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Helpful or Not? – Biostimulant Use in Corn Silage Production

Abstract

There has been a recent increase in both the availability and marketing of biostimulant products to local producers, particularly to dairymen, in southern Idaho. These products claim to increase yield and nutrient use efficiency while improving soil health properties on commercial scale agricultural fields. The objective of this study was to assess the impact of five biostimulants on corn silage production. Measurements included yield, quality, and changes to soil health properties. Results from this two-year study indicate that none of the products tested increased corn silage yield, crop nutrient uptake, or soil health properties, such as infiltration characteristics, microbial activity or abundance, or aggregate stability. Statistical differences were observed in dairy feed quality between treatments, but results were mixed. Individual products may have benefits in some fields under certain conditions, but overall, these products do not seem to have robust impact on corn silage or soil health in southern Idaho.

Introduction

Although biostimulants have been on the market for decades, they were first defined in the 2018 U.S. Farm Bill. Biostimulants are "a substance or microorganism that, when applied to seeds, plants, or on the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient use efficiency, tolerance to abiotic stress, or crop quality and yield" (Agriculture and Nutrition Act, 2018). These products are not fertilizers and are not subject to government regulation. There has been a recent increase in both the availability and marketing of biostimulant products to local producers in southern Idaho. These products claim to increase yield and nutrient use efficiency while improving soil health on agricultural fields. If these claims are true, the use of these products would aid in promoting the overall sustainability of Idaho farms. However, there is a lack of objective data to support these claims, leaving producers uncertain as to if and how these products may benefit their operation. Further, these products contain nutrients, like phosphorus, which may not be credited for crop nutrient recommendations.

In 1979, a University of Idaho extension publication called the biostimulants on the market "wonder products" that are no different from snake oils (McDole and Painter, 1979). They lamented that overall, the sales pitches for these products were not based on scientific data; the evidence of the product effectiveness was often based on visual differences between selectively chosen plants or soil samples between an area receiving the product and an area that was not. While these tactics are still used today, companies also conduct internal research; however, this research does not necessarily reflect the impact of regional climate, soil type, or cropping rotation. On a weekly basis, agricultural extension personnel are asked by agricultural producers and their advisors about whether one of dozens of biostimulants on the market is a worthwhile investment. To provide robust, scientifically justifiable recommendations for southern Idaho, products need to be evaluated in a controlled, well-designed study. It would be impossible to evaluate them all. However, due to the popularity of the products coupled with the lack of local information, a need was identified for research and demonstration in this area. Thus, the objective of this study was to assess four commercially available products and a locally produced one on their effectiveness to increase corn silage yield and quality and soil health properties.

Methods

A two-year study was initiated in 2021 at the University of Idaho Kimberly Research and Extension Center. The field had been planted to spring wheat the year prior; the field had no history of manure application nor were there recent plot studies with differing fertilizer rates. Spring and summer temperatures were higher than average in 2021 and average in 2022 while rainfall was below average for both years. However, curtailment of irrigation water at the Kimberly Research Center did not affect the study. There were 6 treatments with 4 replicates for a total of 24 plots arranged using a randomized complete block design. Plots measured 20 ft wide to accommodate 8 -30” rows of corn silage by 35 ft long. Blocks were separated by a 35 ft buffer of winter wheat; the same field and study design was used in year 2 to assess the effect of multiple years of product application. In 2021, corn was planted on May 20th using a Kinze 7000 finger planter and Winfield United CP2851VT2P/RIB at a population of 40,000 plants/acre. In 2022, the same planter and rate was used, and Winfield United CP2845VT2P/RIB was planted May 25th. The study was sprinkler irrigated. Prior to planting, the field was fertilized using University of Idaho recommendations based on a spring soil sample for a yield goal of 35 T acre^{-1} (Brown et al., 2009). Between year 1 and 2, the field was lightly tilled with a chisel plow and roller harrow to break up compaction and incorporate residue without transporting soil between plots.

Treatments included a control with no biostimulant added and five biostimulant products: Amend (Paradigm Ag Solutions), PS-Foundation (BMZ Biological), Bactifeed (Bactifeed Soil Treatment), Lalrise Max (Lallemand), and compost tea. The biostimulant products were chosen based on feedback from stakeholders to represent locally available and marketed products. In addition, each product represented several types of biostimulants; their rates and description (type) are shown in Table 1. All commercial products were repurchased in year 2 to avoid efficacy loss, and products were stored according to the labels within each season. Briefly, the compost tea was brewed aerobically for 24 hours using dairy manure compost from a local provider. The compost tea was filtered to remove the large particles prior to loading in the tank. Biostimulant treatments were applied in furrow at planting according to instructions at suggested label rates (Figure 1). Water was applied in furrow for the control plots. The products evaluated are applied in-season using an irrigation system. To simulate this, the center four rows of corn was sprayed with a backpack sprayer with the appropriate product (Figure 2). Immediately after biostimulant application, all plots were irrigated.

Figure 1. Corn planter configured to apply biostimulant products in furrow at planting.

Figure 2. In-season application of biostimulants using a backpack sprayer. Irrigation followed immediately afterwards.

Table 1. Biostimulant product information

Product	Manufacturer	Description	Total Product Applied Annually	Application Timing
Amend	Paradigm Ag Solutions	8-26-0	640 oz per acre	In-furrow at plant 3x in-season
PS-Foundation (BMZ)	BMZ Biological	Nutrient concentrate w/ humates, kelp, trace minerals, organic acids, and enzymes	24 oz per acre	In–furrow at plant Optional 1x in-season
Bactifeed	Bactifeed Soil Treatment	Bacteria-based inoculant	Pre-measured powder activated in water	In-furrow at plant 3x in-season
Lalrise Max	Lallemand	mycorrhizae-based inoculant	1.5 oz (dry powder) per acre of seeds	Seed treatment
Compost Tea		Locally produced; negligible NPK	64 oz per acre	In-furrow at plant 3x in-season

Soil was sampled for soil health properties late in the vegetative stage every year. Briefly, three samples 0-6 inches were collected and composited per plot from the center four rows. Samples were kept cool on ice until they were sent to the Soil Health Testing Laboratory at Oregon State University. Analyses completed included microbial biomass carbon, microbial respiration (24 and 96 hours), β-glucosidase activity, and active carbon. Methods for these analyses can be found on their website (http://cropandsoil.oregonstate.edu/shl/soil-health-lab). Soil compaction with a cone penetrometer and infiltration characteristics with a single ring (NRCS, 2001) were assessed at the same time. In year 2, infiltration was too slow to evaluate due to soil crusting. Samples for aggregate stability were taken from the top six inches of soil at the same time using a tile shovel and analyzed using a Cornell Sprinkle Infiltrometer suspended one foot above the soil samples (Schott et al., 2023).

The corn was harvested when it reached approximately 68% whole plant moisture, as estimated using the kernel milk line to gauge maturity. All plots were harvested the same day. The center four rows of each plot were harvested for yield data. The entire 35 feet of each plot was harvested using a Kemper Champion C 1200 two-row forage harvester front mounted on a John Deere 6420. The silage was blown into a Haldrup M-63 silage harvester mounted on the back of the same tractor. The Haldrup unit weighed the cut corn and allowed for a well-mixed sample of the entire plot to be pulled for dry matter and quality analysis. The corn samples were dried at a commercial laboratory. Actual plant moisture was calculated from reported dry matter percentages. Subsamples of silage were sent to commercial laboratories for nutrient analyses of crop uptake (N, P and K) and analyses of feed quality and moisture. Soil was sampled soon after harvest in each plot at 0-12 inches for ending soil fertility and sent to a commercial laboratory for analysis.

Data were analyzed using the *mixed* function in SAS version 9.4 (SAS, 2013). Soil and crop metrics were analyzed as a randomized complete block design with fixed effects of treatment, year, and treatment*year and block set as the random effect. *Lsmeans* was used to determine the least-squares means when fixed effects were significant. Means were deemed statistically significant at a p-value less than 0.05.

Results

Corn silage yield, when corrected to 68% moisture, was not significantly different for treatments (Figure 3) or the interaction of treatment*year. Yield was statistically greater in 2021 than in 2022, averaging 34.6 ton ac^{-1} and 31.9 ton ac^{-1}, respectively. Overall, there was variability in yield within treatments (Figure 3). Silage corn moisture at harvest was statistically significant for treatment and year but not the interaction of treatment*year. In 2021 and 2022, average moisture across all treatments at harvest was 67.0% and 63.7%, respectively. The control had an average moisture of 64.6% (SE=0.55), which was lower than the compost tea (65.8%), Lalrise Max (65.8%), and BMZ (65.9%) treatments.

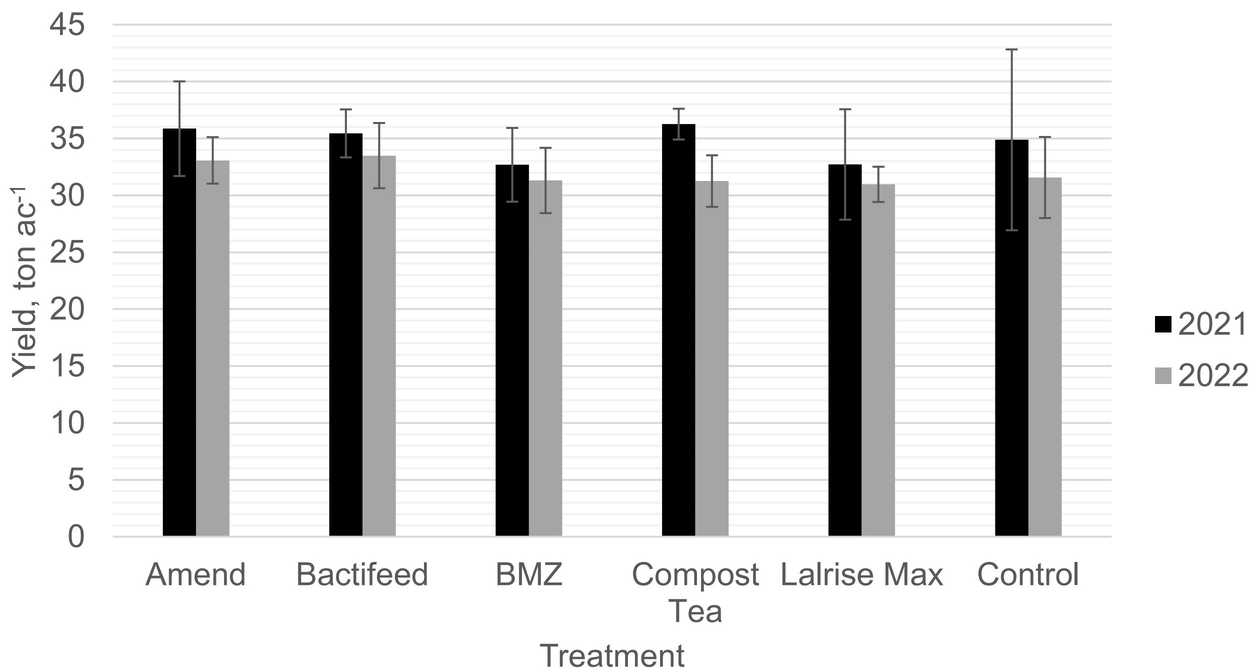

Figure 3. Corn silage yield in 2021 and 2021. Bars represent standard errors. There were no statistically significant differences between treatments in either year.

In terms of feed quality, there were treatment differences (Table 2). For crude protein, treatment, year, and treatment*year were all statistically significant. Crude protein in 2022 was significantly greater than in 2021, 7.6 and 6.5%, respectively. Overall, Lalrise Max had significantly greater crude protein (7.4%) than the control (7.0%). For the treatment*year interaction, the Bactifeed treatment had 0.7% less in 2021 while the

Amend treatment had 0.5% higher crude protein in 2022 when compared to the control. For both ADF and NDF, lower values indicate better forage quality. Year and treatment*year were statistically significant for NDF and ADF. BMZ (PS-Foundation) and Bactifeed had 2.8% and 3.2% higher NDF when compared to the control in 2021 while the compost tea treatment had 3.1% higher NDF in 2022. NDF was 37.4% in 2021 and 36.0% in 2022. For ADF, BMZ and Bactifeed were greater in 2021 compared to the control while all treatments except Bactifeed were greater in 2022. ADF in 2021 was greater (22.2%) than in 2022 (20.4%). There were no statistical differences between treatments in plant uptake in terms of total N, nitrate, P or K (data not shown).

Table 2. Average crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF) via NIR by treatment for 2021 and 2022. Treatments not sharing same letter(s) within column are statistically different ($p<0.05$).

Treatment	**Crude Protein, %DW**		**NDF, %DW**		**ADF, %DW**	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**
Control	6.7 ab	7.3 b	36.1 c	34.7 bc	21.3 b	19.4 b
Amend	6.6 bc	7.8 a	36.6 bc	37.0 ab	21.5 b	21.3 a
Bactifeed	6.0 d	7.6 ab	39.3 a	33.8 c	23.5 a	18.5 b
BMZ	6.3 bcd	7.5 ab	38.9 ab	36.1 abc	23.3 a	20.4 a
Compost Tea	6.3 bc	7.6 ab	38.3 abc	37.8 a	22.9 ab	21.8 a
Lalrise Max	7.1 a	7.7 ab	36.4 c	36.7 ab	21.4 b	21.0 a

Neither treatment nor treatment*year were significantly different in any of the microbial soil health properties. Microbial biomass C, β-glucosidase activity, and active C were all greater in 2022 when compared to 2021 while microbial respiration rates were higher in 2021 (Table 3). There were also no differences between treatments infiltration in 2021 and in penetration resistance at depths of 3, 6, or 12 inches in 2021 or 2022.

Penetration resistance was significantly greater in 2022 than in 2021. This is what likely inhibited the ability to do infiltration testing in 2022. Further, there were no differences in aggregate stability between treatments in either year; the average aggregate size was larger in 2021 compared to 2022 (3.8 and 3.6 mm, respectively).

Table 3. Average soil health properties for 2021 and 2022 for 0-6 inches of soil depth. Years not sharing same letter(s) within column are statistically different ($p<0.05$).

	Microbial Biomass C	**β-glucosidase activity**	**CO_2 24 hr. burst**	**CO_2 96 hr. burst**	**Active C**
	μg biomass per g dry soil	nmol B-gluc per g soil per hour	μg CO_2-C per g soil per day		ppm
2021	1733.9 b	94.3 b	27.4 a	15.1 a	116.7 b
2022	3041.4 a	290.3 a	21.1 b	11.5 b	193.5 a

There was an effect of treatment*year for fall soil total N. There were no differences in total N concentrations in 2021 and the only significant difference in 2022 was Lalrise Max had higher residual total N compared to the control (13.5 and 9.9 ppm, respectively). Further, while there were no differences between treatments in fall soil Olsen P, there were significant differences in soil K (Table 4). The control had significantly higher soil K concentrations after harvest than Lalrise Max, compost tea, and PS-Foundational (BMZ). Interestingly, the Amend treatment was not significantly different even though higher K utilization is one of its key marketing claims. Soil K concentrations were also statistically greater in 2021 than in 2022 (173 ppm and 146 ppm, respectively). There was no statistical difference in treatment*year for soil K concentrations.

Table 4. Average soil nutrient concentrations after harvest by treatment for 0-12 inches of soil depth. Treatments not sharing same letter(s) within column are statistically different ($p<0.05$).

Treatment	**Total N**	**Olsen P**	**K**
	------------ppm------------		
Control	7.9 a	16.5 a	170.5 a
Amend	8.2 a	15.6 a	166.0 ab
Bactifeed	8.1 a	15.8 a	161.6 ab
BMZ	8.2 a	14.0 a	148.6 c
Compost Tea	8.7 a	15.1 a	154.4 bc
Lalrise Max	9.8 a	14.6 a	157.3 bc

Discussion

Overall, none of the products evaluated held up to the claims that were made about them. The biostimulants evaluated tout a wide variety of effects on cropping systems. Amend is marketed to prevent crusting and increase water infiltration, water retention, crop health and growth, and increased nutrient density in crops while mitigating high K and sodium salts in soil. This study found no differences in soil penetration resistance (crusting), water infiltration, crop yield or quality, or soil K. However, we did not assess water retention or use the product in a high salt or high K soil, so we cannot comment on the effect of this product on these properties. PS-Foundation (BMZ) is marketed to improve crop vigor by promoting root growth and improving soil nutrient utilization. We did not find any difference in crop yield or soil nutrients. Both Bactifeed and Lalrise Max are inoculants, applying either bacteria or fungi, respectively, to the soil. Both claim to increase yield as well as improve water infiltration and soil structure. Compost tea contains humic acids, active microorganisms, and plant soluble nutrients. It is often used to improve crop yield, promote soil microbial activity, and improve soil structure.

In general, the results of this study were mixed in terms of forage quality. There were statistical differences between the control and two products, but they were inconsistent between years. The Bactifeed treatment resulted in lower NDF and ADF values but also lower protein while Amend had the opposite effect. Neither one of these indicates a decisive increase in overall forage quality. There were differences in moisture content of the silage at harvest between the control and three of the products (compost tea, Lalrise Max, and BMZ). However, they were wetter than the control indicating that they would potentially be ready for harvest later than the control.

Many products contain macro- and micronutrients, which can impact crop production and soil fertility. For example, Amend was registered as a fertilizer in two states rather than a biostimulant, so it is disclosed as an 8-26-0 (Table 1). However, this information was not disclosed on the label and only suggested application rates of “up to five gallons per season.” At the rate applied, the compost tea treatment accounted for less than 1 oz (weight) acre^{-1} N, P, or K. Neither ending soil fertility nor crop nutrient uptake were different between Amend or compost tea and the control. Further, none of the products increased soil nutrients at the end of the season nor crop uptake compared to the control. However, it is worth noting that if a soil is deficient in a certain nutrient and the biostimulant contains that nutrient (which do not necessarily need to be disclosed as part of the licensing process), crop production could improve.

Compost tea, Bactifeed, and Lalrise Max all rely on microbial populations to be effective. For all three, it is important to manage them correctly or efficacy could be reduced. For example, compost tea needs to remain aerobic until application, which requires aeration while Bactifeed needs to be “activated” in water for a minimum of 24 hours prior to application.

There has been scientific evidence of the effectiveness of biostimulants, such as the ones evaluated in this study, on crop quality, yield, and resistance to abiotic and biotic stresses (Roupheal and Colla, 2020). However, it is important to note that these studies are often done in greenhouse settings and in vegetable/horticulture applications. In these settings, climate, soil, and water applications are highly managed and there is significantly less spatial and temporal variability in pots than in fields where large acreage crops, such as corn silage, are grown. This is why it is important to evaluate products locally.

Conclusions

In summary, initial results from this two-year study indicate that none of the products evaluated increased corn silage yield or moisture, crop uptake, or soil health properties, such as infiltration characteristics, microbial biomass carbon, microbial respiration, active carbon, or penetration resistance. There were statistical differences in dairy feed quality between treatments, but results are mixed. Individual products may have benefits in certain fields under certain conditions, but it would be impossible to evaluate every scenario. Overall, these products do not seem to have robust impact on corn silage or soil in southern Idaho. Producers and advisors interested in using these products should have clear goals in mind and a well-designed plan to evaluate them for their scenario. Large, replicated strip trials are the best way to do this. These products can be pricey and even if they are effective for one year, they should be re-evaluated often to ensure they are positively impacting profitability and meeting expectations.

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Conflicts of Interest

The authors declare no conflict of interest.

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