What have we learned from several years of foliar yield enhancement soybean trials in North Carolina?

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Introduction: North Carolina soybean producers are presented with a wide diversity of foliar products that could impact soybean yield. Profit margins are currently narrow for soybeans and much thought should go into the potential yield advantages and associated costs from the use of these various foliar products. Our goal at NC State University is to provide unbiased data on the impact of these products on soybean yield in diverse environments across the state. The NC State Soybean Extension program has been conducting foliar yield enhancement trials for the past six years across the state. While products have varied from year-to-year, this trial has generally included foliar fungicides and foliar fertilizers. Over the years, we have been able to identify some trends which will discussed later in this publication.

Materials and Methods: This study was conducted across 19 North Carolina environments from 2013-2018 (Table 1). At each location, standard grower production practices were used (variety, row spacing, seeding rate, soil-applied fertility). We asked growers not to apply any additional foliar products to research plots. The Soybean Extension program applied foliar treatments using a 4-wheeler mounted sprayer and applications were made based on targeted soybean growth stage. Each treatment was evaluated in four replications per location. Foliar products evaluated included fungicides, stress reducers, and fertilizers (Table 2). Nutrient applied in foliar fertilizers varied between products (Table 3). Grain yield was collected using a small-plot combine. Soybean yield data is reported at 13% moisture. All data analysis was conducted using PROC Mixed in SAS 9.4. Estimate statements were used to compare treatments to a non-treated control. If a *P*-value is <0.10 we consider that significant.

Table 1. Trial locations by County, year, average yield, participating County Extension Agent, and cooperating grower.

County	Year	Average Yield	Agent	Grower
Cherokee	2018	91 bu/A	Keith Wood	Ed Wood
Johnston	2018	47 bu/A	Tim Britton	Keith Smith
Pender	2018	25 bu/A	Mark Seitz	Don Rawls
Wake	2018	45 bu/A	Emily Mueller	Ryan Broadwell
Alamance	2017	56 bu/A	Dwayne Dabbs	Robert Saunders
Franklin	2017	40 bu/A	Charles Mitchell	Bell and Bell Farms
Tyrrell	2017	54 bu/A	Clayton Butcher	Green Valley
Alamance	2016	34 bu/A	Dwayne Dabbs	Saunders Farm

Randolph	2016	62 bu/A	Jon Wall	Nathan Johnson
Surry	2016	49 bu/A	Tim Hambrick	Draughn Farms
Catawba/Caldwell	2015	34 bu/A	Seth Nagy/George Place	Russell Hendrick
Wilson	2015	49 bu/A	Norman Harrell	Sharp Farms
Greene	2014	45 bu/A	Roy Thaggard	Tommy Hardy
Johnston	2014	24 bu/A	Tim Britton	Batten
Pamlico	2014	55 bu/A	Daniel Simpson	Spencer Farms
Bertie	2013	16 bu/A	Richard Rhodes	Ed Rawls
Hertford	2013	22 bu/A	Wendy Burgess	Jay Revelle
Pasquotank	2013	69 bu/A	Al Wood	Jeff Small
Union	2013	51 bu/A	Andrew Baucom	Cox Brothers

Table 2. Foliar treatment descriptions and years evaluated in the NC State Soybean Extension foliar yield enhancement trials.

Type of Product	Product	Timing	Rate Used	Year/Years Evaluated
Fungicide	Headline (1 MOA)	R2-R3	6 oz/A	2013, 2014, 2015, 2016
Fungicide	Quadris (1 MOA)	R2-R3	6.2 oz/A	2013, 2014, 2015
Fungicide	Domark (1 MOA)	R2-R3	4 oz/A	2013, 2014, 2015
Fungicide	Topguard (1 MOA)	R2-R3	12 oz/A	2013, 2014, 2015, 2016
Fungicide	Stratego Yld (2 MOA)	R2-R3	4.5 oz/A	2013, 2015, 2016, 2017, 2018
Fungicide	Quadris Top (2 MOA)	R2-R3	8 oz/A	2013, 2014, 2015, 2016, 2017, 2018
Fungicide	Priaxor (2 MOA)	R2-R3	4 oz/A	2013, 2014, 2015, 2016, 2017, 2018
Yield Enhancer	Sugar	V2-V4	2 lb/100 gal	2013, 2014, 2015, 2016, 2017
Stress Reducer	Photon	V2/V4 + R2	16 g/A + 16 g/A	2013, 2014, 2015
Stress Reducer	Photon	V2-V4	16 g/A	2014, 2015
Stress Reducer	Photon	R2	16 g/A	2014, 2015
Foliar Fertilizer	BioForge + Sugar	V2-V4	16 oz/A + 2 lb/100 gal	2014, 2015, 2016
Foliar Fertilizer	BioForge	V2-V4	16 oz/A	2014, 2015, 2016

Foliar Fertilizer	Soar Series I	Pre-bloom, full-bloom, and post-bloom	6 qt/A (total)	2013, 2014, 2015, 2016, 2017, 2018
Foliar Fertilizer	Soar Series II	Pre-bloom and full bloom	4 qt/A (total)	2013, 2014, 2015, 2016, 2017, 2018
Foliar Fertilizer	IronMan	V2/V4	2 qt/A	2016, 2017, 2018
Foliar Fertilizer	IronMan	R2/R4	2 qt/A	2016, 2017, 2018
Foliar Fertilizer	IronMan	V2/V4 + R2/R4	2 qt/A + 2 qt/A	2016, 2017, 2018
Foliar Fertilizer	N-Boost	V2-7 + R2	1 qt/A + 1 qt/A	2017, 2018
Foliar Fertilizer	N-Boost	R2	2 qt/A	2017, 2018
Foliar Fertilizer	Smart Quatro	V5-7	1 qt/A	2017, 2018
Foliar Fertilizer	Smart B-Mo	R2	1 pt/A	2017, 2018
-	Nontreated	-	-	2013, 2014, 2015, 2016, 2017, 2018

*Soar Series I consisted of 2 qt/A Soar Soybean Mix applied at each pre-bloom, full bloom, and post bloom. Soar Series II consisted of 2 qt/A of Soar Bloom Mix applied at pre-bloom and 2 qt/A Soar Soybean Mix applied at post-bloom.

Table 3. Nutrients applied in various foliar fertilizer applications based on rates used in these trials.

Foliar Fertilizer	Timing	Rate	Lbs nutrient applied/A in application
Soar Series I	V6/7 + R2 + R4	2 qt/A + 2 qt/A + 2 qt/A	0.16 Ca 0.08 Mg 0.16 B 0.08 Fe 0.47 Mn <0.01 Mo 0.04 Zn
Soar Series II	V6/7 + R4	2 qt/A + 2 qt/A	0.11 Ca 0.05 Mg 0.11 lbs B 0.05 lbs Fe 0.31 lbs Mn <0.01 lbs Mo 0.03 lbs Zn
IronMan	V2/4	2 qt/A	0.90 N 0.14 S 0.23 Fe
IronMan	R2	2 qt/A	0.90 N 0.14 S 0.23 Fe
IronMan	V2/4 + R2	2 qt/A + 2 qt/A	1.80 N

			0.28 S
			0.46 Fe
N-Boost	V2/7 + R2	1 qt/A + 1 qt/A	0.1 N
N-Boost	R2	2 qt/A	0.1 N
Smart Quarto	V5/7	1 qt/A	0.04 S
			0.06 B
			0.08 Mn
			<0.01 Mo
			0.08 Zn
Smart B-Mo	R2	1 pt/A	0.07 B
			<0.01 Mo

Results and Discussion: A diversity of products have been evaluated over the past six years in these trials. The following products/treatment timings were evaluated for one year only and will not be discussed in this publication: Nutran applied at V3/V4, pre-bloom, R1, and post bloom, BioForge applied at R2, Boron applied at V2/V4, N-Boost applied at V2, and Smart Quatro applied at R2. This report will focus on results from products that have been evaluated over multiple years.

How did foliar fungicides impact soybean yield? Fungicide use in soybeans is a topic area where we receive abundant questions. Should I invest in a fungicide application? What is the best application timing? What is the best product? We cannot answer all these questions with the information generated from this trial, but we now have results from testing fungicides and their impact on soybean yield in a wide range of environments and can discuss some trends from these results. Across these environments, two things were variable that can impact the effectiveness of fungicides. 1. Soybean Variety: soybean genetic packages vary in their resistance to certain foliar diseases 2. Environmental Conditions: Heat, moisture, disease pressure, and soybean biomass production are factors that impact foliar disease and varied by environment.

The effect of fungicide use on soybean yield compared to the nontreated control can be found in Figure 1.

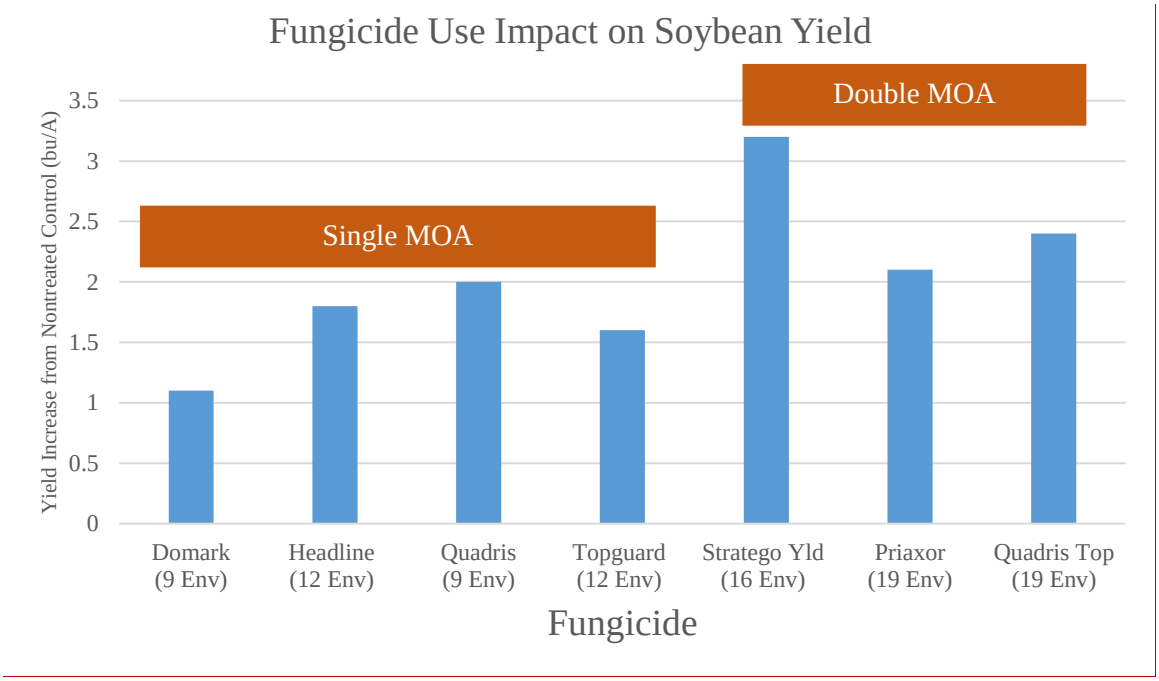
When combining over 19 trial environments and the various fungicide products evaluated, fungicide use provided a 2 bu/A yield advantage on average over the nontreated control (P=0.01). This yield advantage varied by environment; in some environments fungicide use provided up to 8.9 bu/A yield increases and in some environments there was no yield advantage from fungicide use. About 25% of the time, fungicide use led to a statistically significant yield advantage. The soybean yield advantage from the use of foliar fungicides at early reproductive development will vary across environments based on disease presence, environmental conditions that are conducive to disease development, and the resistance package of the soybean variety used in the trial. In addition to the variability in observation of yield increases, application of a fungicide in the absence of observable disease increases the risk of fungicide-resistant populations of pathogens developing.

What about a single MOA vs multi-MOA fungicide? The multi-mode of action (MOA) fungicides evaluated (Priaxor, Quadris Top, Stratego Yld) provided a 2.5 bu/A yield advantage on average over the nontreated control, whereas the single MOA fungicides only provided a 1.6 bu/A yield advantage on average over the nontreated control. The yield advantage provided by the double-MOA fungicides may indicate the presence of fungicide-resistant diseases, which require

additional inputs to manage. In addition to the yield increases from the use of a multi-MOA fungicide, using a multi-MOA fungicide is beneficial for fungicide-resistance management. Please see the NC Soybean Production Guide (Table 8-2) for a list of single and multi-MOA fungicides: https://content.ces.ncsu.edu/north-carolina-soybean-production-guide/soybean-disease-and-nematode-management

How do these results relate to profit? Fungicide product cost varies from grower-to-grower and distributor-to-distributor, but assume an average fungicide application would run a grower $7-15/A (in general, lower end for single-MOA products) plus the cost to run the sprayer across the field, fungicide use on average may provide a small profit increase. Profit impact varies based on disease pressure at the site, varietal resistance, and the selling price of soybeans. Of the foliar products evaluated in this trial, foliar fungicide use at early reproductive development would provide the most consistent positive impact on soybean profit compared with other foliar inputs evaluated.

Figure 1. The impact of fungicide use on soybean yield in the NC State Soybean Extension foliar testing program from 2013-2018.



Do sugar applications increase soybean yield? Within the past few years, there has been discussion from entities outside NC State Soybean Extension regarding the benefits of applying sugar to field crops. The application of sugar alone at V2/V4 (P=0.21) or in combination with BioForge (P=0.66) did not impact soybean yield and would not provide an economic advantage for use in NC soybean production based on these results. These results are consistent with others across the US showing no yield advantage from applying sugar to your soybean crop. This is summarized by Shawn Conley at the University of Wisconsin-Madison and can be found at the following link: https://coolbean.info/2015/06/01/a-tank-full-of-sugar-helps-the-profits-go-down/

How do 'stress reducers' impact soybean yield? The strength of evaluating foliar products aimed at increasing soybean yield by reducing plant stress in a wide range of environments is that stress is likely to occur at some point throughout these evaluations. Photon is a foliar product that is advertised to aid in keeping a crop productive under environmental stressors (heat, cold, drought) by Crop Microclimate Management. In our trials, the use of this product did not impact soybean yield when applied a V2/V4 alone (*P*=0.52), R2 alone (*P*=0.61), or at both application timings (*P*=0.90). We assume that at some point in the nine environments where the product was applied, the soybean plants were under stress (i.e. drought, excess moisture, disease).

Bioforge is a plant growth promoter that is marketed by Stoller USA to protect the plant from stress. It can be applied as a seed treatment, in-furrow, or a foliar application. In this study, BioForge was evaluated as a foliar application applied at early vegetative growth (V2/V4). The application of BioForge alone at V2-V4 (*P*=0.80) or in combination with sugar (*P*=0.66) did not impact soybean yield at any environment. We assume that at some point in the eight environments where the product was applied, the soybean plants were under stress.

How did foliar fertilizers impact soybean yield in our trials? Several foliar fertilizer products have been evaluated over multiple years in this trial and include Soar Products, IronMan, N-Boost, Smart Quatro, and Smart B-Mo (Table 1). The amount of nutrients applied/A in these applications can be found in Table 3.

Soar Products: The Soar Series were evaluated over 19 environments. Soar Series I consisted of 2 qt/A Soar Soybean Mix applied at each pre-bloom, full bloom, and post bloom. Soar Series II consisted of 2 qt/A of Soar Bloom Mix applied at pre-bloom and 2 qt/A Soar Soybean Mix applied at post-bloom. On average, Soar Series I provided a 2.1 bu/A yield advantage (*P*=0.02) and Soar Series II provided a 1.9 bu/A yield advantage (*P*=0.04). Soar Series I would cost growers approximately $23/A and Soar Series II would cost growers approximately $15/A just for the cost of the product, not including the additional cost of two-three additional trips across the field. Considering economics, the limited yield increase from use of these products would not result in a profit under most circumstances.

Ironman: Ironman applied at early vegetative growth stages did not impact soybean yield (*P*=0.68). Ironman applied at early reproductive growth stages provided a slight yield advantage (+2.6 bu/A, *P*=0.03) and trended towards impacting yield when applied at both early and reproductive stages (+1.8 bu/A, *P*=0.14). IronMan applied at 2 qt/A is estimated to cost a grower $3/A for the product plus the cost of the trip across the field.

N-Boost: The N-Boost product applied once or twice did not provide a yield advantage compared to the untreated control (*P*=0.68, *P*=0.32) in the seven environments where the product was evaluated. If you look at Table 3, you can see N-Boost is supplying minimal nitrogen (<1 lb/A), a macronutrient needed in large quantities by soybean plant.

Smart Quatro: The Smart Quatro product did not provide a yield advantage compared to the nontreated control (*P*=0.15) in the seven environments where it was evaluated.

Smart B-Mo: The Smart B-Mo product did provide a 3.2 bu/A yield advantage compared to the nontreated control (*P*=0.04) when combined across seven environments. We would assume the

nutrients this product was supplying were deficient in some of these environments, although do not have the tissue samples to verify this.

Conclusions:

- Foliar fungicides sometimes led to statistically significant soybean yield increases. Double-MOA fungicides were more effective at increasing soybean yield on average than single-MOA fungicides.
- Sugar applications did not increase soybean yield
- Foliar fertilizer use sometimes resulted in a statically significant soybean yield increase depending on growth stage when applied. There are cases where micronutrient deficiencies justify the use of a foliar fertilizer application and positive yield responses can be observed in these situations.

What is the future of foliar yield enhancement testing in the Soybean Extension Program? Over the next two years, we have a nationally collaborative project with other US Soybean Extension Specialists evaluating various foliar fertilizer products and their impact on soybean yield. We will work collaboratively with Dr. Lindsey Thiessen to ensure growers have the data needed to make informed decisions regarding foliar fungicide use in soybeans across North Carolina.

Questions? Please contact Dr. Rachel Vann, Soybean Extension Specialist in the Crop and Soil Sciences Department at NC State, at rachel_vann@ncsu.edu or 919-616-6775.