Evaluation of Commercially Available Biological and Biostimulant Products for Mississippi Soybean Production 03-2024

**Final Report**

Abstract

 Soybean [*Glycine max* (L.) Merr.] producers in Mississippi are interested in investigating new ways to increase their yields, and biologicals is an option with increasing interest. The effects of biological products were evaluated for soybean grain yield, net returns above specified costs, early-season growth, and nutrient uptake and concentration for four locations in Mississippi. Trials were conducted at 7 site-years in Mississippi in a randomized complete block design and evaluated 13 products in 2023 and 11 products in 2024 against an untreated and treated control. No effects from biological products were observed for any measured parameters across site-years. No responses from early-season parameters or nutrient concentration and uptake lead to an increase in yield. In 2023 and 2024 irrigated sites did not show a response on net returns, though 2024 dryland sites did show net losses between 21% to 42% compared to the controls. Adoption of biologicals may be seldom for many producers due to lack of responses.

Introduction

Soybean [*Glycine max* (L.) Merr.] is the most widely grown row crop in Mississippi with 930,000 hectares planted (919,000 hectares harvested) in 2024, producing 3.45 million metric tons, averaging 3.77 t ha-1, and generating a revenue of $1.335 billion (USDA 2025). Soybean accounted for 64% of the row crop hectares and 51% of total row crop revenue in Mississippi for 2024. Soybean yield increased from 2.50 t ha-1 to 3.64 t ha-1 between 2009 and 2017 (USDA 2010, USDA 2018), but yield has started to slow in increases with just 0.13 t ha-1 since 2017 (USDA 2024). Producers are interested in a solution to increase yield. A novel potential solution is biological products.

With many new products entering the market, it is informative to understand biological product classification. One way to classify biologicals is by active ingredient. Active ingredient classifications are subdivided into live biologicals and biostimulants. A biological is a living microorganism formulated to be applied by either a seed treatment, in-furrow, or foliar spray to positively affect plant vigor, plant growth, root nodulation, plant health, nutrient uptake and efficiency, tolerance to abiotic stress, and/or crop quality and yield (Sible et al. 2021). A biostimulant is an abiotic organic substance, such as enzymes, amino acids, and extracts, that can be formulated to be applied by either a seed treatment, in-furrow, or foliar spray to positively affect plant vigor, plant growth, plant health, root nodulation, nutrient uptake and efficiency, tolerance to abiotic stress, and/or crop quality and yield (Sible et al. 2021). Biologicals and biostimulants by this definition meet the OMRI standards if they are stand-alone biological products (Organic Materials Review Institute 2022).

Biologicals and biostimulants can be used to mineralize organic or complexed nutrients into inorganic, plant-available forms. Phosphorus solubilization and organic matter mineralization are the two main modes of action for nutrient mobilization (Sible et al. 2021). Inorganic phosphorus complexes with calcium in high pH soils, and aluminum and iron in low pH soils to form minerals that are unavailable for plant uptake (Anderson 1980). Certain microbes, specifically *Bacillus* spp*.*, and enzymes can solubilize hydroxyapatite and other unavailable phosphorus forms into plant available forms (Kuroshima and Hayano 1982; Li and Manavalan et al. 2021).Organic matter mineralizing biologicals can catalyze the mineralization of organic matter (Sible et al. 2021). Many enzymes and microbes are purported to breakdown organic matter and catalyze the process of mineralization (Kuroshima and Hayano 1982; Sible et al. 2021).

Biological products can be applied to obviate deficiencies in soybean. The use of humates like humic and fluvic acid may alleviate iron and additional micronutrient deficiencies (Chen et al. 2004). Humic substances are composed of many different micronutrients, with iron being the main nutrient in most compositions, in organic forms (Chen et al. 2004; Sible et al. 2021). Humic substances include marine extracts such as seaweed and algae, terrestrial plant extracts, and animal decomposition products. Humic substances could be implemented in high pH calcareous soils for growers to combat iron deficiency chlorosis.

 Incorporating biologicals into Mississippi production systems may be situational for growers. Phosphorus solubilizers and humic substances may be appropriate for calcareous soils of the Blackbelt region, which tend to complex plant-available phosphorus with calcium (Sample et al. 1980) and make iron unavailable for plant uptake (Chen et al. 2004). Organic matter mineralizers may face challenges being adopted in Mississippi due to the soils generally characterized as having low soil organic matter (Mylavarapu, Mitchell, & Savoy 2014). The use of biological products to alleviate micronutrient deficiencies may be useful on soils that either are deficient in micronutrients or tend to make micronutrients unavailable for plant uptake (Bolan et al. 2023). The objective of this study is to evaluate the agronomic response of biological products on soybean in the predominant soybean growing regions of Mississippi.

Materials and Methods

Site Description and Experimental Design

Research was conducted at seven site-years across Mississippi between 2023 and 2024: Starkville (33° 28’34” N, 88° 46’ 33” W, Leeper silt loam, fine, smectitic, nonacid, thermic Vertic Epiaquepts, ridge-till, irrigated), Verona (34° 10’ 07” N, 88° 44’ 44” W, Catalpa silt loam, fine, smectitic, thermic Fluvaquentic Hapludolls, no-till flat, dryland), Stoneville (33° 26’ 04” N, 90° 54’ 31” W, Commerce sandy loam, very fine sandy, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts, ridge-till, irrigated), and Raymond (2024 only) (32° 12' 21" N 90° 30' 47" W, Loring silt loam fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs, ridge-till, dryland). Trials were established as a randomized complete block design at each site. In 2023, four replications were used; in 2024 five replications were used for the Stoneville location and six replications for all other locations. Plots were 4 rows of 1-m seedbeds spaced at 102cm at Stoneville and 96cm for all locations, and 10.67-m long. Rainfall and irrigation for all sites is listed in Tables 1.1 & 1.2. Experiments evaluated 15 treatments in 2023 and 13 treatments in 2024 (Tables 1.3,1.4). Products contained various modes of action such as phosphorus solubilizers, protein digestates, biofungicides, and physiological microbes. An untreated control (untreated soybean seed) serving as a negative control, and a treated control (producer standard fungicide and insecticide seed treatment) serving as a positive control, were used to compare treatments.

Management Practices

Soybean planting occurred during April and May for the 2023 and 2024 crop years (Table 1.3). Soybean variety AG45XF3 (Bayer Crop Science, Pittsburgh, PA) was seeded at 321,230 seeds ha-1 using a four-row John Deere 7100 mechanical planter (Deere and Co, Moline, IL) retrofitted with Almaco 31 cell cones (Almaco, Nevada, IA). At physiological maturity, the center two rows of every plot were mechanically harvested with a two-row Kincaid plot combine (Kincaid Equipment Manufacturing Co, Haven, KS) with a calibrated on-board H2 GrainGage (Juniper Systems and HarvestMaster, Logan, ID) for yield comparison. All pest management decisions were made in accordance with Mississippi State University Extension guidelines (Bryd et al., 2023; Crow et al., 2023). Residual and contact herbicides were applied at soybean planting and throughout the season as need for weed control. Insecticide applications were made when scouting procedures determined insect population or damage thresholds were reached. Irrigated locations were furrow-irrigated as needed, and irrigation water was delivered via lay-flat poly-ethylene tubing.

Measured Parameters

 In-season data collected included plant population, early-season canopy closure, nodulation, and nutrient uptake. Plant populations were measured using a 4.19-m length of row at Starkville, Verona, and Raymond, and a 3.98-m length of row at Stoneville across four randomly selected locations and averaged across each experimental unit at all locations. Canopy closure ratings were taken at 20, 30, and 40 days after planting using Canopeo (Patrignani and Ochsner 2015). Nodule counts were conducted at R1, by collecting four random plants from rows one and four and then rinsing the roots and counting nodules per plant and averaging them for each experimental unit. Nodule weights were taken in 2024 for each plot. Nutrient concentration was monitored by collecting tissue samples at R1, R3, and R5 taking 25 of the uppermost fully developed trifoliates without petioles from rows one and four, and a whole above-ground biomass sample at R6 from 1-m of either rows one or four from all experimental units. Tissue samples were oven dried, and samples were prepared for heavy metals analysis using a Kjeldahl’s wet digestion. Samples were analyzed for heavy metals using an Agilent ICP-MS 7900 (Agilent Technologies, Santa Clara, CA) and for nitrogen and sulfur using a Thermo/Carlo Erba NA 2500 NCS (Thermo Fischer Scientific, Waltham, MA).Yield was mechanically harvested from the center two rows and adjusted to 13g H2O kg-1.

Statistical Analysis

Statistical analysis was conducted through SAS 9.4 using PROC GLIMMIX to detect any treatment differences at α=0.05. Treatment was the fixed effect, and site-year, year, and rep were random effects. Interaction between treatments and site-year as well as between treatments and year were tested. Differences were reported using a Dunnett’s comparison between the treatments and the untreated and treated control using α=0.05.

Results and Discussion

Early-Season Agronomic Response

A tertiary hypothesis of this study was that the tested biological products would influence early-season growth (i.e. stand count, canopy closure, and nodulation). For the 2023 Stoneville site-year, no products influenced plant stand (*P* = 0.5905, Table 1.7), canopy closure for 20 DAP (*P* = 1.0000, Tables 1.7,1.9), 30 DAP (*P* = 0.3274, Tables 1.7,1.9), 40 DAP (*P* = 0.2690, Tables 1.6,1.8), or nodulation (*P* = 0.2615, Tables 1.7, 1.11). At the 2024 Stoneville site-year a very similar scenario occurred compared to the 2023 year. Of the tested biological products, no products had an effect on plant stand (*P* = 0.7211, Table 1.8), canopy closure at 20 DAP (*P* = 0.5677, Tables 1.8, 1.10), 30 DAP (*P* = 0.8843, Tables 1.8, 1.10), 40 DAP (*P* = 0.3602, Tables 1.8,1.10), nodules plant-1(*P* = 0.9533, Tables 1.8,1.11), or nodule weight (*P* = 0.9308, Tables 1.8,1.12). No differences for early season growth parameters were observed at the Stoneville site.

The 2023 Starkville site-year did have differences occur with respect to early-season growth parameters. Treatments did not influence plant stand (*P* = 0.0803, Table 1.7), canopy closure at 20 DAP (*P* = 0.0891, Tables 1.7,1.9), or nodules plant-1 (*P* = 0.4458, Tables 1.7, 1.11). Treatments did influence canopy closure at 30 (*P* = 0.0318, Tables 1.7,1.9) and 40 DAP (*P* = 0.0127, Tables 1.7,1.9), these treatments included the treated control, HM-2163, Zypro, BioWake + B-Sure, BioWake, BioWake + Biofriendly, Fertiactyl + Biofriendly, and the AZterknot low rate having an increase compared to the untreated control, and the untreated control having a decrease compared to the treated control (Table 1.9). Similar differences were seen at the 40 DAP ratings, with Fertiactyl and the AZterknot HR having an increase, but the Fertiactyl + Biofriendly treatment not being different (Table 1.9). At the 2024 Starkville site-year, treatments did not influence plant stand (*P* = 0.1159, Tables 1.8), canopy closure at 30 DAP (*P* = 0.6774, Tables 1.8, 1.10) 40 DAP (*P* = 0.7195, Tables 1.8, 1.10), nodules plant-1(*P* = 0.1680, Tables 1.8, 1.11), or nodule weight (*P* = .1005, Tables 1.8, 1.12). Canopy closure data at 20 DAP was unable to be collected due to the presence of carpetweed (*Mollugo verticillate*) pressure. Some differences for early-season growth parameters were seen at the Starkville site, but they did not occur across years.

Treatments did not influence early-season growth parameters in Verona. The 2023 Verona site-year did not see any differences with respect to early-season growth. Treatments did not influence plant stand (*P* = 0.7521, Table 1.7) canopy closure at 20 DAP (*P* = 0.8527, Tables 1.7,1.9) 30 DAP (*P* = 0.6877, Tables 1.7,1.9) 40 DAP (*P* = 0.3603, Tables 1.7,1.9) or nodules plant-1 (*P* = 0.8839, Tables 1.7,1.11). Similar differences were seen in 2024. Treatments did not influence plant stand (*P* = 0.8946, Table 1.8), canopy closure at 20 DAP (*P* = 0.8527, Tables 1.8, 1.10), 30 DAP (*P* = 0.9154, Tables 1.8, 1.10), 40 DAP (*P* = 0.8747, Tables 1.8, 1.10), nodules plant-1(*P* = 0.9601, Tables 1.8, 1.11), or nodule weight (*P* = 0.9748, Tables 1.8, 1.12). Treatments had no effect on early-season growth parameters at the Verona site.

The 2024 Raymond site-year did not see any differences due to treatment with respect to early-season growth parameters. Treatments did not influence plant stand (*P* = 0.7211, Table 1.8) canopy closure at 20 DAP (*P* = 0.2573, Tables 1.8, 1.10), 30 DAP (*P* = 0.4907, Tables 1.8, 1.10), 40 DAP (*P* = 0.6062, Tables 1.8, 1.10), nodules plant-1(*P* = 0.9246, Tables 1.8, 1.11), or nodule weight (*P* = 0.9308, Tables 1.8, 1.12). Treatments did not influence early season growth parameters at the Raymond site.

Data from this study showed that biological products had very few effects on early-season plant growth and agronomic response. With varying environmental conditions, from irrigated, intensively managed sites like Stoneville and Starkville, to dryland, low maintenance sites like Verona and Raymond, few differences were detected, and differences were site dependent. The increase in canopy closure that did occur at the 2023 Starkville site-year only showed that products increased canopy closure relative to the untreated control but not to the treated control. These differences also occurred on treatments where the product had not been applied yet, so the differences are more likely due to the producer standard seed treatment, rather than the product. These data are concurrent with other larger scale studies like Colet et al. (unpublished) that showed very few significant effects that occurred due to biological products.

Soybean Grain Yield and Net Returns

The primary hypothesis was that the incorporation of biological products would increase soybean grain yield and net returns. Year and site-year differences were detected due to the varying environments that occurred for those locations or years. Due to differences in environment and management results will be discussed by site-year.

Irrigated sites were non-responsive to treatment applications. The 2023 Stoneville site-year did not see a grain yield (*P* =0.7058, Tables 1.45,) or net return (*P* = 0.3025, Table 1.47) response due to treatment application. A similar scenario occurred in 2024 at the Stoneville site. Treatments did not influence soybean grain yield (*P* = 0.4276, Tables 1.45) or net returns (*P* = 0.4119, Table 1.47). Treatments proved unresponsive at the Stoneville site across years. Starkville had a very similar occurrence to Stoneville. For the 2023 Starkville site-year treatments did not influence soybean grain yield (*P* = 0.9082, Tables 1.45,) or net returns (*P* = 0.2686, Table 1.47). The 2024 Starkville site-year was similar to 2023. Treatment application did not affect soybean grain yield (*P* = 0.7788, Tables 1.45) or net returns (*P* = 0.5103, Table 1.47). There was a lack of grain yield and net returns response to applications of biological products at both irrigated sites.

Dryland sites did have responses due to treatment applications. The 2023 Verona site-years showed that soybean grain yield (*P* = 0.5839, Table 1.45) and net returns (*P* = 0.9530, Table 1.47) were unresponsive to applications of biological products. The 2024 site-years were responsive though. The 2024 Verona site-year was showed no yield differences (*P* = 0.5893, Table 1.45) but showed responses for net returns (*P* = 0.0061, Table 1.47). HM-2163, BioWake + B-Sure and AZterknot HR all decreased net returns compared to the untreated control by 33.6%, 36.6%, and 42%, and BioWake + B-Sure and AZterknot HR decreased net returns compared to the treated control by 31.4% and 37.2%. The 2024 Raymond site-year showed no differences in grain yield (*P* = 0.2478, Table 1.45) but did show differences for net returns (*P* = 0.0138, Table 1.47) due to biological products. BioWake + B-Sure decreased net returns compared to the treated control by 21.2%. Biological products negatively affected net returns at many of the dryland sites.

 Biological products showed site-dependent effects on soybean grain yield and net returns. At irrigated sites no differences were observed, but at dryland sites during 2024 negative responses were observed. The lack of differences in yield could be due to the environment not being suitable for the incorporation of a biological product, or the present activity of the microbiomes since the soil temps had been above freezing before planting occurred. With some biological products performing well in the Midwest where soils tend to freeze for longer periods of the year (Sible 2022). Since no differences occurred in grain yield, products that had a higher specified costs like AZterknot HR and BioWake + B-Sure decreased net returns. The differences occurring at dryland sites in 2024 may be due to the low rainfall conditions reducing yields, and income of the soybean crop (Table 1.2). With dryland operations having tighter margins to make profit, the incorporation of biologicals may lead to large profit losses for those operations.

Conclusions

The objective of this research was to evaluate the agronomic response of commercially available biological products on soybean in the predominant soybean growing regions of Mississippi. Few early-season responses were seen by location, and no responses occurred across site-years or years. Furthermore, there were no yield responses at any location during this study. With negative net returns on certain products, and no increases in net returns compared to the untreated and treated control, no products provided a benefit to growers that would justify the use of these products on the tested environments. Adoption of biological products is unlikely due to a lack of yield response and agronomic response across locations, and negative net returns responses at dryland locations. Further research of more biological products across a variety of site-years should be conducted as new products are continually coming to market.

Monthly precipitation (Rain) and irrigation (Irr) volumes for all site-years of soybean biological product efficacy trail conducted in 2023.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Stoneville** | **Starkville** | **Verona** |
| **Month** | **Rain\*** | **Irr^** | **Rain\*** | **Irr^** | **Rain\*** |
|  | **~~---------------------~~ha\*mm~~-----------------------~~** |
| May | 14.5 |  | 3.2 |  | 16.2 |
| June | 24.5 |  | 60.9 |  | 34.6 |
| July | 39.6 | 30.9 | 87.8 | 30.9 | 36 |
| August | 29.4 | 30.9 | 18.8 | 30.9 | 38.2 |
| September | 9.5 |  | 63.9 |  | 19.2 |
| October | 4.2 |  | 0 |  | - |
| **Total** | **183.5** | **296.4** | **144.2** |

**\* Rainfall totals are taken from the date of planting to harvest**

**^ Irrigation events applied 30.9 ha\*mm of water**

Monthly precipitation (Rain) and irrigation (Irr) volumes for all site-years of soybean biological product efficacy trail conducted in 2024.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Raymond** | **Stoneville** | **Starkville** | **Verona** |
| **Month** | **Rain\*** | **Rain\*** | **Irr^** | **Rain\*** | **Irr^** | **Rain\*** |
|  | **~~-------------------------------~~ha\*mm~~------------------------~~** |
| April | 4.2 | - |  | - |  | - |
| May | 78.1 | 39.5 |  | 2.7 |  | 0.2 |
| June | 31.8 | 16.3 | 30.9 | 43.8 |  | 41.1 |
| July | 55.3 | 10.2 | 61.8 | 18.5 | 30.9 | 23.1 |
| August | 11.8 | 13.2 | 30.9 | 13.2 | 30.9 | 0.3 |
| September | 41.3 | 43.5 |  | 56.4 | 30.9 | 53 |
| October | - | - |   | 0 |   | 0 |
| **Total** | **222.5** | **246.3** | **227.3** | **117.7** |

**\* Rainfall totals are taken from the date of planting to harvest**

**^ Irrigation events applied 30.9 ha\*mm of water**

Average air temperature in centigrade for soybean biological efficacy trials conducted in 2023 and 2024

|  |  |  |
| --- | --- | --- |
|  | **2023** | **2024** |
|  | **Stoneville\*** | **Starkville** | **Verona** | **Raymond** | **Stoneville** | **Starkville** | **Verona** |
| **Month** | ~~----------------------------------~~**Average Air Temp (C°) ~~---------------------------~~** |
| **April** |  |  |  | 22.0 |  |  |  |
| **May** | 23.5 | 22.6 | 24.1 | 24.3 | 24.9 | 26.5 | 24.3 |
| **June** | 26.5 | 25.5 | 25.6 | 26.6 | 26.9 | 25.9 | 26.8 |
| **July** | 28.4 | 27.7 | 27.6 | 27.9 | 27.7 | 28.0 | 27.9 |
| **August** | 28.6 | 27.8 | 27.5 | 27.2 | 27.6 | 27.6 | 27.6 |
| **September** | 25.2 | 24.3 | 24.3 | 24.2 | 24.6 | 24.3 | 24.1 |
| **October** | 20.5 | 23.9 |  |  |  | 23.2 | 22.3 |

**\* Temperature averages are taken from planting date to harvest date**

Treatment list for soybean biological product efficacy trials conducted in 2023

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Treatment** | **Product classification** | **Rate** | **Application method** | **Composition** | **Mode of Action** | **Manufacturer** |
| 1 | Untreated check | - | - | - | - | - | - |
| 2 | Treated check | - | - | - | - | - | - |
| 3 | HM-2163 | Biological | 14.78 ml/140,000 seed | Seed treatment | *Bacillus thuringensis* | Phosphorus solubilizer | Helena Agri-Enterprises, LLC |
| 4 | Zypro | Biostimulant | 585 ml/ha | In-furrow | Phospholipase C | Phosphorus solubilizer | Helena Agri-Enterprises, LLC |
| 5 | Bio Wake and B-Sure | BiologicalBiostimulant | 14 g/140,000 seed2,340 ml/ha | Seed treatmentFoliar application at R1 | *Methylobacterium hispanicum*Shrimp protein | Physiological microbes Humic substance | Amvac |
| 6 | Bio Wake | Biological | 14 g/140,000 seed | Seed treatment | *Methylobacterium hispanicum* | Physiological microbes | Amvac |
| 7 | Bio Wake and Biofriendly | BiologicalStimulant | 14 g/140,000 seed | Seed treatmentSeed treatment | *Methylobacterium hispanicum*Microbial nutrients | Physiological microbes | AmvacCentor Group |
| 8 | BioSa and Biofriendly | BiologicalStimulant | 0.0142 ml/1,000 seed6.7 ml/50 kg | Seed treatmentSeed treatment | *Bacillus* amyloliquefaciens and B. subtillisMicrobial nutrients | Phosphorus solubilizer | Centor Group |
| 9 | BioSa and Biofriendly and Polymer | BiologicalStimulant | 0.0142 ml/1,000 seed6.7 ml/50 kg6.7 ml/50 kg | Seed treatmentSeed treatmentSeed treatment | *Bacillus* amyloliquefaciens and B. subtillisMicrobial nutrientsPolymer seed coating | Phosphorus solubilizer | Centor Group |
| 10 | Fertiactyl | Biostimulant | 18.2 ml/50 kg | Seed treatment | 1% zinc and polyphenolic and additional organic acids | Humic substance | Timac Agro USA |
| 11 | Fertiactyl and Biofriendly | BiostimulantStimulant | 18.2 ml/50 kg6.7 ml/50 kg | Seed treatmentSeed treatment | 1% zinc and polyphenolic and additional organic acidsMicrobial nutrients | Humic substance | Timac Agro USACentor Group |
| 12 | AZterknot LR | Commercial fungicide and biostimulant | 584 ml/ha | Foliar at R3 | Azoxystrobin and extract of *Reynoutria sachalinensis* | Biofungicide | Vive Crop Protection |

Table 1.4 (Continued)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 13 | AZterknot HR | Commercial fungicide and biostimulant | 1,168 ml/ha | Foliar at R3 | Azoxystrobin and extract of *Reynoutria sachalinensis* | Biofungicide | Vive Crop Protection |
| 14 | Bio P | Biological | 2,340 ml/ha | In-furrow application | *Bacillus* spp. | Phosphorus solubilizer | Simplot |
| 15 | Bio P | Biological | 2,340 ml/ha | Foliar at V6 | *Bacillus* spp. | Phosphorus solubilizer | Simplot |

Treatment list for soybean biological product efficacy trials conducted in 2024

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Treatment** | **Product classification** | **Rate** | **Application method** | **Composition** | **Mode of Action** | **Manufacturer** |
| 1 | Untreated check | - | - | - | - | - | - |
| 2 | Treated check | - | - | - | - | - | - |
| 3 | HM-2163 | Biological | 14.78 ml/140,000 seed | Seed treatment | *Bacillus thuringensis* | Phosphorus solubilizer | Helena Agri-Enterprises, LLC |
| 4 | Zypro | Biostimulant | 585 ml/ha | In-furrow | Phospholipase C | Phosphorus solubilizer | Helena Agri-Enterprises, LLC |
| 5 | Bio Wake and B-Sure | BiologicalBiostimulant | 14 g/140,000 seed2,340 ml/ha | Seed treatmentFoliar application at R1 | *Methylobacterium hispanicum*Shrimp protein | Physiological microbesHumic substance | Amvac |
| 6 | Bio Wake | Biological | 14 g/140,000 seed | Seed treatment | *Methylobacterium hispanicum* | Physiological microbes | Amvac |
| 7 | Bio Wake and Biofriendly | BiologicalStimulant | 14 g/140,000 seed | Seed treatmentSeed treatment | *Methylobacterium hispanicum*Microbial nutrients | Physiological microbes | AmvacCentor Group |
| 8 | Fertiactyl | Biostimulant | 18.2 ml/50 kg | Seed treatment | 1% zinc and polyphenolic and additional organic acids | Humic substance | Timac Agro USA |
| 9 | Fertiactyl and Biofriendly | BiostimulantStimulant | 18.2 ml/50 kg6.7 ml/50 kg | Seed treatmentSeed treatment | 1% zinc and polyphenolic and additional organic acidsMicrobial nutrients | Humic substance | Timac Agro USACentor Group |
| 10 | AZterknot LR | Commercial fungicide and biostimulant | 584 ml/ha | Foliar application at R3 | Azoxystrobin and extract of *Reynoutria sachalinensis* | Biofungicide | Vive Crop Protection |
| 11 | AZterknot HR | Commercial fungicide and biostimulant | 1,168 ml/ha | Foliar application at R3 | Azoxystrobin and extract of *Reynoutria sachalinensis* | Biofungicide | Vive Crop Protection |
| 12 | Quadris | Commercial fungicide | 490 ml/ha | Foliar application at R3 | Azoxystrobin | Fungicide | - |
| 13 | Regalia | Biostimulant | 2,340 ml/ha | Foliar application at R3 | Extract of *Reynoutria sachalinensis* | Biofungicide | - |

Site description for soybean biological product efficacy trials conducted in 2023 & 2024

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Site-Year** | **Soybean Planting**  | **Water Management** | **Tillage Management** | **Soil Type** | **Harvest Date** |
| Stoneville 2023 | 4 May | Irrigated | Ridge-Till | Sandy Loam | 10 Oct |
| Starkville 2023 | 16 May | Irrigated | Ridge-Till | Silt Loam | 1 Oct |
| Verona 2023 | 10 May | Dryland | Min-Tillage | Silt Loam | 25 Sep |
| Raymond 2024 | 25 Apr | Dryland | Min-Tillage | Silt Loam | 18 Sep |
| Stoneville 2024 | 8 May | Irrigated | Ridge-Till | Sandy Loam | 25 Sep |
| Starkville 2024 | 15 May | Irrigated | Ridge-Till | Silt Loam | 2 Oct |
| Verona 2024 | 28 May | Dryland | Min-Tillage | Silt Loam | 10 Oct |

P-values for early season growth and soybean grain yield for a soybean biological product efficacy trail conducted in 2023

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Source** | **df** | **Stand** | **CC\* 20DAP** | **CC 30DAP** | **CC 40DAP** | **Nodules** | **Yield** |
| **Stoneville** | Product | 14 | 0.5905 | 1.0000 | 0.3274 | 0.2690 | 0.2615 | 0.7058 |
| **Starkville** | Product | 14 | 0.0803 | 0.0891 | 0.0318 | 0.0127 | 0.4458 | 0.9082 |
| **Verona** | Product | 14 | 0.7813 | 0.7521 | 0.6877 | 0.3603 | 0.8839 | 0.5839 |
| **All** | Product | 14 | 0.4941 | 0.1621 | 0.3308 | 0.1880 | 0.6982 | 0.4731 |
| Site | 2 | < 0.0001 | < 0.0001 | <0.0001 | < 0.0001 | 0.2536 | < 0.0001 |
| Site\*Product | 28 | 0.4269 | 0.8999 | 0.5266 | 0.2896 | 0.5090 | 0.8442 |

**\* CC = percent canopy closure**

P-values for early season growth and soybean grain yield for a soybean biological product efficacy trail conducted in 2024

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Source** | **df** | **Stand** | **CC\* 20DAP** | **CC 30DAP** | **CC 40DAP** | **Nodules** | **NW** | **Yield** |
| **Raymond** | Product | 12 | 0.7211 | 0.2573 | 0.4907 | 0.6062 | 0.9246 | 0.9308 | 0.2478 |
| **Stoneville** | Product | 12 | 0.2494 | 0.5677 | 0.8843 | 0.3602 | 0.9533 | 0.9097 | 0.4276 |
| **Starkville** | Product | 12 | 0.1159 | . | 0.6774 | 0.7195 | 0.1680 | 0.1005 | 0.7788 |
| **Verona** | Product | 12 | 0.8946 | 0.8527 | 0.9154 | 0.8747 | 0.9601 | 0.9748 | 0.2074 |
| **All** | Product | 12 | 0.5403 | 0.9447 | 0.9849 | 0.8883 | 0.6294 | 0.5895 | 0.8106 |
| Site | 3 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| Site\*Product | 36 | 0.6615 | 0.8235 | 0.9990 | 0.8244 | 0.9962 | 0.6826 | 0.7636 |

**\* CC = percent canopy closure**

Early season canopy closure percentages collected from soybean biological efficacy trials in 2023.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Stoneville** | **Starkville** | **Verona** |
| **Treatment** | **20 DAP** | **30 DAP** | **40 DAP** | **20 DAP** | **30 DAP** | **40 DAP** | **20 DAP** | **30 DAP** | **40 DAP** |
|  | **~~-----------------------------------------~~Percent Canopy Closure~~------------------------~~** |
| 1‡ | 12.0 | 26.6 | 54.6 | 6.97 | 40.1A | 50.1A | 10.9 | 19.2 | 40.3 |
| 2 | 12.0 | 27.9 | 54.5 | 9.04 | 48.1B | 60.2B | 10.8 | 18.3 | 39.8 |
| 3 | 12.1 | 26.4 | 51.5 | 10.15 | 51.0B | 64.4B | 12.1 | 18.9 | 30.5 |
| 4 | 11.8 | 27.7 | 54.5 | 9.72 | 49.7B | 64.8B | 11.4 | 19.2 | 41.3 |
| 5 | 12.0 | 28.0 | 53.8 | 9.96 | 50.5B | 63.3B | 10.2 | 18.7 | 46.6 |
| 6 | 11.8 | 28.2 | 55.1 | 9.26 | 49.1B | 61.9B | 11.1 | 19.6 | 45.3 |
| 7 | 12.0 | 27.7 | 5.1 | 10.24 | 49.9B | 61.5B | 11.6 | 17.4 | 37.8 |
| 8 | 11.9 | 29.9 | 57.5 | 7.57 | 43.6 | 55.8 | 9.4 | 16.4 | 39.2 |
| 9 | 11.9 | 27.2 | 55.2 | 7.93 | 47.0 | 58.9 | 10.3 | 18.4 | 41.9 |
| 10 | 11.5 | 29.8 | 56.5 | 8.47 | 46.5 | 63.6B | 10.0 | 17.2 | 38.3 |
| 11 | 12.0 | 30.8 | 56.5 | 9.01 | 49.0B | 58.1 | 10.8 | 19.6 | 42.7 |
| 12 | 11.9 | 29.3 | 57.8 | 8.94 | 50.5B | 62.6B | 12.0 | 21.0 | 47.6 |
| 13 | 11.8 | 30.9 | 57.0 | 8.30 | 47.5 | 61.2B | 11.2 | 19.8 | 47.9 |
| 14 | 11.8 | 30.1 | 57.3 | 8.87 | 46.2 | 58.5 | 10.4 | 19.0 | 45.6 |
| 15 | 12.04 | 29.5 | 58.7 | 9.25 | 48.2 | 59.8 | 10.2 | 18.6 | 40.4 |
| **P-Value** | **NS** | **NS** | **NS** | **NS** | **0.0318** | **0.0127** | **NS** | **NS** | **NS** |
| **Dunnett’s 0.05** | **NS** | **NS** | **NS** | **NS** | **8.047** | **10.0998** | **NS** | **NS** | **NS** |

**‡ 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Biosa + Biofriendly, 19 = Biosa + Biofriendly + Polymer, 10 = Fertiactyl, 11 = Fertiactyl + Biofriendly, 12 = AZterknot LR, 13 = AZterknot HR, 14 = BioP at-plant, 15 = BioP at V6**

**A denotes a significant difference as compared to the treated control**

**B denotes a significant difference as compared to the untreated control**

Early season canopy closure percentages collected from soybean biological efficacy trials in 2024 in Mississippi.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Stoneville** | **Starkville** | **Verona** | **Raymond** |
| **Treatment** | **20 DAP** | **30 DAP** | **40 DAP** | **30 DAP** | **40 DAP** | **20 DAP** | **30 DAP** | **40 DAP** | **20 DAP** | **30 DAP** | **40 DAP** |
|   | **~~-------------------------------------~~Precent Canopy Closure~~------------------------------------------------~~** |
| 1† | 19.57 | 44.26 | 71.59 | 21.05 | 41.96 | 3.67 | 7.34 | 16.05 | 8.09 | 20.31 | 37.59 |
| 2 | 17.41 | 43.81 | 68.26 | 21.43 | 41.87 | 4.16 | 8.59 | 18.93 | 8.59 | 21.64 | 43.56 |
| 3 | 18.11 | 43.65 | 69.52 | 20.27 | 38.98 | 4.20 | 8.09 | 17.56 | 7.77 | 18.87 | 40.63 |
| 4 | 16.95 | 41.13 | 67.19 | 19.55 | 40.47 | 4.44 | 9.07 | 17.98 | 8.38 | 19.62 | 36.65 |
| 5 | 17.48 | 43.30 | 68.94 | 21.76 | 41.90 | 4.51 | 9.32 | 19.13 | 7.94 | 18.36 | 37.74 |
| 6 | 17.77 | 42.49 | 69.02 | 21.28 | 40.83 | 4.39 | 8.68 | 19.56 | 8.10 | 21.15 | 40.79 |
| 7 | 17.75 | 44.55 | 69.12 | 21.88 | 42.01 | 3.56 | 7.26 | 16.09 | 8.35 | 20.68 | 39.70 |
| 8 | 18.29 | 42.93 | 69.24 | 20.88 | 39.09 | 4.85 | 8.76 | 19.43 | 8.69 | 20.40 | 39.58 |
| 9 | 19.61 | 43.47 | 71.12 | 19.38 | 40.12 | 4.41 | 8.57 | 18.14 | 7.65 | 19.50 | 43.42 |
| 10 | 18.27 | 44.04 | 70.94 | 21.17 | 40.84 | 4.53 | 8.92 | 20.50 | 8.05 | 19.74 | 40.51 |
| 11 | 16.83 | 43.16 | 67.12 | 22.93 | 42.19 | 4.59 | 8.80 | 20.32 | 7.54 | 19.74 | 38.17 |
| 12 | 18.03 | 44.77 | 68.11 | 21.70 | 41.60 | 3.77 | 7.75 | 18.09 | 7.54 | 19.47 | 39.64 |
| 13 | 18.50 | 43.90 | 56.48 | 19.92 | 39.60 | 3.74 | 7.74 | 16.44 | 7.96 | 20.17 | 45.84 |
| **P-Value** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Dunnett's 0.05** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**† 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Fertiactyl, 9 = Fertiactyl + Biofriendly, 10 = AZterknot LR, 11 = AZterknot HR, 12 = Azoxystrobin, 13 = Regalia**

Nodules per plant for soybean biological efficacy trials conducted in 2023 and 2024 at four different locations in Mississippi

|  |  |  |
| --- | --- | --- |
|  | **2023** | **2024** |
|  | **Stoneville** | **Starkville** | **Verona** |  | **Raymond** | **Stoneville** | **Starkville** | **Verona** |
| **Treatment** | **~~-------~~Nodules plant-1~~--------~~** | **Treatment** | **~~---------------~~Nodules plant-1~~----------~~** |
| 1‡ | 25.63 | 22.31 | 12.31 | 1† | 28.10 | 20.76 | 36.80 | 23.50 |
| 2 | 20.81 | 25.91 | 12.38 | 2 | 25.06 | 17.03 | 37.72 | 25.31 |
| 3 | 22.94 | 17.33 | 13.31 | 3 | 22.57 | 17.36 | 47.25 | 25.10 |
| 4 | 23.85 | 22.00 | 12.34 | 4 | 25.83 | 14.16 | 39.63 | 25.22 |
| 5 | 21.75 | 19.24 | 12.81 | 5 | 25.76 | 13.96 | 38.73 | 27.07 |
| 6 | 28.81 | 21.38 | 12.17 | 6 | 24.37 | 15.03 | 37.92 | 24.73 |
| 7 | 20.06 | 18.38 | 15.13 | 7 | 23.93 | 13.55 | 32.67 | 24.60 |
| 8 | 27.31 | 37.07 | 12.83 | 8 | 22.87 | 19.80 | 40.47 | 23.50 |
| 9 | 23.31 | 19.24 | 10.48 | 9 | 26.02 | 14.40 | 30.77 | 23.30 |
| 10 | 19.81 | 16.66 | 9.69 | 10 | 26.53 | 20.94 | 41.78 | 24.90 |
| 11 | 23.50 | 25.74 | 10.94 | 11 | 28.13 | 17.52 | 39.28 | 26.73 |
| 12 | 26.00 | 18.38 | 11.69 | 12 | 23.13 | 11.72 | 37.37 | 24.86 |
| 13 | 22.94 | 26.07 | 13.31 | 13 | 22.77 | 18.12 | 38.32 | 25.70 |
| 14 | 31.33 | 16.56 | 13.98 |  |  |  |  |  |
| 15 | 31.69 | 16.94 | 13.13 |  |  |  |  |  |
| **P-value** | **NS** | **NS** | **NS** | **P-value** | **NS** | **NS** | **NS** | **NS** |
| **Dunnett's 0.05** | **NS** | **NS** | **NS** | **Dunnett's 0.05** | **NS** | **NS** | **NS** | **NS** |

**‡ 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Biosa + Biofriendly, 19 = Biosa + Biofriendly + Polymer, 10 = Fertiactyl, 11 = Fertiactyl + Biofriendly, 12 = AZterknot LR, 13 = AZterknot HR, 14 = BioP at-plant, 15 = BioP at V6**

**† 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Fertiactyl, 9 = Fertiactyl + Biofriendly, 10 = AZterknot LR, 11 = AZterknot HR, 12 = Azoxystrobin, 13 = Regalia**

Nodule weights for soybean biological efficacy trials conducted in 2024 across four sites

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Raymond** | **Stoneville** | **Starkville** | **Verona** |
| **Treatment** | **~~--------------------~~mg nodule-1~~--------------------~~** |
| 1† | 12.7 | 7.8 | 4.4 | 2.2 |
| 2 | 16.2 | 9.0 | 4.5 | 3.1 |
| 3 | 16.7 | 10.1 | 4.3 | 3.0 |
| 4 | 15.4 | 9.5 | 4.4 | 3.2 |
| 5 | 15.7 | 8.9 | 4.9 | 3.3 |
| 6 | 15.4 | 5.9 | 5.0 | 3.1 |
| 7 | 18.3 | 9.0 | 4.3 | 3.1 |
| 8 | 13.6 | 8.4 | 3.8 | 3.0 |
| 9 | 15.6 | 7.5 | 5.3 | 2.7 |
| 10 | 15.8 | 6.8 | 4.9 | 2.6 |
| 11 | 14.6 | 9.8 | 4.6 | 3.5 |
| 12 | 17.4 | 8.5 | 4.7 | 3.3 |
| 13 | 18.1 | 8.5 | 4.0 | 3.1 |
| **P-value** | **NS** | **NS** | **NS** | **NS** |
| **Dunnett's 0.05** | **NS** | **NS** | **NS** | **NS** |

**† 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Fertiactyl, 9 = Fertiactyl + Biofriendly, 10 = AZterknot LR, 11 = AZterknot HR, 12 = Azoxystrobin, 13 = Regalia**

Soybean grain yield for all site-years and averaged across all site years for soybean biological efficacy trials conducted in 2023 & 2024 in Mississippi

|  |  |  |
| --- | --- | --- |
| **2023** | **2024** | **2023 & 2024** |
|  | **DREC\*** | **STRK** | **VN** |  | **RAY** | **DREC** | **STRK** | **VN** | **All** |
| **Treatment** | **Yield** | **Yield** | **Yield** | **Treatment** | **Yield** | **Yield** | **Yield** | **Yield** | **Yield** |
|  | **~~-----------~~kg ha-1~~-----------~~** |  | **~~-----------------------~~ kg ha-1~~---------------------~~** |
| 1‡ | 5795 | 3402 | 4646 | 1† | 3288 | 3711 | 4014 | 1907 | 3680 |
| 2 | 4958 | 3559 | 4451 | 2 | 3474 | 3571 | 4285 | 1841 | 3735 |
| 3 | 5016 | 3345 | 3382 | 3 | 3221 | 3512 | 4214 | 1487 | 3599 |
| 4 | 5036 | 3559 | 4493 | 4 | 3536 | 4057 | 4010 | 1639 | 3826 |
| 5 | 5056 | 3503 | 4806 | 5 | 3122 | 3760 | 4029 | 1693 | 3711 |
| 6 | 4966 | 3489 | 4841 | 6 | 3387 | 4232 | 4027 | 1701 | 3809 |
| 7 | 5218 | 3590 | 4285 | 7 | 3485 | 3432 | 4330 | 1841 | 3776 |
| 8 | 4881 | 3577 | 4507 | 8 | 3734 | 3468 | 4317 | 1585 | 3783 |
| 9 | 5146 | 3589 | 4608 | 9 | 3336 | 3181 | 4122 | 1689 | 3652 |
| 10 | 5050 | 3509 | 4804 | 10 | 3424 | 3432 | 3986 | 1597 | 3743 |
| 11 | 5052 | 3521 | 4651 | 11 | 3471 | 4047 | 4147 | 1494 | 3780 |
| 12 | 5232 | 3496 | 4941 | 12 | 3178 | 3096 | 4123 | 1747 | . |
| 13 | 4864 | 3462 | 4895 | 13 | 3195 | 3753 | 4360 | 1764 | . |
| 14 | 5044 | 3509 | 4916 | . | . | . | . | . | . |
| 15 | 4977 | 3410 | 4280 | . | . | . | . | . | . |
| **P-value** | NS | NS | NS | **P-value** | NS | NS | NS | NS | NS |
| **Dunnett's 0.05** | NS | NS | NS | **Dunnett's 0.05** | NS | NS | NS | NS | NS |

**‡ 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Biosa + Biofriendly, 9 = Biosa + Biofriendly + Polymer, 10 = Fertiactyl, 11 = Fertiactyl + Biofriendly, 12 = AZterknot LR, 13 = AZterknot HR, 14 = BioP at-plant, 15 = BioP at V6**

**† 1 = Untreated control, 2 = Treated control, 3 = HM-2163, 4 = Zypro, 5 = BioWake + B-Sure, 6 = BioWake, 7 = BioWake + Biofriendly, 8 = Fertiactyl, 9 = Fertiactyl + Biofriendly, 10 = AZterknot LR, 11 = AZterknot HR, 12 = Azoxystrobin, 13 = Regalia**

**\* DREC = Stoneville, STRK = Starkville, VN = Verona, RAY = Raymond**

Specified costs for biological products in a soybean biological efficacy trail conducted in Mississippi in 2023 and 2024.

|  |  |
| --- | --- |
| **Treatment** | **$/ha** |
| **Untreated†** | 148.24 |
| **Treated** | 166.50 |
| **HM-2163** | 179.47 |
| **Zypro** | 175.70 |
| **BioWake + B-Sure** | 272.18 |
| **BioWake** | 180.09 |
| **BioWake + Biofriendly** | 188.74 |
| **BioSa + Biofriendly** | 188.12 |
| **BioSa + Biofriendly + Polymer** | 191.82 |
| **Fertiactyl** | 172.25 |
| **Fertiactyl + Biofriendly** | 180.90 |
| **Azterknot LR** | 197.38 |
| **Azterknot HR** | 228.27 |
| **BioP** | 206.03 |
| **Azoxystrobin** | 179.43 |
| **Regalia** | 245.72 |

**† Specified costs, Seed = $148.24 ha-1, Seed treatment = $18.26 ha-1, HM-2163 = $12.98 ha-1, Zypro = $9.20 ha-1, BioWake = $13.59 ha-1, B-Sure = $92.09 ha-1, Biofriendly = $8.65 ha-1, BioSa = $12.97 ha-1, Polymer = $3.71 ha-1, Fertiactyl = $5.76 ha-1, AZterknot LR = $30.89 ha-1, AZterknot HR = $61.78 ha-1, BioP = $39.54 ha-1, Azoxystrobin = $12.93 ha-1, Regalia = $79.27 ha-1**

**Biological product prices were obtained from sales representatives or product fact sheets, Azoxystrobin and Regalia prices were obtained from receipts of purchase, and seed and seed treatment prices were obtained from Mississippi State Extension Soybean 2025 Planning Budgets (Maples et al. 2024)**

Net returns after specified costs for soybean biological product efficacy trials conducted in 2023 and 2024 in Mississippi

|  |  |  |  |
| --- | --- | --- | --- |
|  | **2023** |  | **2024** |
|  | **DREC\*** | **STRK** | **VN** |  | **RAY** | **DREC** | **STRK** | **VN** |
| **Treatment** | **$ ha-1 above specified expenses** | **Treatment** | **~~--------~~$ ha-1 above specified expenses~~-------~~** |
| 1 | 1613.77 | 1107.67 | 1559.33 | 1 | 1059.72 | 1215.36 | 1326.56 | 552.32 |
| 2 | 1655.46 | 1141.46 | 1469.41 | 2 | 1109.78 | 1145.48 | 1365.41 | 509.98 |
| 3 | 1663.9 | 1055.32 | 1471.45 | 3 | 1004.00 | 1110.83 | 1368.82 | 366.88A |
| 4 | 1730.13 | 1137.8 | 1608.19 | 4 | 1123.36 | 1314.93 | 1297.71 | 426.50 |
| 5 | 1586.04 | 1014.99 | 1494.18 | 5 | 875.05B | 1109.33 | 1208.12 | 349.94AB |
| 6 | 1644.87 | 1102.08 | 1598.95 | 6 | 1064.47 | 1374.92 | 1312.37 | 444.90 |
| 7 | 1729.05 | 1130.58 | 1512.3 | 7 | 1091.73 | 1072.31 | 1391.53 | 487.57 |
| 8 | 1605.68 | 1126.39 | 1468.16 | 8 | 1199.89 | 1102.00 | 1414.07 | 410.29 |
| 9 | 1699.44 | 1127.05 | 1501.68 | 9 | 1044.86 | 988.04 | 1333.52 | 439.86 |
| 10 | 1683.71 | 1117.28 | 1593.3 | 10 | 1060.66 | 1063.72 | 1540.40 | 389.31 |
| 11 | 1675.56 | 1113.08 | 1528.19 | 11 | 1046.92 | 1258.54 | 1295.39 | 320.49AB |
| 12 | 1725.3 | 1087.41 | 1604.91 | 12 | 988.34 | 958.14 | 1625.55 | 462.53 |
| 13 | 1559.1 | 1044.12 | 1557.28 | 13 | 928.05 | 1133.32 | 1356.10 | 402.31 |
| 14 | 1591.81 | 1083.53 | 1428.97 |  |  |  |  |  |
| 15 | 1622.91 | 1047.29 | 1366.76 |  |  |  |  |  |
| **P-Value** | 0.3025 | 0.2686 | 0.9530 | **P-Value** | **0.0138** | 0.4119 | 0.5103 | **0.0061** |
| **Dunnett's 0.05** | NS | NS | NS | **Dunnett's 0.05** | **200** | NS | NS | **160** |

**Soybean grain prices were calculated at $367.44 metric tonne-1**

**Specified costs are listed in Table 1.46**

**A denotes a difference to the untreated control**

**B denotes a difference to the treated control**

**\* DREC = Stoneville, STRK = Starkville, VN = Verona, RAY = Raymond**

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