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Using Biostimulants and Soil Additives to Improve Corn Yield in South Texas

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Abstract: Field studies were conducted in 2016, 2017, and 2020 in south-central and the Coastal Bend regions of Texas to determine the effects of various biostimulants and soil additives on corn growth and yield. In south-central Texas, the use of pop-up fertilizer (9-30-0 + Zn) either alone or in combination with either 2% N, bifenthrin, or bifenthrin + pyraclostrobin resulted in the greatest corn vigor but a yield response was only noted with pop-up fertilizer alone at 28062 or 46771 ml ha^{-1} in one year. In the Coastal Bend region, leaf tissue analysis showed that only Fe was affected with the use of any soil additive. *Bacillus licheniformis* + *bacillus megaterium* + *bacillus pumilus* increased Fe leaf tissue content by 20% over the untreated check. Radicoat seed coating at 438 ml ha^{-1} reduced corn plant stand by 10% and *Pseudomonas brassicaceanum* reduced corn height when compared with the untreated check; however, no differences in test weight or yield from the untreated check were noted with any soil additive. Little if any impacts of the use of biostimulants or soil amendments were seen in these studies.

Keywords: fungicide; inoculant; insecticide; microbial enhancer; soil activator; soil conditioner; soil stimulant

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1. Introduction

Growers are always trying to find ways to economically and efficiently improve their production systems. Since the early 1900's the use of soil additives such as fungicides, insecticides, soil activators, soil conditioners, wetting agents, inoculants, microbial enhancers, soil stimulants, etc., have been promoted as a means to improve crop growth and yield [1,2]. Recent increases in production costs, especially for fertilizers, have renewed producers interest in these products. Many of these products have not been investigated scientifically and the claims about what these products can do are unproven.

Generally, soil additives can be distinguished from fertilizers in that they usually have little or no nutrient content. They also differ from fertilizers in that they do not provide a guaranteed analysis (e. g., 10-34-0 or 32-0-0). The manufacturers of these products often suggest that adding these products to the soil will enhance crop production by improving root growth, nutrient uptake, and increased yield. These enhancements are generally said to occur when standard fertilizer applications are made to a crop at the recommended or near recommended levels, although some additives claim to replace or significantly reduce the need for fertilizers [1,2].

Soil amendments are added to the soil to change and improve the soil. Unlike fertilizers, which add nutrients to the soil, amendments modify the condition of the soil itself. Tilth is the condition of the soil and specifically its suitability for supporting plant roots. With improved tilth, roots penetrate surrounding soil more easily and water infiltration improves. Soil amendments alter the soil in ways that affect the availability of plant nutrients that occur naturally or that are added by fertilizers [1,2].

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Fertilizers impact plant growth directly while soil amendments affect growth indirectly and sometimes deliver nutrients as a bonus. Soil amendments are not fertilizer substitutes; instead, they help fertilizers become more effective by improving soil texture and tilth. Soil additives can typically be divided into three catagories: 1) soil conditioners, 2) soil activators, and 3) wetting agents and surfactants. Soil conditioners usually are defined as materials that improve a soil's physical condition or structure and, in turn, the soil's aeration and water relationships [1,2].

Maintaining and/or improving soil structure is highly desirable in crop production and one of the most common method of improving soil structure is by adding organic matter. Soil activators are marketed on the basis that they stimulate existing soil microbes or inoculate the soil with new beneficial organisms. Some manufacturers suggest that such products may improve soil physical properties (increase structure, reduce compaction), increase fertilizer and soil nutrient uptake, improve crop yields and/or quality, correct soil 'toxicities' (such as salinity), and provide disease and insect control/resistance [3]. Wetting agents and surfactants have long been used to reduce the surface tension of water droplets and improve leaf surface coverage with foliar sprays. Surfactants are also used to reduce the risk of crop injury and improve the efficiency or preemergence herbicides having residual soil activity [4]. However, many related products are marketed on the basis that they will loosen tight or compacted soils, improve water infiltration and retention, enhance nutrient availability, and increase crop yields [5].

Several traditional soil amendments and commercial fertilizers have been tested extensively through research trials to document both their benefits and limitations. Unfortunately, sufficient research funds often are not available to investigate the many new products being marketed, including non-traditional additives. Nevertheless, producers need to be aware of the types of products available and have some knowledge of their potential for improved crop production. Therefore, this research was conducted to evaluate biostimulants and soil additives that are currently on the market to determine corn growth and yield response.

2. Materials and Methods

Field studies were conducted on grower's fields in south-central Texas near Ganado during the 2016 and 2017 growing seasons and in the Coastal Bend region at the Texas A&M AgriLife Research and Extension Center near Corpus Christi during the 2020 growing season to determine corn response to various biostimulants and soil additives applied in-furrow at planting. Biostimulants and additives used at each location are listed in Tables 1 and 2 while variables for each location are presented in Table 3. The experimental design was a randomized complete block with three to four replications depending on location. An untreated check was included each year at all locations.

At all three locations, treatments were applied in 46.8 L ha^{-1} of water using a CO_2-pressurized sprayer with one Teejet® orifice disc # 45 nozzle per row immediately after seed drop but prior to furrow closure. For the studies near Ganado each plot consisted of two rows spaced 97 cm apart and 7.6 m long while at the Corpus Christi location plot size was 4 rows spaced 102 cm apart and 9.1 m long. Traditional production practices were used to maximize corn growth, development, and yield at each location.

At Ganado, corn vigor was estimated visually on a scale of 1 to 9 (1 = most vigorous and 9 being least vigorous). Vigor was evaluated 21 and 51 days after planting (DAP) in 2016 and 6 and 16 DAP in 2017. At Corpus Christi, plant height was measured at tassel by measuring the distance from the soil surface to the ear node and the tip of the tassel. Plant damage from stressors were measured for leaf damage (30 days after planting and during silk), drought stress (one indicator being plant height) and ear injury from insects and diseases observed at the soft dough stage. Lodging was not detected pre-harvest at any location. Corn yield was determined near Ganado using a Gleaner K2 small plot combine with a Harvest Master 800 scale system while at the Corpus Christi location harvested was completed using a 4-row New Holland TR 87 combine. Harvest was at 13 to 17% moisture and yield at all locations was adjusted to 15% moisture.

Data for percentage of corn vigor, plant height, plants ha^{-1}, test weight, and yield were transformed to the arcsine square root prior to analysis; however, non-transformed means are presented because arscine transformation did not affect interpretation of the data. Data were subjected to ANOVA and analyzed using the SAS PROC MIXED procedure 23 [6].

Treatment means were separated using Fisher's Protected LSD at $P \leq 0.10$ at the Ganado locations and $P \leq 0.05$ at the Corpus Christi location. The untreated check was used for all data analysis.

3. Results

3.1. Ganado locations

3.1.1. Vigor

In 2016 when evaluated 21 days after planting (DAP), any treatment which included the pop up fertilizer resulted in the greatest vigor. Tebuconazole (Torque) and gibberellic acid (Pro-Gibb) + cytokinin (Radiate) also had greater vigor than the untreated check (Table 4). At the 51 DAP evaluation, any pop-up fertilizer treatment, ionized sodium silicate (Quicksol), *Bacillus amyloliquefaciens* + pyraclostrobin (Xanthion), and the microalgae (Pure Algae) treatment resulted in greater vigor than the untreated check. In research on peanut (*Arachis hypogaea* L.), Phipps [7] reported that the use of tebuconazole applied in-furrow suppressed *Cylindrocladium* black rot (caused by *Cylindrocladium parasiticun*).

In 2017 at the 6 DAP evaluation, all treatments with the exception of those that contained pop-up fertilizer, *Bacillus amyloliquefaciens* strain MBI 600 + pyraclostrobin, pyraclostrobin alone (Headline), and 2% N (Levesol) resulted in greater vigor than the untreated check (Table 5). The only exception to those treatments that contained pop-up fertilizer was pop-up fertilizer at the low rate which resulted in a 19% increase in vigor over the untreated check. *Bacillus licheniformis* (VGR) + bifenthrin (Capture LFR) resulted in the greatest vigor. Mascagni et al. [8] reported that pop-up fertilizer at high rates may injure plants and this may have accounted for the reduced vigor with pop-up fertilizer at this early evaluation.

At 15 DAP corn vigor evaluations had changed considerably as all treatments which contained pop-up fertilizer produced the greatest plant vigor. Treatments containing the *Bacillus amyloliquefaciens* strain D747 + bifenthrin (Ethos XB), 2% N, and both rates of the microalgae resulted in plant vigor similar to that of the untreated check. Mascagni et al. [8] reported on sandy loam and silt soils, growth responses with pop-up fertilizer over N alone was primarily due to the P in pop-up. This effect was probably because of reduced P availability on the sandy, low organic matter, and light colored soils which are typically cold-natured.

Interestingly, tebuconazole had no effect on early season corn vigor. Jordan et al. [9] reported in peanut the use of tebuconazole in-furrow resulted in slow emergence and reduced early-season growth. They reported that tebuconazole reduced yield in only one of five experiments even though peanut emergence was delayed in most experiments and peanut diameter was less when tebuconazole was applied.

3.1.2. Test weight

In 2016, only the 7% total N + 10% chelated Fe (Sprint) treatment resulted in a lower test weight than the untreated check (Table 4) while in 2017 no differences were noted between the untreated check and any treatment (Table 5).

3.1.3. Yield

In 2016, although not significantly different from the untreated check, pop-up fertilizer + Zn and pop-up fertilizer + Zn + pyraclostrobin produced the highest numerical yields (Table 4). Several treatments, 7% total N + 10% chelated Fe, ionized sodium silicate, both gibberellic acid treatments (Pro-Gibb), bifenthrin alone, *Bacillus amyloliquefaciens* strain MBI 600 + pyraclostrobin at 44 + 219 mi ha^{-1}, pyraclostrobin alone, and 2% N, produced yields that were lower than the untreated check but none of those treatments included any pop-up fertilizer treatment. Lemus et al. [10] reported that seasonal annual ryegrass (*Lolium multiflorum* Lam.) dry matter yield was not different between the untreated check and gibberellic acid treatments. They concluded that temperatures in the southern US during annual ryegrass production may be too mild to observe a gibberellic acid response.

In 2017, pop-up fertilizer alone at 28062 and 46771 ml ha^{-1} resulted in corn yields that were greater than the untreated check while the microalgae treatment at 1462 m ha^{-1} produced yield lower than the untreated check (Table 5). No other treatments resulted in any differences from the untreated check. Placing small amounts of starter fertilizer in close proximity to the seed at planting can alleviate the effects of cold soil temperature on P uptake and early corn growth [8]. They reported in 15 trials in Louisiana that starter fertilizer increased yield in only one third of the studies; however, early season plant growth was increased in all trials. The largest yield increases occurred on sandy loam soils with low organic matter.

Pop-up or starter fertilizers have shown mixed results in other studies [11–15]. Niehaus et al., [11] researched starter fertilizer placements of direct seed contact, dribble over-the-row, and a subsurface band (5 cm below and 5 cm to the side of the seed row) and reported that starter fertilizer, regardless of placement, often increased early-season dry matter production and significantly increased grain yields. Pierson et al., [12] concluded that the use of a fungicide and/or starter (pop-up) fertilizer in soybean [*Glycine max* (L.) Merr.] was not profitable if soil-borne diseases or nutrient deficiencies were not present.

Wise [16] reported that the use of *Bacillus amyloliquefaciens* strain D747, MBI 600 *Bacillus amyloliquefaciens* strain MBI 600 + pyraclostrobin, or pyraclostrobin alone did not improve corn plant populations or yield at three planting dates. They concluded that where growers do not have a history of seedling disease may not need in-furrow fungicides even when planting in cool, wet conditions.

A. brasilense has been used on corn as a seed treatment in Brazil to improve N use and yield and resulted in increased corn growth and yield when combined with only half of the optimum rate of fertilizer N [17,18]. A meta-analysis of *Azospirillum* spp. indicated that yield increases in corn were achieved when the bacteria was applied without additional N and only minimal increases when applied with N [19].

3.2. Corpus Christi location

3.2.1. Tissue samples

No differences were noted in leaf content with P, K, Ca, Mg, Na, Zn, Cu, Mn, S, or B (Table 6). N levels in the tissue samples were highest with starter fertilizer only, while Fe levels were highest with *Bacillus licheniformis* + *Bacillus megaterium* + *Bacillus pumilu* (Accomplish LM) at 2339 ml ha^{-1}. No other differences were noted. In research on guar (*Cyamopsis tetragonoloba* L.) El-Sawah et al. [20] reported that biofertilizers produced from *Bacillus* spp. and arbuscular mycorrhizal fungi improved N, P, and K content in guar leaves. They suggested that biofertilizers increased the availability of essential nutrients in the soil which translocated to the guar through the root system and therefore improved guar growth and yield.

3.2.2. Plant populations

Seed coating (Radicoat) at 438 ml ha^{-1} resulted in a 10% stand reduction when compared with the untreated check. No other differences were noted (Table 7).

3.2.3. Plant height.

Pseudomonas brassicaceanum (Bio-Yield) resulted in a 5% reduction in plant height compared with the untreated check. No other differences were noted (Table 7).

3.2.4. Leaf damage

Bacillus licheniformis + *Bacillus megaterium* + *Bacillus pumilu* at 2339 ml ha^{-1} and pop-up fertilizer resulted in the greatest leaf damage (Table 7). Leaf damage was very low because of the use of a hybrid with B_t gene [21](Pruter et al., 2020a,b).

3.2.5. Test weight

No differences were noted between any treatments (Table 7).

3.2.6. Yield

No differences were noted between any treatments (Table 7).

4. Conclusion

Little if any impacts of the use of biostimulants or soil amendments were seen in these studies; however, other studies have reported varying results. McFarland [2] reported in various studies across the US that the use of soil activators have shown no significant beneficial effects on crop quality and yield. He also reported that lab evaluations of these products indicated that they did not increase the number or activity of soil microbes and thus, would not be expected to increase the rate or extent of crop residue decomposition. In contrast, El Sawah et al. [20] reported that various components of guar production (shoot length, root length, leaf area, plant dry weight, nutrient uptake, and yield) were significantly affected by the application of biofertilizers and their combination. Activities of soil enzymes such as dehydrogenase, phosphatase, protease, and invertase also improved in the rhizosphere soil of plants treated with biofertilizers. They also stated that increasing soil enzymes in the rhizosphere and the essential nutrients available for the guar plants increased seed quality by improving the proteins, carbohydrates, starch, fatty acids, and guaran content and reduced the use of chemical fertilizers by 25%.

Also, the use of the biostimulants and soil additives will require recommendations specific to each individual farm to determine the appropriate organisms to use and with the right agronomic management practices to insure a positive crop response. Since many similar products are being introduced into the marketplace, additional research is needed to determine the effectiveness of these biostimulants and/or soil additives on crop growth and yield. Achieving maximum economic yield depends on using only those inputs which will provide a return on investment.

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Data Availability Statement: We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics.

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