or how the product is being shared. This report narrative is required of all projects.
- For a project just initiated, please note that status.
- Narrative is limited to 3,200 characters and spaces.

S-NPK Nutrient Use Efficiency

We evaluated the interactions of S, N, P, and K in 2022 at three locations (Wanatah, LaCrosse, and West Lafayette) to represent various soil types (e.g., CEC, texture). Nine S-NPK regimes were arranged in a 2 x 4 factorial plus untreated control as the baseline treatments. Two S levels were 0 and 20 lb S/ac via ammonium sulfate (AMS). Four NPK levels were: 17.5 lb N/ac (via AMS or urea), 40 lb P_2O_5/ac via triple super phosphate (TSP, 0-45-0), and 60 lb K_2O/ac via KCl (0-0-60). These were applied as individual nutrient treatments then in full combinations. All fertilizer sources were broadcasted prior to soybean emergence.

A single variety was used at our S-deficient location of LaCrosse since these fields are bulk planted. The 9 S-NPK regimes were factored across two varieties (chloride includer: P30T99, and chloride intermediate: P34T21) to total 18 treatments at Wanatah and West Lafayette (high fertility) Indiana.

Plant stands were taken near V2 and harvest on all the treatments. Most recent mature leaves were taken at R2 to R3 for all treatments to determine nutritional status. Yield was determined with small plot harvest and adjusted to 13% grain moisture. Grain subsamples were collected to determine seed size, protein, and oil.

Soil samples were taken within each replication prior to fertilizer application and averaged across the five replications. Soil fertility was not lacking at any location, but differences in locations were noted such as organic matter and CEC (Table 1).

Sulfur x Foliar Protection

Twelve treatments were designed in a 3 x 4 factorial. Three S levels were 0, 20 lb S/ac prior emergence, and 20 lb S/ac at V4. Ammonium sulfate (AMS) was the source and broadcasted to the soil surface. Four foliar protection levels were none, fungicide (Revytek @ 8 oz/ac), insecticide (Fastac CS @ 3.2 oz/ac), and fungicide + insecticide at early R4 (full pod). These 12 treatments were replicated five times within each of the following locations: Wanatah, LaCrosse (S-deficient location), and West Lafayette (high fertility) Indiana. Most recent mature leaves were taken R2 to 3 as a baseline for AMS effects then all treatments 10-14 days after the R4 foliar protection (late R4 to R5) to determine nutritional status. Yield was determined with small plot harvest. Grain subsamples were collected to determine seed size, protein, and oil.

Soil samples were taken within each replication prior to fertilizer application and averaged across the five replications. Soil phosphorus and potassium was somewhat low at Wanatah. Otherwise, soil fertility was not lacking at any location, but differences in locations were noted such as organic matter and CEC (Table 6).

2. Outcomes/Impacts - Explain the beneficial results (potential yield increase, financial benefits, new use, pollution or erosion reduction, change of behavior, etc.) of this project for farmers and other stakeholders.

- Describe how findings, results, techniques, or other products that were developed from the project generated or contributed to an outcome/impact.
- Describe the results of the project evaluation. Indicate how resources and activities helped to produce project outputs and achieve project outcomes and impacts.

- This report narrative is required of all projects.
- For a project just initiated, please note that status.
- Narrative is limited to 3,200 characters and spaces.

S-NPK Nutrient Use Efficiency

LaCrosse 2022. Soybean response to sulfur was very strong in the first half of the growing season, which were confirmed with leaf nutrition (Table 2). Soybean treated with AMS (individually or in combination) were highest in N, P, K, S, Mn, and Cu. The N:S ratio was highly imbalanced (over 20:1) in all treatments that did not have AMS applied. This ratio was more balanced (~17:1) when AMS was applied. Individual nutrient applications of N, P, and K did not improve these respective nutrients in the leaves (Table 2). The individual application of potash (0-0-60) impeded N concentration, which continues to confirm the negative effects of the Cl on nodulation and fixation (i.e., Cl toxic to root hairs and thereby, inhibit or delay nodulation and fixation). This negative impact translated to a yield suppression of 7.6 bu/ac when compared to the untreated control (UTC). The addition of AMS to K did improve yield compared to K alone, but it did not improve yield above the UTC. The addition of N and P did not offset the yield penalty from K. Late season drought severely impacted the yield potential and response to the AMS. Pod development and seed fill were compromised as the drought hasten senescence (i.e., seed weights were similar regardless of fertility treatment, Table 2). Even with the lack of yield response to AMS, protein was improved (~35% → ~37%) and oil declined (~22.5% → 21.5%).

Variety x S-NPK: Wanatah 2022. Variety did not interact with S-NPK fertility treatments at Wanatah in 2022. The main effect of S-NPK treatments did influence the leaf nutrition at R2 (full bloom). The AMS-containing treatments improved S, Zn, and N:S ratio. However, these improvements were small and the S concentration in the non-AMS treatments were not considered deficient (Table 3). As seen at LaCrosse, the application of potash alone resulted in the lowest concentration of N in the leaves. Yield, seed weight, protein, and oil were not impacted by S-NPK fertility which is likely linked to the late season drought conditions that were observed at Wanatah (similar to LaCrosse). Varietal differences were noted in seed weight, protein, oil, N, P, S, Mn, Cu, B, and N:S, but no yield differences.

Variety x S-NPK: West Lafayette, 2022. In general, variety did not interact with S-NPK fertility treatments at West Lafayette in 2022. Leaf nutrition was improved by AMS-containing treatments on leaf S (~0.27 → 0.30%S) and N:S (17.5 → 16.5) with no other nutrient changes regardless of N, P, K, and/or S treatments (Table 4). The greatest yield improvements were with P and AMS+P (~6.5 bu/ac) followed by the addition of AMS alone (3.8 bu/ac); which, were related to increases in seed weight (17.3 → ~18.0 g per 100 seeds). The lowest yielding treatments were the untreated control (66.7 bu), K (68.1 bu) and AMS+K (68.5 bu). Protein was improved with AMS-containing treatments (0.5 to 1.0%); whereas, oil was reduced (Table 4). Variety impacted seed weight, protein, oil, N, P, S, and B, but yield did not differ.

Sulfur x Foliar Protection

Lacrosse, 2022. Plant population was near 100,000 plants/ac during early and late season counts with no differences based on treatments. Baseline leaf nutrition at R3 was improved with the AMS-containing treatments for N, P, K, Ca, Mg, S, Mn, and Cu. Leaf S was deficient (0.22% S) and leaf N:S ratio was highly imbalanced (~20:1) when AMS was not applied. Leaf S and N:S improved with the addition of AMS (0.32% S and 17.3, respectively). Leaf N increased in a stepwise fashion with the addition of AMS (4.3%N < 5.5% N < 5.8% N, Table 7). The foliar protection applications at R4 did not alter the leaf nutrient concentrations. AMS-containing treatments continued to provide adequate leaf N, P, K, S, Mn, and Cu when taken ~10 days after the R4 foliar protection applications. Leaf N and S concentrations were improved to 5.5% N and 0.33% S with the addition of AMS with a N:S balance of ~17:1 (Table 7).

Foliar protection did not impact yield, seed weight, protein, and oil. Yield was increased only 3.3 bu/ac with AMS treatments due to drought conditions during pod development and seed fill. Seed weight was marginally higher with AMS treatments (Table 7). However, protein was improved with AMS additions (35.3% vs. 37.3% and 38.1%) while oil decreased slightly.

Wanatah, 2022. Plant population was near 100,000 plants/ac during early and late season counts with no differences based on treatments. Baseline leaf N, S, and Mn at R3 was improved with the AMS-containing treatments though none were deficient (Table 8). Leaf N:S was balanced (~17:1) regardless of AMS treatment. The foliar protection applications at R4 did not alter the leaf nutrient concentrations. AMS-containing treatments improved leaf P, S, and Mn when taken ~10 days after the R4 foliar protection applications. Leaf S was close to critical levels with a marginal improvement from AMS treatments (0.27% S vs. 0.29%S) and subsequently, a marginal improvement in N:S ratio (Table 8). Yield, protein, and oil were not influenced by AMS or foliar protection with averages of 58.9 bu/ac, 39.2 % protein, and 19.5% oil. Late season drought hastened senescence at this location as well.

West Lafayette, 2022. Plant population was near 100,000 plants/ac at V2 and 94,000 plants/ac at harvest with no differences based on treatments. Baseline leaf nutrition at R2 was improved with the AMS-containing treatments for N, K, Ca, and S. Leaf S was somewhat low (0.28% S), but not deficient and leaf N:S ratio was imbalanced (~18:1) when AMS was not applied. Leaf S and N:S improved with the addition of AMS (0.33% S and 16.3, respectively). Leaf N increased in a stepwise fashion with the addition of AMS (5.1%N < 5.3% N < 5.6% N, Table 9). The combination of fungicide and insecticide did improve leaf N and Mn while slightly decreasing K. Otherwise, the foliar protection applications at R4 did not alter the leaf nutrient concentrations. AMS-containing treatments were the highest in leaf N, S, and Mn when taken ~10 days after the R4 foliar protection applications. Leaf N and S concentrations were improved to 5.4% N and 0.30% S with the addition of AMS with a N:S balance of ~17:1 (Table 9).

Yield, seed weight, protein, and oil were not influenced by the interaction of AMS and foliar protection. The addition of AMS increased yield (71.3 → 76.3 bu/ac), seed weight (17.4 → 18.0 g per 100 seeds), and protein (35.6 → 37.1%) when pooled over foliar protection. The combination of fungicide and insecticide with AMS increased yield the most (80.3 bu/ac); whereas, fungicide and insecticide alone did not increase yield.

3. Publications/Extension/Outreach - Describe how findings and results were shared. Report number of website hits, number of meetings where results shared, number of people attending meetings, etc.

- List publications, documents, meetings or events that are specific to the project during this reporting period.
- Include only those publications, documented meetings not previously reported.
- Include research and extension publications, handouts, electronic publications, websites, etc.

- If there are no publications, documents or meetings to report for the period, leave this field blank.
- Narrative is limited to 3,200 characters and spaces.

The results of these trials have been shared throughout the 2022 growing season at Purdue field days and DTC training workshops. I shared some of these findings at many major conferences with industry and Extension: Corteva's North America Conference (AgroCon), Crop Life Webinar (national), Ag Lab Testing Association (national), Maizex (Ontario), and Sylvite (Ontario). Additional state and regional conferences like Indiana CCA Conference and Purdue Crop Management Workshop. Initial recommendations based on these trials have been shared through written articles in Purdue Pest and Crop Newsletter and CCA corner of Indiana Prairie Farmer as well as Purdue Crop Chat.

Conclusions and Recommendations

The application of potash (0-0-60, KCl) near planting has impeded soybean yield 2 out of 8 site-years since 2019 (yield decreases of 3.4 and 7.6 bu/ac on coarse-textured soil). These yield suppressions were likely linked to Cl toxicity to the developing roots, root hairs, and nodules rather than the potassium itself. Leaf N often decreased in the potash treatments, but reset with the addition of AMS. The addition of AMS offset the yield penalty, but the yields did not differ than the untreated control. Farmers that are blending potash and AMS may not be realizing the full yield potential of their fields as the AMS is simply offsetting the Cl toxicity. Soil K levels were adequate in all site-years and the addition of potash did not improve yield in the remaining 6 site-years. We evaluated varieties that were classed as Cl includers and Cl intermediate with no apparent advantage in the loam and silty clay loam soils.

The addition of AMS improved yield in 6 out of 8 site-years with increases from 3 to 13 bu/ac. The combination of AMS and phosphorus (triple superphosphate, 0-45-0) was the highest yielding combination in 4 of 8 site-years even when soil P was adequate. Leaf nutrition (primarily N, S, and Mn) was enhanced with the addition of AMS in most site-years.

Farmers should avoid applying potash (0-0-60, KCl) close to soybean planting to protect developing roots and nodules. Potash applications should be at least a month before planting or even longer if the soil can retain the potassium (i.e., higher CEC soils). These trials indicate that soybean benefit more from sulfur and phosphorus combinations for the current growing season than any other nutrient combination. Earlier application timing of phosphorus (triple superphosphate or MAP or DAP), potassium (potash), and sulfur (AMS) needs to be evaluated to determine if the Cl toxicity can be avoided and if the synergy in sulfur and phosphorus can be replicated across timing of nutrient application.

Pre-emerge applications of AMS improved leaf N, S, and N:S ratio in all site-years; and improved yield and protein in 3 of 5 site-years of the foliar protection trials (2021 and 2022). The highest yield was from the combination of AMS applied prior to emergence followed by foliar protection with fungicide and insecticide at R4 in 2 of 5 site-years; whereas, the individual treatment did not yield as much. The best opportunities for high yield management of soybean are based on timely plantings, adequate supply of sulfur (and phosphorus), and protection of leaves and pods with fungicide and insecticide when warranted.

4. Project Modifications - Describe any significant changes to project content from original funded project proposal.

Select one of the following options:

__x__ Not applicable for this period, nothing significant to report.

_____Report narrative entered in the box below.

Explanation:

5. Completion Date - Describe any foreseen possibility of a no cost extension request. Be specific as possible as to why a no cost extension might be requested.

Select one of the following options:

___x__Project completed on schedule.

_____Project delay explanation for any extension.

Explanation:

6. Attachments: Attach any copies of graphs, charts, publications, reports, field day flyers, etc. regarding project.

See below

Table 1. Soil fertility at the time of planting at West Lafayette, Wanatah, and LaCrosse in 2022.

	OM	CEC	ph	P	K	Mg	Ca	S	Zn	Mn	Cu
W.Laf	4.2	24.8	7.1	68	216	697	3598	15.4	17.3	28.2	5.4
Wanatah	2.5	14.8	5.9	53	122	361	1676	15.0	2.3	17.6	2.7
LaCrosse	2.2	10.1	6.5	75	126	270	1269	10.6	1.5	11.2	1.3

Table 2. Effects of S-NPK fertility at Rice Farm (LaCrosse, IN) in 2022 on grain yield, seed weight, protein, oil, and leaf nutrition at R2 (full bloom).

LaCrosse 22																								
Source	Yield		Seed Wt		Protein		Oil		N		P		K		S		Zn	Mn		Cu		B	N_S	
UTC	50.8	a	16.2	ab	34.6	c	22.5	cd	4.5	ef	0.35	cd	2.25	cde	0.218	cd	36	41	b	8.6	cd	35	20.6	b
N	48.8	a	15.9	b	35.2	c	23.0	ab	4.4	ef	0.35	cd	2.16	e	0.204	d	34	38	b	8.0	cd	34	22.0	a
P	51.4	a	16.5	a	35.3	c	22.7	bc	4.7	d	0.36	c	2.22	de	0.232	c	33	42	b	8.8	bc	31	20.9	ab
K	43.2	b	16.2	ab	35.1	c	23.3	a	4.2	f	0.34	d	2.30	cde	0.206	d	34	38	b	7.8	d	32	20.9	ab
NPK	43.6	b	15.3	c	35.0	c	23.0	abc	4.5	e	0.36	c	2.35	bcd	0.220	cd	35	41	b	8.6	cd	30	20.8	ab
AMS	52.1	a	16.4	ab	37.3	ab	21.3	f	5.4	a	0.42	a	2.56	a	0.335	a	36	48	a	10.3	a	32	16.2	c
AMS+P	52.8	a	16.2	ab	37.0	b	21.9	de	5.4	ab	0.41	ab	2.41	abc	0.314	b	35	48	a	9.6	ab	30	17.3	c
AMS+K	50.9	a	16.0	ab	37.9	a	21.6	ef	5.2	bc	0.39	b	2.40	abc	0.310	b	36	49	a	9.6	ab	29	16.8	c
AMS+PK	52.0	a	16.0	ab	37.4	ab	22.0	de	5.1	c	0.40	ab	2.48	ab	0.308	b	38	53	a	10.0	a	31	16.7	c
Fert	**		*		***		***		***		***		*		***		ns	***		***		ns	***	
CV (%)	7.9		3.0		2.4		2.3		4.3		6.2		7.0		6.1		11.4	11.9		8.2		14.2	5.9	

Means separated at alpha 0.10

Table 3. Effects of Variety x S-NPK fertility at Pinney (Wanatah, IN) in 2022 on grain yield, seed weight, protein, oil, and leaf nutrition at R2 (full bloom).

Pinney 22	Pooled Over Varieties																			
Source	Yield	Seed Wt	Protein	Oil	N		P		K		S		Zn		Mn		Cu	B	N_S	
UTC	60.7	17.7	38.7	20.7	5.35	cd	0.37	c	1.85	d	0.297	d	47	d	39	cd	11	49	18.0	bc
N	59.8	17.8	38.8	20.9	5.37	bcd	0.38	bc	1.90	bcd	0.296	d	49	abc	39	d	11	48	18.2	ab
P	61.9	17.9	39.0	20.8	5.52	a	0.39	ab	1.86	d	0.310	b	47	d	41	b	11	50	17.8	cd
K	60.4	17.9	38.8	20.8	5.32	d	0.37	c	1.89	cd	0.296	d	47	cd	41	bc	12	49	18.0	bc
NPK	58.3	18.0	39.4	20.6	5.55	a	0.40	a	2.02	a	0.303	c	50	a	44	a	12	48	18.3	a
AMS	59.3	18.1	38.8	20.5	5.53	a	0.38	bc	1.87	d	0.317	a	49	ab	40	bcd	12	47	17.5	e
AMS+P	59.8	18.3	39.2	20.7	5.49	ab	0.38	bc	1.89	cd	0.314	ab	48	bcd	41	bc	11	48	17.5	e
AMS+K	57.9	18.0	39.2	20.4	5.49	a	0.37	c	1.95	ab	0.313	ab	49	ab	44	a	12	45	17.6	de
AMS+PK	58.7	18.3	39.5	20.2	5.47	abc	0.38	bc	1.94	bc	0.311	b	49	ab	45	a	11	46	17.6	de
Var	ns	*	***	**	*		*		ns		***		ns		**		*	***	***	
Fert	ns	ns	ns	ns	*		*		**		***		**		**		ns	ns	**	
Var*Fert	ns	ns	ns	ns	ns		ns		ns		ns		ns		ns		ns	ns	ns	
CV (%)	7.1	3.2	2.2	3.0	2.8		4.1		5.3		3.4		4.7		10.0		5.6	10.0	3.0	
30T99	60.1	17.8	39.8	20.3	5.5		0.38		1.92		0.315		48		43		11	46	17.6	
P34T21	59.2	18.2	38.3	20.9	5.4		0.38		1.90		0.298		49		40		12	50	18.1	

Means separated at alpha 0.10

Table 4. Effects of Variety x S-NPK fertility at ACRE (West Lafayette, IN) in 2022 on grain yield, seed weight, protein, oil, and leaf nutrition at R2 (full bloom).

ACRE22	Pooled Over Varieties																		
Source	**Yield**		**Seed Wt**		**Protein**		**Oil**		**N**	**P**	**K**	**S**		**Zn**	**Mn**	**Cu**	**B**	**N_S**	
UTC	66.7	d	17.3	e	37.6	bc	21.2	ab	4.8	0.29	1.92	0.273	c	58	38	9.9	60	17.4	a
N	69.3	c	17.4	de	37.2	c	21.6	a	4.8	0.30	1.95	0.272	c	56	39	10.0	59	17.6	a
P	73.1	a	17.8	bc	38.1	ab	21.1	b	4.9	0.32	2.05	0.276	c	53	39	10.4	61	17.8	a
K	68.1	cd	17.4	de	38.0	ab	21.0	b	4.8	0.32	2.05	0.272	c	54	36	10.1	60	17.6	a
NPK	69.9	c	17.5	cde	38.4	a	20.8	bc	4.8	0.32	1.98	0.275	c	55	39	9.8	61	17.6	a
AMS	70.5	bc	18.1	a	38.6	a	20.4	c	4.9	0.31	2.01	0.296	ab	56	37	9.8	60	16.5	b
AMS+P	72.8	ab	18.0	ab	38.1	ab	20.3	c	5.0	0.32	1.99	0.303	a	57	38	9.7	59	16.3	b
AMS+K	68.5	cd	17.6	cd	38.4	a	20.9	bc	4.8	0.30	1.99	0.294	b	59	42	9.6	62	16.5	b
AMS+PK	69.4	c	17.7	bc	38.5	a	20.8	bc	4.8	0.31	2.08	0.299	ab	57	46	9.6	61	16.0	b
Var	ns		**		***		***		**	*	ns	**		ns	ns	ns	***	ns	
Fert	**		**		*		*		ns	ns	ns	***		ns	ns	ns	ns	***	
Var*Fert	ns		ns		ns		ns		ns	ns	ns	x		ns	ns	x	ns	ns	
CV (%)	4.6		2.4		2.4		3.6		3.1	8.5	7.7	2.8		7.7	19.9	8.3	3.4	3.0	
30T99	69.9		17.8		38.9		20.5		5.0	0.32	2.02	0.293		56	39	9.9	57	17.0	
P34T21	69.7		17.5		37.3		21.3		4.7	0.31	1.98	0.275		56	39	9.9	64	17.1	

Means separated at alpha 0.10

Table 6. Soil fertility at the time of planting at West Lafayette, Wanatah, and LaCrosse in 2022.

	OM	CEC	ph	P	K	Mg	Ca	S	Zn	Mn	Cu
LaCrosse	2.4	10.5	6.5	70	135	286	1297	10.4	1.6	10.8	1.4
Wanatah	2.1	15.5	6.1	15	81	426	1781	10.6	1.3	28.4	2.3
W. Lafayette	3.5	22.0	6.4	36	118	722	2718	6.6	1.7	12.6	2.6

Table 7. Effects of AMS x Foliar Protection on leaf N, S, and N:S at R2 and R4; yield, seed size, protein, and oil in 2022 at LaCrosse.

LaCrosse 2022																					
AMS	**Protect**	**N @ R3**		**S @ R3**		**N:S @ R3**		**N @ R4**		**S @ R4**		**N:S @ R4**		**Yield**		**Seed Wt**		**Protein**		**Oil**	
None	None	4.5	**4.3 c**	0.22	**0.22 c**	20.6	**19.9 a**	4.5	**4.4 b**	0.23	**0.22 b**	20.0	**19.9 a**	48.1	**50.7 b**	16.0	**16.3 b**	35.3	**35.3 c**	22.6	**22.5 a**
	Fung.	4.4		0.23		19.5		4.4		0.22		20.1		51.9		16.6		35.4		22.8	
	Insect.	4.4		0.22		19.7		4.4		0.22		19.7		52.2		16.2		35.3		22.5	
	Both	4.1		0.21		20.0		4.4		0.22		19.8		50.4		16.4		35.3		22.3	
PRE	None	5.4	**5.5 b**	0.31	**0.32 b**	17.5	**17.3 b**	5.3	**5.5 a**	0.31	**0.33 a**	17.2	**17.0 b**	55.2	**54.0 a**	16.7	**16.7 ab**	37.4	**37.3 b**	21.3	**21.4 b**
	Fung.	5.5		0.32		17.3		5.7		0.34		16.8		53.9		16.7		37.3		21.3	
	Insect.	5.5		0.32		16.9		5.4		0.33		16.5		53.6		16.6		37.3		21.3	
	Both	5.5		0.32		17.3		5.6		0.32		17.3		53.4		16.7		37.3		21.7	
V4	None	6.0	**5.8 a**	0.34	**0.34 a**	17.5	**17.2 b**	5.8	**5.6 a**	0.35	**0.34 a**	16.3	**16.5 b**	53.7	**54.0 a**	16.6	**17.0 a**	38.8	**38.1 a**	21.2	**21.3 b**
	Fung.	5.8		0.34		17.3		5.5		0.33		16.5		55.5		16.5		37.5		21.6	
	Insect.	5.9		0.35		16.9		5.6		0.34		16.4		52.4		17.3		38.2		20.9	
	Both	5.6		0.33		17.2		5.6		0.34		16.6		54.5		17.6		37.9		21.6	
AMS		***		***		***		***		***		***		x		x		***		***	
Protect		ns		x		ns		ns		ns		ns		ns		ns		ns		ns	
AMS*Protect		ns		ns		ns		ns		ns		ns		ns		ns		ns		ns	
CV (%)		4.8		4.9		3.3		4.7		5.6		3.5		5.7		4.1		2.3		2.7	

Table 8. Effects of AMS x Foliar Protection on leaf N, S, and N:S at R2 and R4; yield, seed size, protein, and oil in 2022 at Wanatah.

Pinney 2022													
AMS	Protect	N @ R2	S @ R2	N:S @ R2	N @ R4	S @ R4		N:S @ R4		Yield	Seed Wt	Protein	Oil
None	None	4.8 b	0.29 b	16.9	4.6	0.27	0.27 b	17.1	17.0 a	58.5	17.0	38.9	19.5
	Fung.				4.5	0.26		16.9		59.4	17.7	38.9	19.9
	Insect.				4.5	0.27		17.0		59.1	16.9	38.6	19.9
	Both				4.6	0.27		17.2		61.0	16.9	39.0	19.8
PRE	None	5.1 a	0.31 a	16.5	4.5	0.29	0.29 a	15.5	15.9 b	57.9	16.9	39.7	19.0
	Fung.				4.6	0.28		16.2		59.7	17.4	39.6	19.1
	Insect.				4.5	0.28		15.8		58.3	17.0	39.2	19.4
	Both				4.6	0.29		16.0		59.4	16.8	38.8	19.9
V4	None	5.2 a	0.31 a	17.1	4.6	0.29	0.29 a	16.0	15.7 b	58.8	17.1	39.4	19.4
	Fung.				4.6	0.30		15.4		57.9	17.1	39.7	19.1
	Insect.				4.5	0.29		15.6		58.0	16.9	38.9	20.0
	Both				4.6	0.29		15.9		58.2	17.1	39.6	19.1
AMS		*	*	ns	ns	**		***		ns	ns	ns	ns
Protect		.	.	.	ns	ns		ns		ns	*	ns	ns
AMS*Protect		.	.	.	ns	ns		ns		ns	ns	ns	ns
CV (%)		4.0	4.3	3.6	3.2	2.6		3.1		2.9	2.2	2.0	3.3

Means separated at alpha 0.10

Table 9. Effects of AMS x Foliar Protection on leaf N, S, and N:S at R2 and R4; yield, seed size, protein, and oil in 2022 at West Lafayette.

ACRE 2022																					
AMS	Protect	N @ R2		S @ R2		N:S @ R2		N @ R4		S @ R4		N:S @ R4		Yield		Seed Wt		Protein		Oil	
None	None	5.1	5.1 c	0.28	0.28 c	17.9	17.8 a	4.4	4.7 b	0.24	0.25 b	18.3	18.2 a	69.2	71.3 b	17.4	17.4 b	35.8	35.6 b	22.2	22.2 a
	Fung.	5.0		0.29		17.4		4.3		0.24		17.9		72.1		17.4		35.7		22.2	
	Insect.	5.1		0.28		18.1		4.4		0.25		18.1		70.3		17.2		35.7		22.5	
	Both	5.1		0.29		17.9		4.5		0.24		18.6		73.7		17.6		35.3		21.8	
PRE	None	5.3	5.3 b	0.33	0.33 b	16.3	16.3 b	5.1	5.4 a	0.29	0.30 a	17.7	17.6 b	74.7	76.3 a	17.7	18.0 a	37.2	37.1 a	21.8	21.7 b
	Fung.	5.3		0.33		16.3		5.1		0.29		17.4		75.9		18.1		37.6		21.7	
	Insect.	5.3		0.33		16.2		5.1		0.29		17.7		74.5		17.9		37.2		21.7	
	Both	5.3		0.32		16.4		5.3		0.30		17.7		80.3		18.2		36.6		21.6	
V4	None	5.6	5.6 a	0.36	0.34 a	15.9	16.2 b	5.1	5.3 a	0.30	0.30 a	16.9	16.9 c	76.7	76.9 a	18.0	18.1 a	37.8	37.4 a	21.5	21.6 b
	Fung.	5.6		0.34		16.4		5.1		0.30		16.9		76.5		18.2		37.7		21.5	
	Insect.	5.6		0.34		16.4		5.2		0.31		16.8		75.9		17.8		37.3		21.6	
	Both	5.4		0.34		16.2		5.2		0.31		17.0		78.7		18.3		36.8		21.6	
AMS		***		***		***		***		***		***		**		**		***		*	
Protect		ns		ns		ns		**		ns		ns		**		**		ns		ns	
AMS*Protect		ns		ns		ns		ns		ns		ns		ns		ns		ns		ns	
CV (%)		3.6		4.4		4.6		3.0		3.6		2.8		3.5		1.9		2.0		2.6	

Means separated at alpha 0.10

Systems that Improve Nutrient Efficiency, Foliar Protection, and Yield of Soybean: 2022 Summary (Year 2)

Dr. Shaun N. Casteel – Purdue Agronomy, Extension Soybean Agronomist

S-NPK Nutrient Use Efficiency

We evaluated the interactions of S, N, P, and K in 2022 at three locations (Wanatah, LaCrosse, and West Lafayette) to represent various soil types (e.g., CEC, texture). Nine S-NPK regimes were arranged in a 2 x 4 factorial plus untreated control as the baseline treatments. Two S levels were 0 and 20 lb S/ac via ammonium sulfate (AMS). Four NPK levels were: 17.5 lb N/ac (via AMS or urea), 40 lb P_2O_5/ac via triple super phosphate (TSP, 0-45-0), and 60 lb K_2O/ac via KCl (0-0-60). These were applied as individual nutrient treatments then in full combinations. All fertilizer sources were broadcasted prior to soybean emergence.

A single variety was used at our S-deficient location of LaCrosse since these fields are bulk planted. The 9 S-NPK regimes were factored across two varieties (chloride includer: P30T99, and chloride intermediate: P34T21) to total 18 treatments at Wanatah and West Lafayette (high fertility) Indiana.

Plant stands were taken near V2 and harvest on all the treatments. Most recent mature leaves were taken at R2 to R3 for all treatments to determine nutritional status. Yield was determined with small plot harvest and adjusted to 13% grain moisture. Grain subsamples were collected to determine seed size, protein, and oil.

Soil samples were taken within each replication prior to fertilizer application and averaged across the five replications. Soil fertility was not lacking at any location, but differences in locations were noted such as organic matter and CEC (Table 1).

Table 1. Soil fertility at the time of planting at West Lafayette, Wanatah, and LaCrosse in 2022.

	OM	CEC	ph	P	K	Mg	Ca	S	Zn	Mn	Cu
W.Laf	4.2	24.8	7.1	68	216	697	3598	15.4	17.3	28.2	5.4
Wanatah	2.5	14.8	5.9	53	122	361	1676	15.0	2.3	17.6	2.7
LaCrosse	2.2	10.1	6.5	75	126	270	1269	10.6	1.5	11.2	1.3

LaCrosse 2022. Soybean response to sulfur was very strong in the first half of the growing season, which were confirmed with leaf nutrition (Table 2). Soybean treated with AMS (individually or in combination) were highest in N, P, K, S, Mn, and Cu. The N:S ratio was highly imbalanced (over 20:1) in all treatments that did not have AMS applied. This ratio was more balanced (~17:1) when AMS was applied. Individual nutrient applications of N, P, and K did not improve these respective nutrients in the leaves (Table 2). The individual application of potash (0-0-60) impeded N concentration, which continues to confirm the negative effects of the Cl on nodulation and fixation (i.e., Cl toxic to root hairs and thereby, inhibit or delay nodulation and fixation). This negative impact translated to a yield suppression of 7.6 bu/ac when compared to the untreated control (UTC). The addition of AMS to K did improve yield compared to K alone, but it did not improve yield above the UTC. The addition of N and P did not offset the yield penalty from K. Late season drought severely impacted the yield potential and response to the AMS. Pod development and seed fill were compromised as the drought hasten senescence (i.e., seed weights were similar regardless of fertility treatment, Table 2). Even with the lack of yield response to AMS, protein was improved (~35% → ~37%) and oil declined (~22.5% → 21.5%).

Table 2. Effects of S-NPK fertility at Rice Farm (LaCrosse, IN) in 2022 on grain yield, seed weight, protein, oil, and leaf nutrition at R2 (full bloom).

LaCrosse 22																								
Source	Yield		Seed Wt		Protein		Oil		N		P		K		S		Zn	Mn		Cu		B	N_S	
UTC	50.8	a	16.2	ab	34.6	c	22.5	cd	4.5	ef	0.35	cd	2.25	cde	0.218	cd	36	41	b	8.6	cd	35	20.6	b
N	48.8	a	15.9	b	35.2	c	23.0	ab	4.4	ef	0.35	cd	2.16	e	0.204	d	34	38	b	8.0	cd	34	22.0	a
P	51.4	a	16.5	a	35.3	c	22.7	bc	4.7	d	0.36	c	2.22	de	0.232	c	33	42	b	8.8	bc	31	20.9	ab
K	43.2	b	16.2	ab	35.1	c	23.3	a	4.2	f	0.34	d	2.30	cde	0.206	d	34	38	b	7.8	d	32	20.9	ab
NPK	43.6	b	15.3	c	35.0	c	23.0	abc	4.5	e	0.36	c	2.35	bcd	0.220	cd	35	41	b	8.6	cd	30	20.8	ab
AMS	52.1	a	16.4	ab	37.3	ab	21.3	f	5.4	a	0.42	a	2.56	a	0.335	a	36	48	a	10.3	a	32	16.2	c
AMS+P	52.8	a	16.2	ab	37.0	b	21.9	de	5.4	ab	0.41	ab	2.41	abc	0.314	b	35	48	a	9.6	ab	30	17.3	c
AMS+K	50.9	a	16.0	ab	37.9	a	21.6	ef	5.2	bc	0.39	b	2.40	abc	0.310	b	36	49	a	9.6	ab	29	16.8	c
AMS+PK	52.0	a	16.0	ab	37.4	ab	22.0	de	5.1	c	0.40	ab	2.48	ab	0.308	b	38	53	a	10.0	a	31	16.7	c
Fert	**		*		***		***		***		***		*		***		ns	***		***		ns	***	
CV (%)	7.9		3.0		2.4		2.3		4.3		6.2		7.0		6.1		11.4	11.9		8.2		14.2	5.9	

Means separated at alpha 0.10

Variety x S-NPK: Wanatah 2022. Variety did not interact with S-NPK fertility treatments at Wanatah in 2022. The main effect of S-NPK treatments did influence the leaf nutrition at R2 (full bloom). The AMS-containing treatments improved S, Zn, and N:S ratio. However, these improvements were small and the S concentration in the non-AMS treatments were not considered deficient (Table 3). As seen at LaCrosse, the application of potash alone resulted in the lowest concentration of N in the leaves. Yield, seed weight, protein, and oil were not impacted by S-NPK fertility which is likely linked to the late season drought conditions that were observed at Wanatah (similar to LaCrosse). Varietal differences were noted in seed weight, protein, oil, N, P, S, Mn, Cu, B, and N:S, but no yield differences.

Table 3. Effects of Variety x S-NPK fertility at Pinney (Wanatah, IN) in 2022 on grain yield, seed weight, protein, oil, and leaf nutrition at R2 (full bloom).

Pinney 22	Pooled Over Varieties																			
Source	Yield	Seed Wt	Protein	Oil	N		P		K		S		Zn		Mn		Cu	B	N_S	
UTC	60.7	17.7	38.7	20.7	5.35	cd	0.37	c	1.85	d	0.297	d	47	d	39	cd	11	49	18.0	bc
N	59.8	17.8	38.8	20.9	5.37	bcd	0.38	bc	1.90	bcd	0.296	d	49	abc	39	d	11	48	18.2	ab
P	61.9	17.9	39.0	20.8	5.52	a	0.39	ab	1.86	d	0.310	b	47	d	41	b	11	50	17.8	cd
K	60.4	17.9	38.8	20.8	5.32	d	0.37	c	1.89	cd	0.296	d	47	cd	41	bc	12	49	18.0	bc
NPK	58.3	18.0	39.4	20.6	5.55	a	0.40	a	2.02	a	0.303	c	50	a	44	a	12	48	18.3	a
AMS	59.3	18.1	38.8	20.5	5.53	a	0.38	bc	1.87	d	0.317	a	49	ab	40	bcd	12	47	17.5	e
AMS+P	59.8	18.3	39.2	20.7	5.49	ab	0.38	bc	1.89	cd	0.314	ab	48	bcd	41	bc	11	48	17.5	e
AMS+K	57.9	18.0	39.2	20.4	5.49	a	0.37	c	1.95	ab	0.313	ab	49	ab	44	a	12	45	17.6	de
AMS+PK	58.7	18.3	39.5	20.2	5.47	abc	0.38	bc	1.94	bc	0.311	b	49	ab	45	a	11	46	17.6	de
Var	ns	*	***	**	*		*		ns		***		ns		**		*	***	***	
Fert	ns	ns	ns	ns	*		*		**		***		**		**		ns	ns	**	
Var*Fert	ns	ns	ns	ns	ns		ns		ns		ns		ns		ns		ns	ns	ns	
CV (%)	7.1	3.2	2.2	3.0	2.8		4.1		5.3		3.4		4.7		10.0		5.6	10.0	3.0	
30T99	60.1	17.8	39.8	20.3	5.5		0.38		1.92		0.315		48		43		11	46	17.6	
P34T21	59.2	18.2	38.3	20.9	5.4		0.38		1.90		0.298		49		40		12	50	18.1	

Means separated at alpha 0.10

Variety x S-NPK: West Lafayette, 2022. In general, variety did not interact with S-NPK fertility treatments at West Lafayette in 2022. Leaf nutrition was improved by AMS-containing treatments on leaf S (~0.27 → 0.30%S) and N:S (17.5 → 16.5) with no other nutrient changes regardless of N, P, K, and/or S treatments (Table 4). The greatest yield improvements were with P and AMS+P (~6.5 bu/ac) followed by the addition of AMS alone (3.8 bu/ac); which, were related to increases in seed weight (17.3 → ~18.0 g per 100 seeds). The lowest yielding treatments were the untreated control (66.7 bu), K (68.1 bu) and AMS+K (68.5 bu). Protein was improved with AMS-containing treatments (0.5 to 1.0%); whereas, oil was reduced (Table 4). Variety impacted seed weight, protein, oil, N, P, S, and B, but yield did not differ.

Table 4. Effects of Variety x S-NPK fertility at ACRE (West Lafayette, IN) in 2022 on grain yield, seed weight, protein, oil, and leaf nutrition at R2 (full bloom).

ACRE 22	Pooled Over Varieties																		
Source	Yield		Seed Wt		Protein		Oil		N	P	K	S		Zn	Mn	Cu	B	N_S	
UTC	66.7	d	17.3	e	37.6	bc	21.2	ab	4.8	0.29	1.92	0.273	c	58	38	9.9	60	17.4	a
N	69.3	c	17.4	de	37.2	c	21.6	a	4.8	0.30	1.95	0.272	c	56	39	10.0	59	17.6	a
P	73.1	a	17.8	bc	38.1	ab	21.1	b	4.9	0.32	2.05	0.276	c	53	39	10.4	61	17.8	a
K	68.1	cd	17.4	de	38.0	ab	21.0	b	4.8	0.32	2.05	0.272	c	54	36	10.1	60	17.6	a
NPK	69.9	c	17.5	cde	38.4	a	20.8	bc	4.8	0.32	1.98	0.275	c	55	39	9.8	61	17.6	a
AMS	70.5	bc	18.1	a	38.6	a	20.4	c	4.9	0.31	2.01	0.296	ab	56	37	9.8	60	16.5	b
AMS+P	72.8	ab	18.0	ab	38.1	ab	20.3	c	5.0	0.32	1.99	0.303	a	57	38	9.7	59	16.3	b
AMS+K	68.5	cd	17.6	cd	38.4	a	20.9	bc	4.8	0.30	1.99	0.294	b	59	42	9.6	62	16.5	b
AMS+PK	69.4	c	17.7	bc	38.5	a	20.8	bc	4.8	0.31	2.08	0.299	ab	57	46	9.6	61	16.0	b
Var	ns		**		***		***		**	*	ns	**		ns	ns	ns	***	ns	
Fert	**		**		*		*		ns	ns	ns	***		ns	ns	ns	ns	***	
Var*Fert	ns		ns		ns		ns		ns	ns	ns	x		ns	ns	x	ns	ns	
CV (%)	4.6		2.4		2.4		3.6		3.1	8.5	7.7	2.8		7.7	19.9	8.3	3.4	3.0	
30T99	69.9		17.8		38.9		20.5		5.0	0.32	2.02	0.293		56	39	9.9	57	17.0	
P34T21	69.7		17.5		37.3		21.3		4.7	0.31	1.98	0.275		56	39	9.9	64	17.1	

Means separated at alpha 0.10

Sulfur x Foliar Protection

Twelve treatments were designed in a 3 x 4 factorial. Three S levels were 0, 20 lb S/ac prior emergence, and 20 lb S/ac at V4. Ammonium sulfate (AMS) was the source and broadcasted to the soil surface. Four foliar protection levels were none, fungicide (Revytek @ 8 oz/ac), insecticide (Fastac CS @ 3.2 oz/ac), and fungicide + insecticide at early R4 (full pod). These 12 treatments were replicated five times within each of the following locations: Wanatah, LaCrosse (S-deficient location), and West Lafayette (high fertility) Indiana. Most recent mature leaves were taken R2 to 3 as a baseline for AMS effects then all treatments 10-14 days after the R4 foliar protection (late R4 to R5) to determine nutritional status. Yield was determined with small plot harvest. Grain subsamples were collected to determine seed size, protein, and oil.

Soil samples were taken within each replication prior to fertilizer application and averaged across the five replications. Soil phosphorus and potassium was somewhat low at Wanatah. Otherwise, soil fertility was not lacking at any location, but differences in locations were noted such as organic matter and CEC (Table 6).

Table 6. Soil fertility at the time of planting at West Lafayette, Wanatah, and LaCrosse in 2022.

	OM	CEC	ph	P	K	Mg	Ca	S	Zn	Mn	Cu
LaCrosse	2.4	10.5	6.5	70	135	286	1297	10.4	1.6	10.8	1.4
Wanatah	2.1	15.5	6.1	15	81	426	1781	10.6	1.3	28.4	2.3
W. Lafayette	3.5	22.0	6.4	36	118	722	2718	6.6	1.7	12.6	2.6

Lacrosse, 2022. Plant population was near 100,000 plants/ac during early and late season counts with no differences based on treatments. Baseline leaf nutrition at R3 was improved with the AMS-containing treatments for N, P, K, Ca, Mg, S, Mn, and Cu. Leaf S was deficient (0.22% S) and leaf N:S ratio was highly imbalanced (~20:1) when AMS was not applied. Leaf S and N:S improved with the addition of AMS (0.32% S and 17.3, respectively). Leaf N increased in a stepwise fashion with the addition of AMS (4.3%N < 5.5% N < 5.8% N, Table 7). The foliar protection applications at R4 did not alter the leaf nutrient concentrations. AMS-containing treatments continued to provide adequate leaf N, P, K, S, Mn, and Cu when taken ~10 days after the R4 foliar protection applications. Leaf N and S concentrations were improved to 5.5% N and 0.33% S with the addition of AMS with a N:S balance of ~17:1 (Table 7).

Foliar protection did not impact yield, seed weight, protein, and oil. Yield was increased only 3.3 bu/ac with AMS treatments due to drought conditions during pod development and seed fill. Seed weight was marginally higher with AMS treatments (Table 7). However, protein was improved with AMS additions (35.3% vs. 37.3% and 38.1%) while oil decreased slightly.

Table 7. Effects of AMS x Foliar Protection on leaf N, S, and N:S at R2 and R4; yield, seed size, protein, and oil in 2022 at LaCrosse.

LaCrosse 2022																					
AMS	**Protect**	**N @ R3**		**S @ R3**		**N:S @ R3**		**N @ R4**		**S @ R4**		**N:S @ R4**		**Yield**		**Seed Wt**		**Protein**		**Oil**	
None	None	4.5	**4.3 c**	0.22	**0.22 c**	20.6	**19.9 a**	4.5	**4.4 b**	0.23	**0.22 b**	20.0	**19.9 a**	48.1	**50.7 b**	16.0	**16.3 b**	35.3	**35.3 c**	22.6	**22.5 a**
	Fung.	4.4		0.23		19.5		4.4		0.22		20.1		51.9		16.6		35.4		22.8	
	Insect.	4.4		0.22		19.7		4.4		0.22		19.7		52.2		16.2		35.3		22.5	
	Both	4.1		0.21		20.0		4.4		0.22		19.8		50.4		16.4		35.3		22.3	
PRE	None	5.4	**5.5 b**	0.31	**0.32 b**	17.5	**17.3 b**	5.3	**5.5 a**	0.31	**0.33 a**	17.2	**17.0 b**	55.2	**54.0 a**	16.7	**16.7 ab**	37.4	**37.3 b**	21.3	**21.4 b**
	Fung.	5.5		0.32		17.3		5.7		0.34		16.8		53.9		16.7		37.3		21.3	
	Insect.	5.5		0.32		16.9		5.4		0.33		16.5		53.6		16.6		37.3		21.3	
	Both	5.5		0.32		17.3		5.6		0.32		17.3		53.4		16.7		37.3		21.7	
V4	None	6.0	**5.8 a**	0.34	**0.34 a**	17.5	**17.2 b**	5.8	**5.6 a**	0.35	**0.34 a**	16.3	**16.5 b**	53.7	**54.0 a**	16.6	**17.0 a**	38.8	**38.1 a**	21.2	**21.3 b**
	Fung.	5.8		0.34		17.3		5.5		0.33		16.5		55.5		16.5		37.5		21.6	
	Insect.	5.9		0.35		16.9		5.6		0.34		16.4		52.4		17.3		38.2		20.9	
	Both	5.6		0.33		17.2		5.6		0.34		16.6		54.5		17.6		37.9		21.6	
AMS		***		***		***		***		***		***		x		x		***		***	
Protect		ns		x		ns		ns		ns		ns		ns		ns		ns		ns	
AMS*Protect		ns		ns		ns		ns		ns		ns		ns		ns		ns		ns	
CV (%)		4.8		4.9		3.3		4.7		5.6		3.5		5.7		4.1		2.3		2.7	

Wanatah, 2022. Plant population was near 100,000 plants/ac during early and late season counts with no differences based on treatments. Baseline leaf N, S, and Mn at R3 was improved with the AMS-containing treatments though none were deficient (Table 8). Leaf N:S was balanced (~17:1) regardless of AMS treatment. The foliar protection applications at R4 did not alter the leaf nutrient concentrations. AMS-containing treatments improved leaf P, S, and Mn when taken ~10 days after the R4 foliar protection applications. Leaf S was close to critical levels with a marginal improvement from AMS treatments (0.27% S vs. 0.29%S) and subsequently, a marginal improvement in N:S ratio (Table 8). Yield, protein, and oil were not influenced by AMS or foliar protection with averages of 58.9 bu/ac, 39.2 % protein, and 19.5% oil. Late season drought hastened senescence at this location as well.

Table 8. Effects of AMS x Foliar Protection on leaf N, S, and N:S at R2 and R4; yield, seed size, protein, and oil in 2022 at Wanatah.

Pinney 2022													
AMS	**Protect**	**N @ R2**	**S @ R2**	**N:S @ R2**	**N @ R4**	**S @ R4**		**N:S @ R4**		**Yield**	**Seed Wt**	**Protein**	**Oil**
None	None	**4.8 b**	**0.29 b**	**16.9**	4.6	0.27	**0.27 b**	17.1	**17.0 a**	58.5	17.0	38.9	19.5
	Fung.				4.5	0.26		16.9		59.4	17.7	38.9	19.9
	Insect.				4.5	0.27		17.0		59.1	16.9	38.6	19.9
	Both				4.6	0.27		17.2		61.0	16.9	39.0	19.8
PRE	None	**5.1 a**	**0.31 a**	**16.5**	4.5	0.29	**0.29 a**	15.5	**15.9 b**	57.9	16.9	39.7	19.0
	Fung.				4.6	0.28		16.2		59.7	17.4	39.6	19.1
	Insect.				4.5	0.28		15.8		58.3	17.0	39.2	19.4
	Both				4.6	0.29		16.0		59.4	16.8	38.8	19.9
V4	None	**5.2 a**	**0.31 a**	**17.1**	4.6	0.29	**0.29 a**	16.0	**15.7 b**	58.8	17.1	39.4	19.4
	Fung.				4.6	0.30		15.4		57.9	17.1	39.7	19.1
	Insect.				4.5	0.29		15.6		58.0	16.9	38.9	20.0
	Both				4.6	0.29		15.9		58.2	17.1	39.6	19.1
AMS		*	*	ns	ns	**		***		ns	ns	ns	ns
Protect		.	.	.	ns	ns		ns		ns	*	ns	ns
AMS*Protect		.	.	.	ns	ns		ns		ns	ns	ns	ns
CV (%)		4.0	4.3	3.6	3.2	2.6		3.1		2.9	2.2	2.0	3.3

Means separated at alpha 0.10

West Lafayette, 2022. Plant population was near 100,000 plants/ac at V2 and 94,000 plants/ac at harvest with no differences based on treatments. Baseline leaf nutrition at R2 was improved with the AMS-containing treatments for N, K, Ca, and S. Leaf S was somewhat low (0.28% S), but not deficient and leaf N:S ratio was imbalanced (~18:1) when AMS was not applied. Leaf S and N:S improved with the addition of AMS (0.33% S and 16.3, respectively). Leaf N increased in a stepwise fashion with the addition of AMS (5.1%N < 5.3% N < 5.6% N, Table 9). The combination of fungicide and insecticide did improve leaf N and Mn while slightly decreasing K. Otherwise, the foliar protection applications at R4 did not alter the leaf nutrient concentrations. AMS-containing treatments were the highest in leaf N, S, and Mn when taken ~10 days after the R4 foliar protection applications. Leaf N and S concentrations were improved to 5.4% N and 0.30% S with the addition of AMS with a N:S balance of ~17:1 (Table 9).

Yield, seed weight, protein, and oil were not influenced by the interaction of AMS and foliar protection. The addition of AMS increased yield (71.3 → 76.3 bu/ac), seed weight (17.4 → 18.0 g per 100 seeds), and protein (35.6 → 37.1%) when pooled over foliar protection. The combination of fungicide and insecticide with AMS increased yield the most (80.3 bu/ac); whereas, fungicide and insecticide alone did not increase yield.

Table 9. Effects of AMS x Foliar Protection on leaf N, S, and N:S at R2 and R4; yield, seed size, protein, and oil in 2022 at West Lafayette.

ACRE 2022																					
AMS	**Protect**	**N @ R2**		**S @ R2**		**N:S @ R2**		**N @ R4**		**S @ R4**		**N:S @ R4**		**Yield**		**Seed Wt**		**Protein**		**Oil**	
	None	5.1		0.28		17.9		4.4		0.24		18.3		69.2		17.4		35.8		22.2	
None	Fung.	5.0	**5.1 c**	0.29	**0.28 c**	17.4	**17.8 a**	4.3	**4.7 b**	0.24	**0.25 b**	17.9	**18.2 a**	72.1	**71.3 b**	17.4	**17.4 b**	35.7	**35.6 b**	22.2	**22.2 a**
	Insect.	5.1		0.28		18.1		4.4		0.25		18.1		70.3		17.2		35.7		22.5	
	Both	5.1		0.29		17.9		4.5		0.24		18.6		73.7		17.6		35.3		21.8	
	None	5.3		0.33		16.3		5.1		0.29		17.7		74.7		17.7		37.2		21.8	
PRE	Fung.	5.3	**5.3 b**	0.33	**0.33 b**	16.3	**16.3 b**	5.1	**5.4 a**	0.29	**0.30 a**	17.4	**17.6 b**	75.9	**76.3 a**	18.1	**18.0 a**	37.6	**37.1 a**	21.7	**21.7 b**
	Insect.	5.3		0.33		16.2		5.1		0.29		17.7		74.5		17.9		37.2		21.7	
	Both	5.3		0.32		16.4		5.3		0.30		17.7		80.3		18.2		36.6		21.6	
	None	5.6		0.36		15.9		5.1		0.30		16.9		76.7		18.0		37.8		21.5	
V4	Fung.	5.6	**5.6 a**	0.34	**0.34 a**	16.4	**16.2 b**	5.1	**5.3 a**	0.30	**0.30 a**	16.9	**16.9 c**	76.5	**76.9 a**	18.2	**18.1 a**	37.7	**37.4 a**	21.5	**21.6 b**
	Insect.	5.6		0.34		16.4		5.2		0.31		16.8		75.9		17.8		37.3		21.6	
	Both	5.4		0.34		16.2		5.2		0.31		17.0		78.7		18.3		36.8		21.6	
AMS		***		***		***		***		***		***		**		**		***		*	
Protect		ns		ns		ns		**		ns		ns		**		**		ns		ns	
AMS*Protect		ns		ns		ns		ns		ns		ns		ns		ns		ns		ns	
CV (%)		3.6		4.4		4.6		3.0		3.6		2.8		3.5		1.9		2.0		2.6	

Means separated at alpha 0.10

Communication and Outreach

The results of these trials have been shared throughout the 2022 growing season at Purdue field days and DTC training workshops. I shared some of these findings at many major conferences with industry and Extension: Corteva's North America Conference (AgroCon), Crop Life Webinar (national), Ag Lab Testing Association (national), Maizex (Ontario), and Sylvite (Ontario). Additional state and regional conferences like Indiana CCA Conference and Purdue Crop Management Workshop. Initial recommendations based on these trials have been shared through written articles in Purdue Pest and Crop Newsletter and CCA corner of Indiana Prairie Farmer as well as Purdue Crop Chat.

Conclusions and Recommendations

The application of potash (0-0-60, KCl) near planting has impeded soybean yield 2 out of 8 site-years since 2019 (yield decreases of 3.4 and 7.6 bu/ac on coarse-textured soil). These yield suppressions were likely linked to Cl toxicity to the developing roots, root hairs, and nodules rather than the potassium itself. Leaf N often decreased in the potash treatments, but reset with the addition of AMS. The addition of AMS offset the yield penalty, but the yields did not differ than the untreated control. Farmers that are blending potash and AMS may not be realizing the full yield potential of their fields as the AMS is simply offsetting the Cl toxicity. Soil K levels were adequate in all site-years and the addition of potash did not improve yield in the remaining 6 site-years. We evaluated varieties that were classed as Cl includers and Cl intermediate with no apparent advantage in the loam and silty clay loam soils.

The addition of AMS improved yield in 6 out of 8 site-years with increases from 3 to 13 bu/ac. The combination of AMS and phosphorus (triple superphosphate, 0-45-0) was the highest yielding combination in 4 of 8 site-years even when soil P was adequate. Leaf nutrition (primarily N, S, and Mn) was enhanced with the addition of AMS in most site-years.

Farmers should avoid applying potash (0-0-60, KCl) close to soybean planting to protect developing roots and nodules. Potash applications should be at least a month before planting or even longer if the soil can retain the potassium (i.e., higher CEC soils). These trials indicate that soybean benefit more from sulfur and phosphorus combinations for the current growing season than any other nutrient combination. Earlier application timing of phosphorus (triple superphosphate or MAP or DAP), potassium (potash), and sulfur (AMS) needs to be evaluated to determine if the Cl toxicity can be avoided and if the synergy in sulfur and phosphorus can be replicated across timing of nutrient application.

Pre-emerge applications of AMS improved leaf N, S, and N:S ratio in all site-years; and improved yield and protein in 3 of 5 site-years of the foliar protection trials (2021 and 2022). The highest yield was from the combination of AMS applied prior to emergence followed by foliar protection with fungicide and insecticide at R4 in 2 of 5 site-years; whereas, the individual treatment did not yield as much. The best opportunities for high yield management of soybean are based on timely plantings, adequate supply of sulfur (and phosphorus), and protection of leaves and pods with fungicide and insecticide when warranted.