2018 Soybean Test Plot: 25/201JL18

The Trial

Six 1/1000 acre rows, 17’5” in length each, from a uniform soil zone with uniform emergence were selected for the trial. Prior harvest data showed no obvious yield discrepancies in this area in 2016. The field was planted in corn in 2017.

Both ends of each row were marked with a flag. At growth stage VC, each row received a separate foliar treatment. Row 1 received 3% EDTA Calcium only. Row 2 received 10% B only. Row 3 received both products combined, and at an equal ratio. Rows 3-6 repeated this pattern, but each row also received TEVA Corporation’s C-CAT Carbon Catalyst and MMTS sugar.

The plot received four other foliar treatments. In each foliar treatment, all plants received identical rates and mixtures of the products listed in the following section. This allowed for continued plant response, plant health, and higher yield potential, while isolating the VC applications as the variable.

A decision was made at the R2/R3 timing to test the effectiveness of 3% EDTA Ca in the foliar mixture. The south 5’ (the back of each row) was sprayed uniformly across rows 1-6. This provided additional information on post-bloom calcium application. Previous experience with calcium post-bloom resulted in increased vegetative growth during the reproductive stages, making the stalks larger and the plants taller, but a reduction in pod count and seeds developed through maturity. This occurred on quantities of 1qt, so a 4oz./A equivalent was used on this trial. Twelve feet of each row did not receive this separate calcium-containing blend, nor any other foliar calcium post-bloom.

The total number of soybean plants in the test plot was 507. By harvest, 16 soybean plants from each section of the plot, plus 24 plants from outside of the plot, for a total of 120 hand-harvested plants. The pulled plants were averaged by section to compare results. Pod and seed counts were tracked, and pod weight and seed weights were calculated. To make a final analysis at R8, six adjacent soybean plants were taken from each section, and 3 adjacent plants were taken from outside of the plot to serve as a check.

Timeline

5/11/2018: Planted, 4.1 maturity group LL

5/24/18: VC, 17’5” rows, 30” spacing

Emerged populations: (Planted at 118-125K)

Row 1: 79; Row 2: 89; Row 3: 85; Row 4: 88; Row 5: 85; Row 6: 81.

-First app at VC (Unifoliates)

Row 1: Equivalent of 1qt/A of 3% EDTA Calcium

Row 2: Equivalent of 1qt/A of 10% Boron

Row 3: Equivalent of 1qt/A each of 3% EDTA Ca and 10% B

Row 4: Equivalent of 1qt/A of 3% EDTA Calcium, 1qt/A C-CAT, 8oz/A MMTS

Row 5: Equivalent of 1qt/A of 10% Boron, 1qt/A C-CAT, 8oz/A MMTS

Row 6: Equivalent of 1qt/A of 3% EDTA Ca, 1qt/A 10% B, 1qt/A C-CAT, 8oz/A MMTS

6/6/18: V2/V3 sprayed (row 1: V2; rows 2-5: V3; row 6: V4)

Equivalent of 1pt/A C-CAT, 4-6oz/A MMTS, 1qt/A 10-20-10, 4oz/A each 9% EDTA Zn, 10% B, 3% EDTA Ca, 6% EDTA Manganese. (This was a corn mix diluted 4:1 with water to use on the beans)

-All plants in rows 1-6 were sprayed evenly.

6/20/18: V5 (R1) Sprayed but rained heavily 15 minutes after application (application likely washed off)

Equivalent of 2qt/A C-CAT, 8oz/A MMTS, 1pt/A 3-18-18, 4oz/A 6% Mn, 4oz/A 10% B

-All plant in rows 1-6 were sprayed evenly.

7/13/18: Sprayed R2/R3 (full bloom/early pods)

Equivalent of 2qt/A C-CAT, 8oz/A MMTS, 1gal/A 3-18-18, 1qt/A 25-0-0, 1pt/A 10%B and 6% Mn

-All plants in rows 1-6 were sprayed evenly.

-An additional application was applied at the equivalent of 4oz/A 3% EDTA Ca for application on south 5' of all rows 1-6

8/14/18: Sprayed (R6-R7)

Equivalent of 2qt/A C-CAT, 8oz/A MMTS, 1qt/A 25-0-0, 1pt/A 6% EDTA Manganese, 1pt/A 10% B

-All plants in rows 1-6 were sprayed evenly.

9/5/18: Pulls

Number of foliar application: 5 (V5/R1 washed out 15 minutes post-application)

Timings: VC, V2/V3, V5(R1), R2/R3, R6-R7

Costs of Inputs

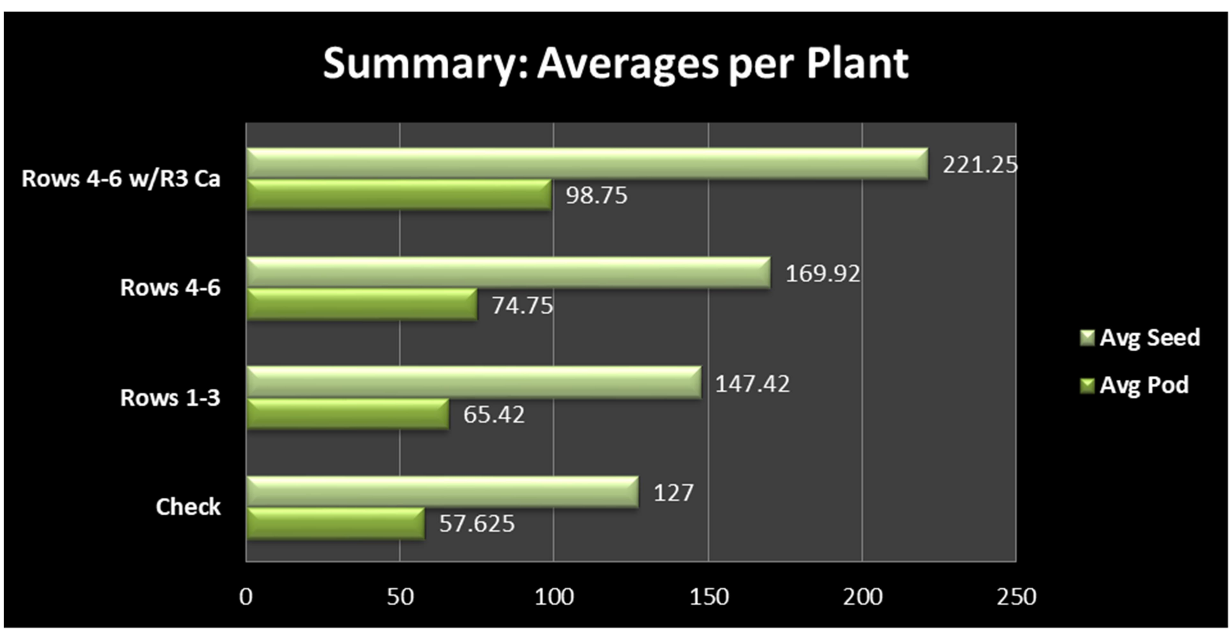
Product Totals:

C-CAT	6.5 – 7.5 quarts/A
MMTS	2 – 2.25 lbs/A
3-18-18	1.25-1.5 gal/A (inc. 10-20-10)
25-0-0	2 qts/A
3% EDTA Ca	1-1.5qt/A
6% EDTA Mn	1.25qt/A
10% B	3pt/A
9% EDTA Zn	4oz/A (was a component of a diluted mix used as a foliar on the soybean plot)

Total product cost: **$58.06/A**

Results

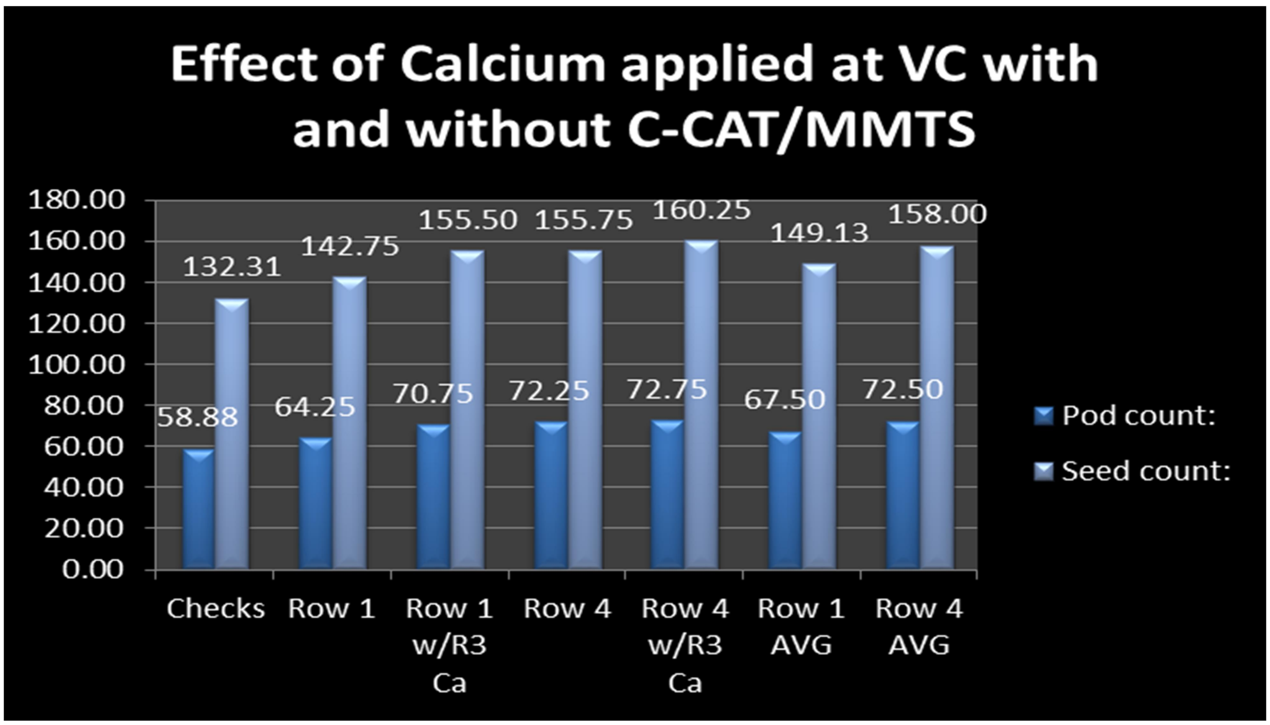
Rows treated with C-CAT and MMTS sugar, and rows treated with 3% Calcium at R2/R3: (figure 1)



The average per-plant pod and seed counts based on C-CAT/MMTS-treatment are shown above. Rows 1-3 did not contain C-CAT/MMTS. Rows 4-6 received C-CAT/MMTS at VC. Rows 4-6 w/R3 Ca received the extra post-bloom calcium application.

Rows 1-3 averaged nearly 8 pods per plant higher, and nearly 20 more seeds per plant. Rows 4-6 raised the pod count increase to 17 more pods than check, with 43 more seeds per plant. The back section of rows 4-6, where the extra calcium application occurred at R3, resulted in 41 pods over check, and 94 additional seeds.

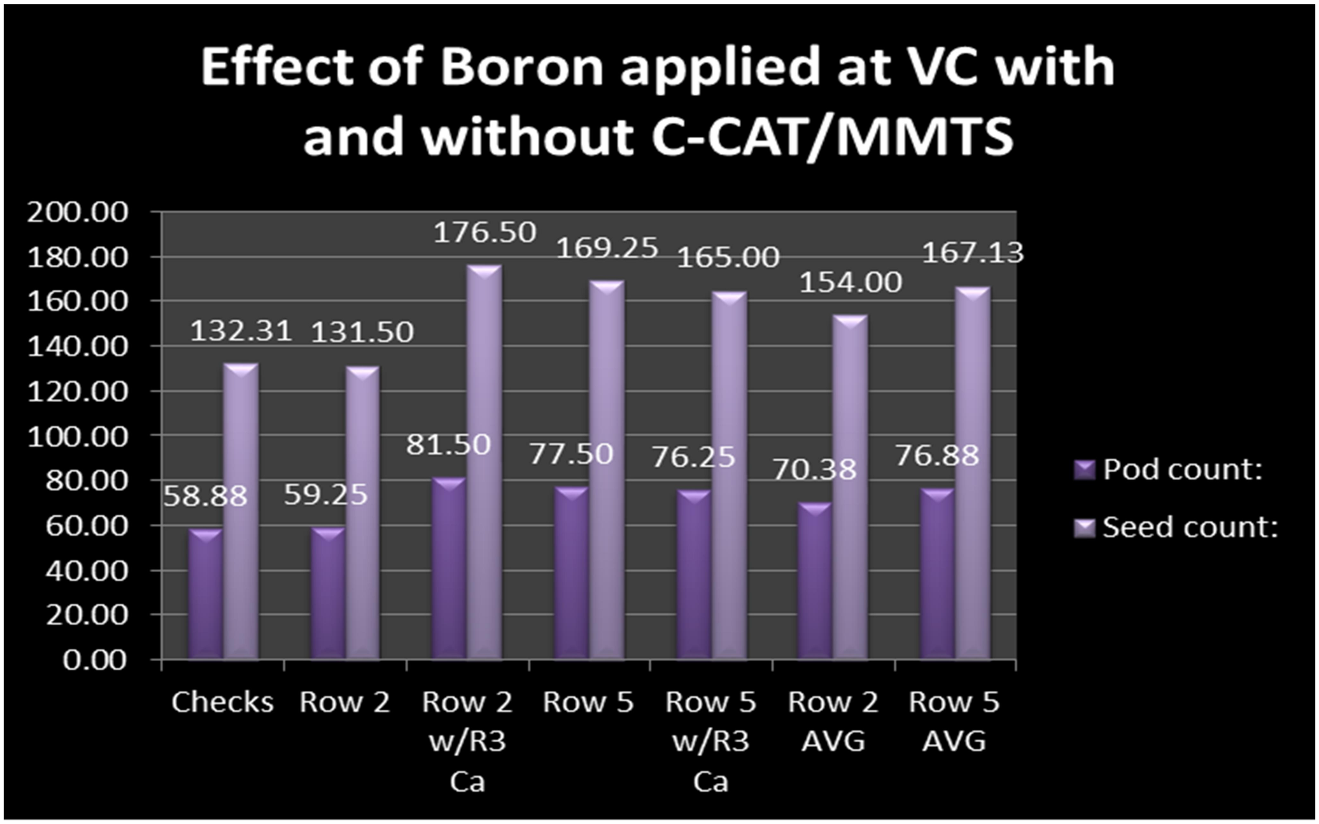
Rows 1 and 4: Results pertaining to Calcium (figure 2)



The chart above shows the pre-harvest check versus rows 1 and 4, with and without the R3 calcium application. Row 1 received 3% EDTA Ca at VC. Row 4 received 3% EDTA Ca plus C-CAT and MMTS sugar at VC. The rows marked "w/R3 Ca" are adjacent plants that received the R3 calcium blend.

All test plot rows performed above the checks. Row 4 data was consistently higher than row 1, with C-CAT and MMTS sugar as the delivery method to the plant. The portions of the rows that received R3 calcium also showed higher pod and seed counts consistently. The Row 1 AVG and Row 4 AVG columns in the chart are averages of all pulls from each row, and again show a consistently higher pod and seed count in row 4, which contained C-CAT and MMTS sugar.

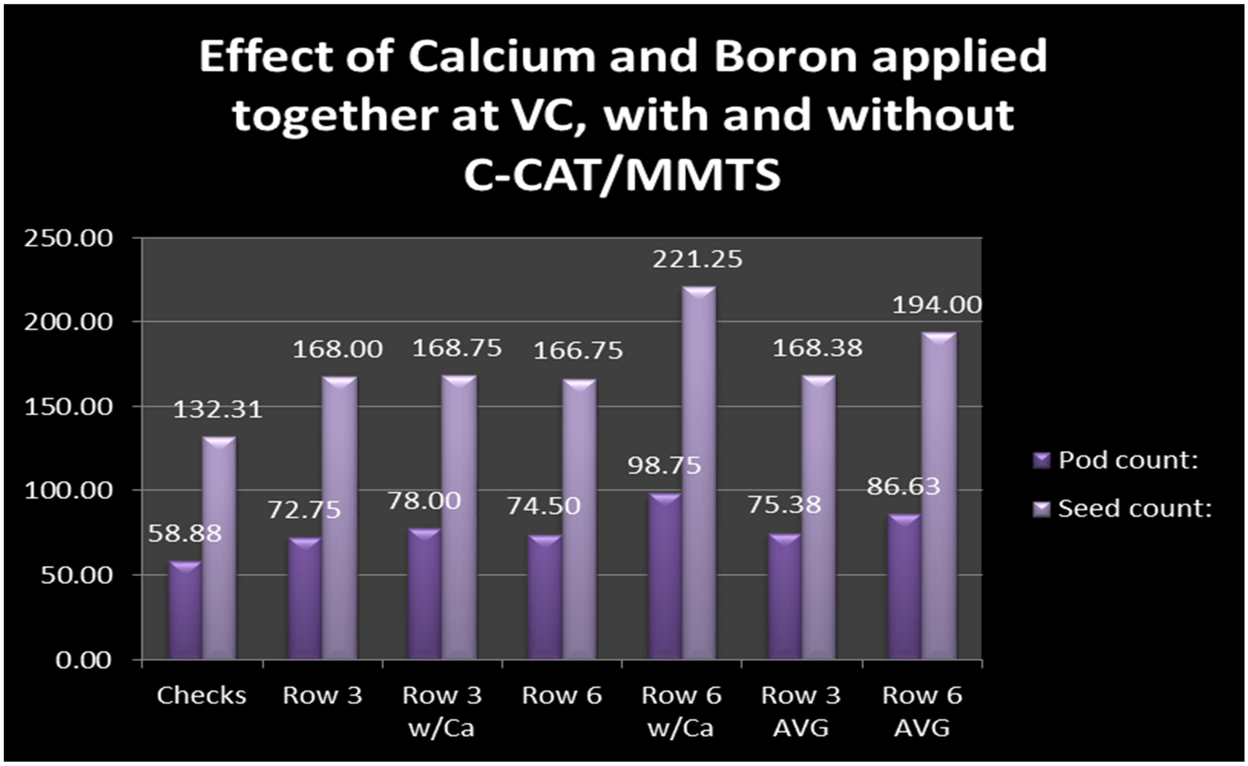
Rows 2 and 5: Results pertaining to Boron (figure 3)



The chart above shows the pre-harvest check versus rows 2 and 5, with and without the R3 calcium application. Row 2 received 10% B at VC. Row 5 received 10% B plus C-CAT and MMTS sugar at VC. The rows marked "w/R3 Ca" are adjacent plants that received the R3 calcium blend.

All test plot rows performed above the checks. Row 5 data was higher than row 2, with C-CAT and MMTS sugar as the delivery method to the plant. The portions of the rows that received R3 calcium resulted in much higher pod and seed counts without C-CAT/MMTS, but had essentially flat results in the C-CAT/MMTS-treated row 5. The Row 2 AVG and Row 5 AVG columns in the chart are averages of all pulls from each row, and again show a consistently higher pod and seed count in row 5, which contained C-CAT and MMTS sugar.

Rows 3 and 6: Calcium and Boron applied together (figure 4)

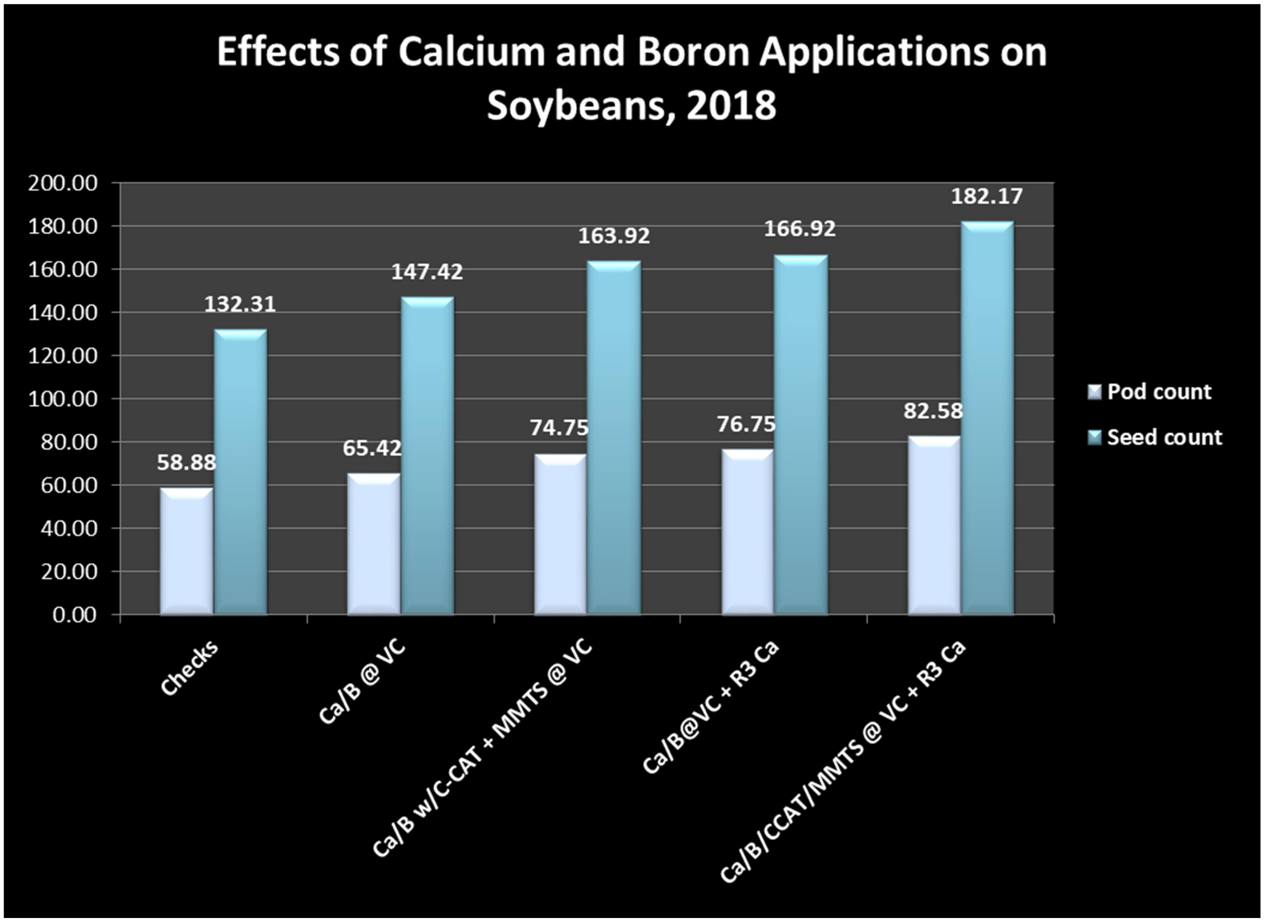


The chart above shows the pre-harvest check versus rows 3 and 6, with and without the R3 calcium application. Row 3 received equal rates of 3% EDTA Ca and 10% B at VC. Row 6 received 3% EDTA Ca, 10% B, plus C-CAT and MMTS sugar at VC. The rows marked “w/R3 Ca” are adjacent plants that received the R3 calcium blend.

All test plot rows performed above the checks. Row 6 data was nearly identical to row 3 data. The portions of the rows that received R3 calcium resulted in some interesting results. In the C-CAT/MMTS-treated row 6, the extra calcium application resulted in much higher pod and seed counts. The R3-calcium treated portion of row 3 had essentially flat results. The Row 3 AVG and Row 6 AVG columns in the chart are averages of all pulls from each row, and show an overall higher pod and seed count in row 6, which contained C-CAT and MMTS sugar.

Calcium and Boron Charts

Figure 5.



The above chart summarizes pod and seed counts for combinations of calcium, boron, C-CAT/MMTS, and R3 calcium.

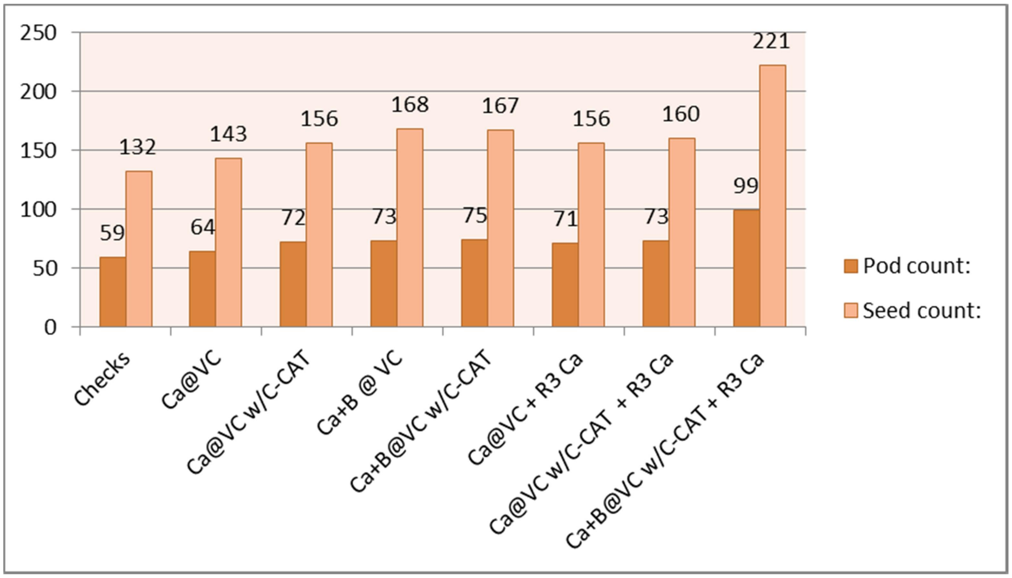


Figure 6.

The above chart summarizes pod and seed counts pertaining to calcium, and its performance with boron, C-CAT/MMTS, and R3 calcium.

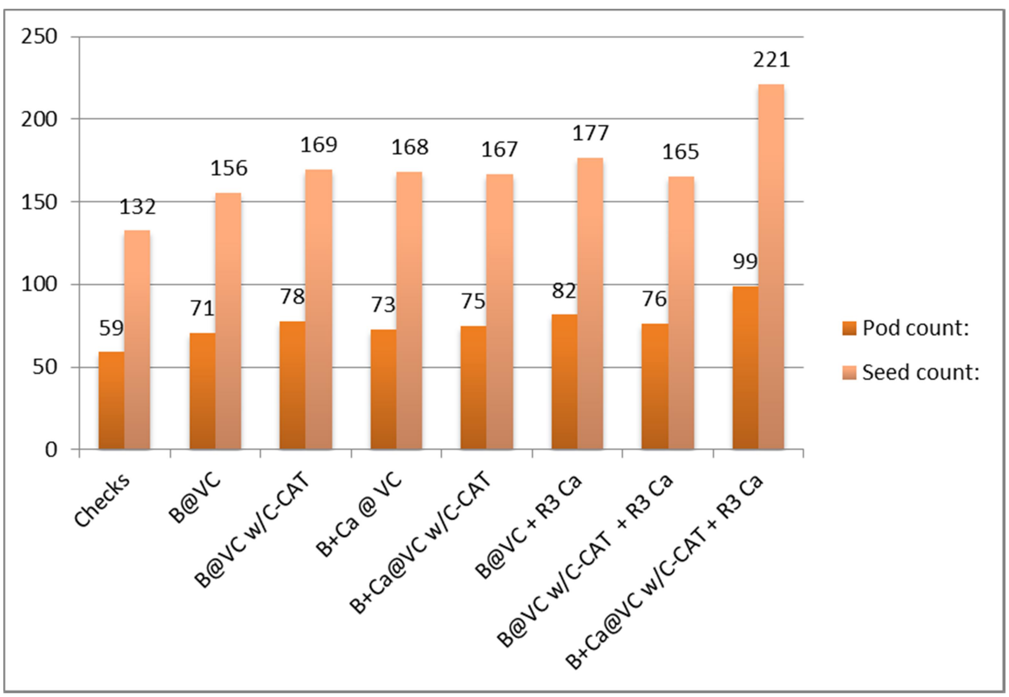


Figure 7.

The above chart summarizes pod and seed counts pertaining to boron, and its performance with calcium, C-CAT/MMTS, and R3 calcium.

Discussion

The Soil

The soil data from this field revealed adequate P for a 100+ bu/A soybean crop. K levels were lower than desired. Calcium base saturation was in the low 60s, and pH was falling toward 6. Magnesium levels were elevated, which further suppresses Ca uptake. Manganese levels were high, but boron levels were very low at 0.4-0.5ppm.

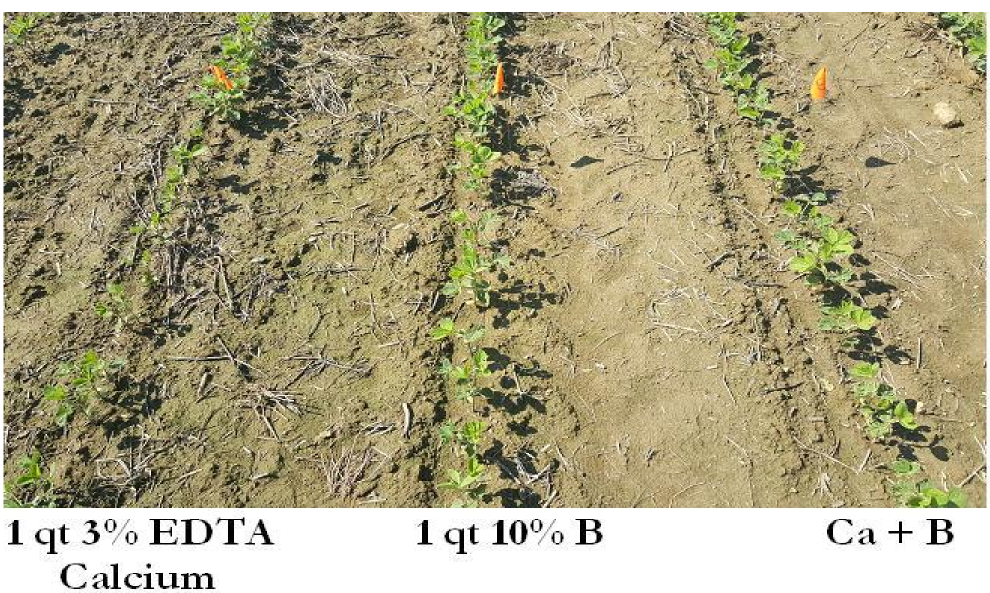
These soil characteristics guided the foliar program to include chelated calcium, slight levels of P-K, boron, and some chelated manganese due to uncertainty of the availability of the soil Mn. By utilizing C-CAT Carbon Catalyst to open up the soybeans to feed, and getting the nutrients into the plant cells, I designed the foliar applications to compensate for these soil uncertainties. The MMTS ag sugar was used as a sticker for the nutrient mix, as well as a neutral-charged sucrose energy source.

The grower used liquid fertility on the planter on this field. He applied 100% orthophosphate 3-18-18 and C-CAT/MMTS at planting. I did not factor this into the test plot since it was a uniform application to all plants, even the checks.

The Results

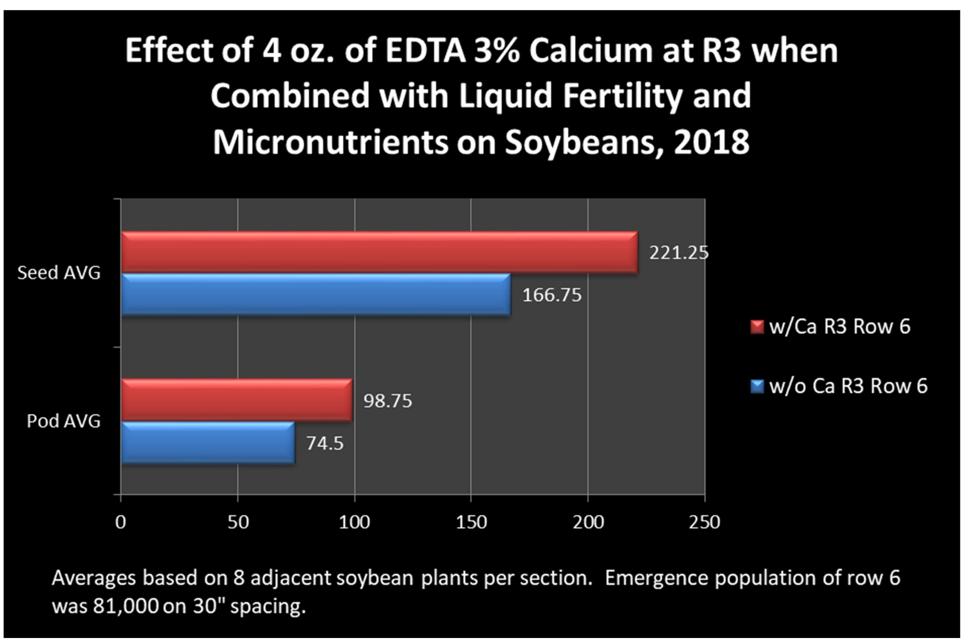
It was anticipated that foliar applied Ca and B could result in a quantifiable outcome for yield. It was also anticipated that C-CAT/MMTS would aid in the foliar efficiency and plant use of these applied nutrients. It was the combination of Ca and B that proved interesting. Early on in the trial, at early V-stages, there was a marked visual difference in plant height and vigor. Notice where the treated row ends at the top of the photo below. The treated plants were very stunted compared to plants outside of the test plot.

Figure 8.



The visual plant differences per row were apparent for most of the growing season. Notice the stunted, treated rows on the left. The row receiving calcium+boron did not exhibit such stunted appearance. The rows containing C-CAT and MMTS sugar showed very little appearance of stunted growth, with Ca and B individually (rows 4 & 5) or together (row 6). Figure 9.

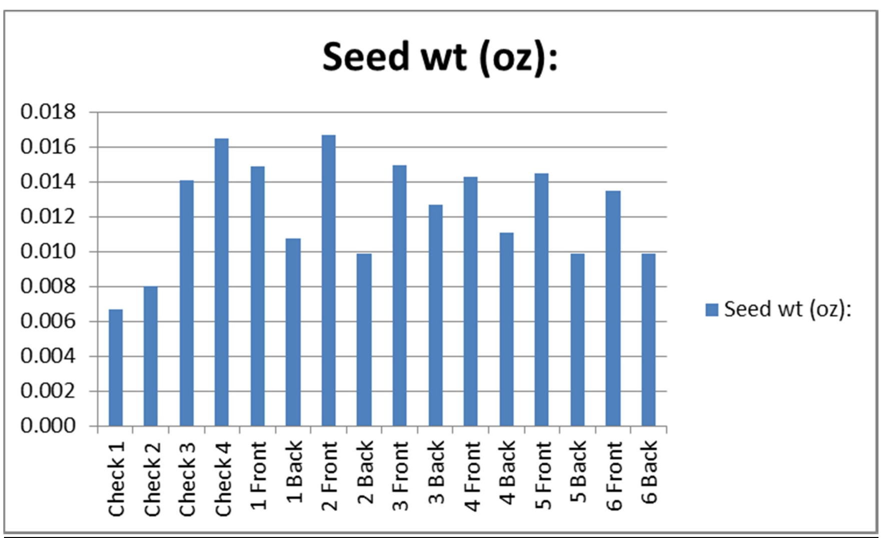
The Post-Bloom Calcium Effect (Figure 10)



While calcium should not be randomly used on soybeans post-bloom, I believe that this instance shows that available calcium levels were not adequate to mobilize and utilize the amount of nutrition supplied to this crop. The row 6 data that excluded the calcium was very unremarkable versus the row 3 data (figure 4). Figures 2 and 3 show that when B and Ca applications were not combined, there were also unremarkable results when comparing rows 4 and 5 that did, and did not, receive the R3 calcium blend. It was only when the plot sections received both B and Ca did the greatest gains in pod and seed counts result. Interestingly, and further supporting the R3 calcium effectiveness, the row 1 and 2 gains between the sections that did, and did not, receive the R3 calcium were impressive, with 6-12 pods and 12-35 seeds above the section that did not receive the R3 calcium.

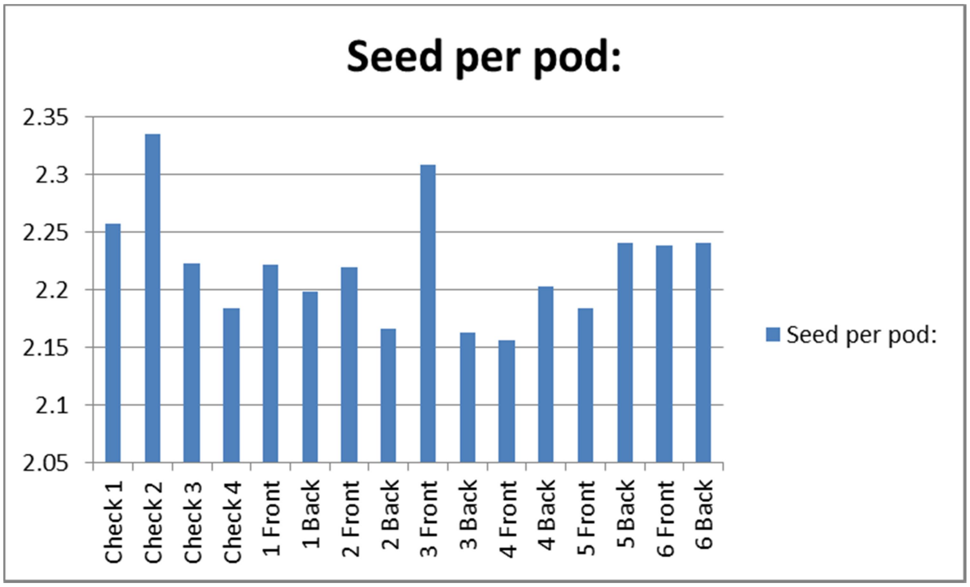
The variance in gains with R3 calcium in the foliar mixture is worth some additional exploration. When boron and calcium were applied together in simple foliar mixes, it generally resulted in increased pod and seed counts. There appears to be a synergism, but also an unclear correlation concerning when, and how much, additional calcium is necessary. Row 6, which received the highest quantity of products throughout the trial, responded the most. Row 3, which also contained both B and Ca, showed a much smaller response. Rows 1 and 2 responded well, while rows 4 and 5 responded very little. Whether this is due to the relationship between Ca and B, soil characteristics, or another variable is unclear. Future test plots designed to measure the response of various B to Ca ratios may help answer this question. As a general finding, it appears that an application of foliar B is improved by adding Ca, and an application of foliar Ca is improved by adding B. I will continue to use 16-32 ounce/A rates pre-bloom, but limit post-bloom applications to 4 oz/A until research can show that it will not affect the reproductive stages by enhancing vegetative growth.

<u>Seed Weight Results</u>



Seed weights among the harvested plants differed very little. From all but 2 groups of plants harvested, seed weights rounded to the hundredth weighed 0.01 ounce. The slight variance in weights are likely attributable to seed moisture. All seeds fell between 0.006oz and 0.017oz, for a range of 11/1000th of an ounce. The average seed weight from all harvested plants was 0.012 ounces.

Seed per Pod Results



Seeds per pod ranged from 2.15 to 2.3. The average of all plants harvested was 2.22 seeds per pod. There were no visible patterns, and such small differences in the averages of the groups are attributable to plant variance.

How do pod and seed counts correspond to yield?

	Check	Rows 1-3	Rows 4-6	Rows 4-6 w/R3 Ca
Avg Pod	57.625	65.42	74.75	98.75
Avg Seed	127	147.42	169.92	221.25

Some quick set-up mathematics:

50lb = 140K seeds = 2800seeds/lb = 175 seeds/oz = 0.0064 oz/seed

Average Soybean Population of Trial: 80K seeds/A

80K*.0064=512oz/A = 32lbA = 0.53bu/A per seed

Seed count calculations from above table (assuming 0.0064oz/seed)

Check: 127*80000=10,160,000sd/A * .0064 = 65,024oz/A = 4,064lb/A = 67.3bu/A

Rows 1-3: 147.42*80000=11,793,600sd/A*.0064= 75,479.04oz/A = 4,717.44lb/A = 78.624bu/A

Over check: +20.42 seeds = 11.324 bu/A = 1 seed = 0.555 bu/A

Rows 4-6: 169.92*80000=13,593,600sd/A*.0064= 86,999.04oz/A = 5,437.44lb/A = 90.624bu/A

Over Rows 1-3: +22.5 seeds = +12 bu/A = 1 seed = 0.5333 bu/A

Rows 4-6 w/R3 Ca: 221.25*80000=17,700,000sd/A*.0064= 113,280oz/A = 7,080lb/A = 118bu/A

Over Rows 4-6: +51.33 seeds = +18 bu/A = 1 seed = 0.351 bu/A

These calculations give an approximate relationship between seed counts and yields, but are based on a seed weight of 0.0064oz/seed. This will underestimate heavier seed, and overestimate lighter seed. For this reason, I prefer to state equivalent bu/A yield estimates in a range. I have used 3 seeds per bushel for a generic math shortcut in the past with fairly close results. **I find most yield increases can range from 0.3-0.5 bu/A per extra seed.**

For example, the rows 4-6 increase of 22.5 seeds-per-plant average could give a yield increase in the range of 6.75-11.25 bu/A. (22.5 * 0.3 = 6.75 and 22.5 * 0.5 = 11.25) There is no perfect method for this "guess"-timate. Keep in mind that all per-acre yield estimates are making assumptions that the plants selected are a representative sample for the rest of the field population. Here, you are looking at approximately 48 plants harvested from rows 4-6. By forming a bu/A yield estimate, you are assuming that the other 79,952 in the field have the same seed counts as the average of the 48 measured. Based on field variations, soil differences, water flow, elevation, and countless other variables, this is a broad assumption that is the best educated guess possible, but it will always remain a guess. For this reason, I prefer to avoid converting test plot rows to bu/A yield estimates, but I will include it below to illustrate the plot potential.

Check: 127 seeds (38.1-63.5bu/A using 0.3-0.5bu/seed multipliers)

Rows 1-3: 147.42 seeds (+20.42 seeds over check * 0.3 = +6 bu/A over check)

Rows 4-6: 169.92 seeds (+42.92 seeds over check * 0.3 = +12.9 bu/A over check)

Rows 4-6 w/R3 Ca: 221.25 seeds (+94.25 seeds over check * 0.03 = +28.3 bu/A over check)

At $8.00/bu soybeans (which is intentionally lower than the current price), that equates to:

Rows 1-3: **+ $48.00/A** over check yield

Rows 4-6: **+ $103.20/A** over check yield

Rows 4-6 w/R3 Ca: **+ $226.40/A** over check yield

I am more confident in using mathematics to state a *change* in yield than an actual yield. More seeds will yield additional bushels, regardless of the baseline bu/A from the check. Whether the check is closer to 38.1bu/A or 63.5bu/A will not change the yield increase from additional seed counts. In nutrient-dense soybeans, it is possible to have 0.4-0.5oz seed sizes, which would add to yield. Using the 0.3oz/seed number when calculating increases is typically conservative, and gets the guess fairly close if the samples represent the population well.

A Note about ROI

Based on the input costs of $58.06/acre maximum, those interested in return-on-investment calculations can evaluate ROI from these example calculations. As the test plot designer, it is important to me to state that every effective foliar program is designed purposefully for the crop and the soil characteristics where the crop is growing. Portions of the foliar program in this trial may not be necessary in some cases, and may be missing essential components in others. A key to ROI is doing purposeful applications; i.e. you should understand *why* it is being applied, and know *how* it should impact the crop in a positive way.

Summary of 2017 and 2018 Soybean Trials:

The following chart summarizes soybean trials from 2017 and 2018. The averages of treated (T) and untreated (UT) per-plant pod and seed counts are recorded. Across eight trials experimenting with foliar-treated soybeans versus checks, the 2-year average for pod count increases is 13.9 pods, with 35.94 more seeds per plant. Using the 0.3-0.5bu/seed range, that is an approximately 11-18 additional bushels-per-acre increase.

	2018 Trial	2018 Trial	2017 Trial	2017 Trial	2017 Trial	2017 Trial	2017 Trial	2017 Trial	
	25/201JL18	M/ED18	SW17	ZS17	K/201JL17	K/201JL17	K/201JL17	K/201JL17	**Averages**
UT pods	58.9	46.5	46.4	82	44	32	59.5	52	**52.66**
T pods	72.5 (+13.6)	60 (+13.5)	59.4 (+13)	96 (+14)	63.7 (+19.7)	48.7 (+16.7)	64.25 (+4.75)	68 (+16)	**66.57 (+13.9 pods)**
UT seeds	132.3	107.5	96	198	109	82.8	147.5	124.5	**124.7**
T seeds	158 (+25.7)	141.5 (+34)	123 (+27)	252 (+54)	165.3 (+56.3)	112.3 (+29.5)	161 (+13.5)	172 (+47.5)	**160.64 (+35.94 seeds)**

Closing

Field trials such as this serve to help me answer questions about nutrient synergisms and antagonisms. The relationship between calcium and boron are documented in a variety of plants and animals, but forms and quantities are rarely tested. Since various forms of calcium are non-chelated and very reactive, or include metal impurities and/or sulfates, Teva Corporation's 3% EDTA Calcium was the perfect choice to ensure the Ca made it to the leaf surface. To avoid sulfur content and metal impurities in the foliar application, the 3% EDTA calcium is derived from calcium carbonate rather than a sulfate from sulfuric acid. The boron used was TEVA Corporation's 10% Boron from boric acid. Future trials may include various forms of calcium to test the effectiveness of EDTA chelation versus other forms of chelated and non-chelated calciums. The ratio of calcium to boron in both pre- and post-bloom applications will also be tested in the future. The additional of tissue analysis may provide insight into how boron and calcium levels in the plant are being impacted in various applications.

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