Open Journal of Ecology, 2022, 12, 499-512
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

The Effect of Organic Biostimulants on Beneficial Soil Microorganism Activity

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How to cite this paper: Waguespack, E., Bush, E. and Fontenot, K. (2022) The Effect of Organic Biostimulants on Beneficial Soil Microorganism Activity. *Open Journal of Ecology*, **12**, 499-512.
https://doi.org/10.4236/oje.2022.128027

Received: January 30, 2022
Accepted: August 6, 2022
Published: August 9, 2022

Abstract

Organic biostimulants and organic fertilizers can improve soil health for various horticultural crops. The objectives of these experiments were to determine if biostimulants beneficially increase soil microorganism activity in soilless medium, and additionally measure the impact of synthetic and organic fertilizers with blackstrap molasses on plant nutrient uptake nutrient runoff. It was hypothesized that the addition of biostimulants will increase soil microbe activity. Evolution of soil carbon dioxide was measured by comparing different rates (0, 15, 30, and 45 mL/3.8 L of water) of blackstrap molasses using a randomized block design with 3 replications in nursery containers. Also, a second study using St. Augustinegrass and tomatoes fertilized with organic and synthetic fertilizers was evaluated with and without a biostimulant rate (30 mL/3.8 L of water). The plants were arranged in randomized complete block design with 6 replications. Soil biostimulants did significantly increase the microorganism activity at the 0.05 level. The highest rate of blackstrap molasses improved soil biological activity over a 4-week period. Additionally, fertilizer combined with molasses did show significant increases in soil microbiology for over 5 weeks for both tomatoes and St. Augustinegrass. Molasses increased soil microbial activity but not plant nutrition. Organic fertilizer though resulted in higher levels of phosphorus, calcium, magnesium, and sulfur in plant tissue. Further research is being conducted to measure the influence of biostimulants on the breakdown of composting plant matter. Organic fertilizer slightly increased soil water pH but reduced nutrient load pollution based on a 7-day nutrient effluent study. Total nutrients (nitrates, P, Ca, Mg, and S) runoff was significantly less than synthetic fertilizer. Organic fertilizer reduced nutrient dumping in waste effluent. Organic fertilizers can improve nutrient use efficiency.

Keywords

Urban Gardening, Tomato Plants, St. Augustinegrass, Microbial Community,

Nutrient Pollution

1. Introduction

Biostimulants and organic fertilizers have been used by farmers for thousands of years [1]. Soil is a living entity with many components containing a balance of microbes, nutrients, animals, water, and air [2]. Commonly, farmers use additives to soil to improve crop yield and growth [3]. Four rates of biostimulant (0, 15, 30, 45 mL/3.8 L of water) were evaluated for increased microorganism activity. These additives can be made of many substances with some being organic and some being synthetic. The soil carbon-nitrogen ratio is essential for maintaining soil health. By applying sources of carbon and nitrogen, a farmer can improve the stability, health, and workability of soils [4]. Biostimulants, such as blackstrap molasses, can increase the microbial activity of the soil, and therefore the health of the plants being grown [5]. Biostimulants have also been found to improve plant growth and productivity [6]. Additionally, the application of organic fertilizers provides essential elements for plants and microorganisms. Additionally, the application of organic, animal-based fertilizer as opposed to synthetic, mineral-based fertilizer has been shown to increase biomass and uptake of nutrients [7]. The scope, though, of the many benefits of biostimulants and organic fertilizer is not fully known. However, CO_2 evolution has been established as a method to measure microbial activity [8]. The Solvita burst-test, a method of measuring CO_2 evolution from microorganisms, is useful in determining the changes in populations of organisms in a sealed vessel. The Solvita quick burst method can be accomplished in 24 hours using a CO_2-sensitive paddle that can be read using a digital Solvita reader. This greatly simplifies and expedites measurement of microbial activity [8]. Research to determine the benefits of biostimulants and organic fertilizer is essential.

Fertilizer sources can influence both soil and plant uptake. Slow-release fertilizers have become the preferred method of farms today to provide plant crops necessary fertility. Since ancient Roman times natural organic fertilizers (animal manure, green waste, compost), have provided slow-release forms of essential plant nutrients [9]. Soil microbial breakdown of organic products produces a natural release of N through the N cycle, P through the P cycle and likewise for the other elements [10] [11]. Previous research shows a steady release pattern of essential fertilizer elements compared with rapid release of synthetically manufactured quick release fertilizers [12]. Fertilizer off-site runoff and aquifer contaminations can occur when excessive soluble fertilizer sources exceed the capacity of the plant and soil uptake. Quick release fertilizers are prone to runoff when infrequent fertilizer applications occur, particularly with low cation exchange capacity soils. Today, organic farming is being looked at again to reduce pollution and encourage beneficial soil organisms and increase organic buildup in the soil. Guidroz [13] reported increased organic matter accumulation in an organic vegetable farm in Baton Rouge, Louisiana. This in turn improves nutrient availability, an increase in soil health and reduced fertilizer pollution. Leaf tissue analysis is a good method of determining nutrient uptake [14] [15].

The objectives of these experiments were to determine if biostimulants beneficially increase soil microorganism activity in soilless medium, and additionally to measure the impact of synthetic and organic fertilizers with blackstrap molasses on plant nutrient uptake nutrient runoff.

2. Materials and Methods

Study 1: On April 6, 2020 a study was initiated to determine the efficacy of biostimulants on soil microbial activity. Organic blackstrap molasses solutions were applied at 4 rates (0, 15, 30, and 45 mL/3.8 L of water) with 100 mL of treatment solutions applied to 3 L nursery containers filled with a pine bark substrate. Each treatment had 3 replications. The solutions of blackstrap molasses were drenched over the soil surface, simulating drip irrigation, and CO_2 evolution was measured on a weekly basis for 4 weeks. Containers were irrigated every other day as needed with 100 mL of water. A sample (30 mL) of the substrate was harvested and was incubated 24 hours before measuring the CO_2 evolution using a Solvita CO_2 burst test, an established method of measuring soil health [8] [16]. Data was recorded and analyzed using SAS.

Study 2: On May 20, 2020 a second study was initiated to determine the efficacy of biostimulants and different types of fertilizer sources (6% N-2% P_2O_5-4% K_2O) on soil microbial activity and plant health. Fertilizer rate was 1lb N/yd^3. Treatments consisted of 1) synthetic fertilizer applied without molasses solution, 2) synthetic fertilizer with molasses solution at the rate of 30 mL/3.8 L of water, 3) organic fertilizer without molasses solution, and 4) organic fertilizer with molasses solution at the rate of 30 mL/3.8 L of water. Each treatment had 5 replications. The solutions of blackstrap molasses were drenched, and CO_2 evolution was measured on a weekly basis for 5 weeks. Containers were irrigated every other day as needed with 100 mL of water. A sample (30 mL) of the substrate was harvested and was incubated 24 hours before measuring the CO_2 evolution using a Solvita CO_2 burst test. Plant tissue was collected and analyzed using the LSU soil testing lab to determine nutrient content [14]. Data was recorded and analyzed using SAS.

Study 3: On March 27, 2021 a third study was initiated to determine the change in soil pH, EC and loss of fertilizer nutrients. Fertilizers (6% N-2% P_2O_5-4% K_2O) regardless of source (synthetic or organic) were applied at the rate of 1 lb N/yd^3. Four-inch nursery containers having a soil capacity of 225 ml were filled with treatment amendments at the established rate. Each fertilizer source had 3 replications. Containers were filled and positioned onto 1 L mason jars to collect excess water which will be referred to as effluent over a 7-day period. Containers were drenched daily with 125 ml of water. Effluent was measured after the 7-day period and used to calculate pH, EC and total nutrient load (nitrates, P, K, Ca, Mg, and S). Data was analyzed using SAS at the 0.05 level.

3. Results and Discussion

Soil health: Soil microbial activity measured over a 6-week period resulted in significant differences. After 1 week, all treatments were significantly different from each other. The highest CO_2 evolution increased with rate of molasses (**Figure 1**). After 2 weeks, the highest rate had the greatest CO_2 evolution compared to all treatments. The two middle rates were statistically similar, and both greater than the control. All molasses rates were statistically different and greater than the control. At week 4, all treatments were statistically similar except the highest treatment, which was slightly higher than the other treatments (**Figure 1**). The organic fertilizer treatment with no molasses was significantly higher than all other treatments after 1 week (**Figure 2**). After 2 weeks, organic fertilizer with molasses was significantly higher than all other treatments. After 3 weeks, organic fertilizer with molasses was significantly greater than the other treatments.

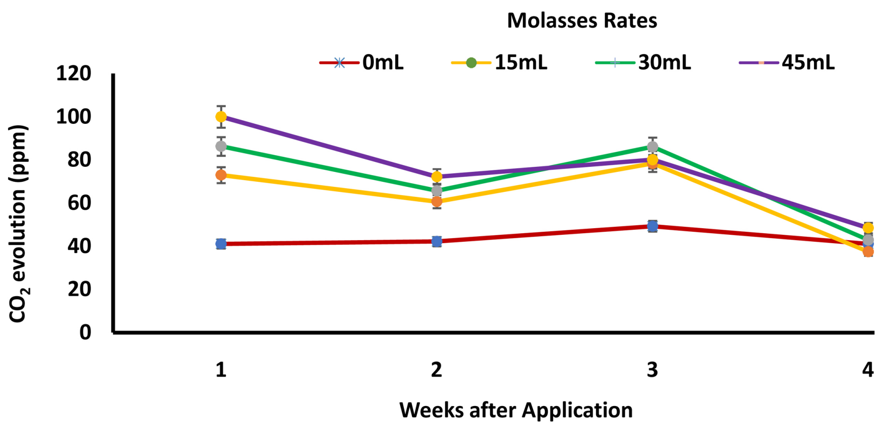

Figure 1. CO_2 evolution of different rates of organic molasses in pine bark substrate after 4 weeks.

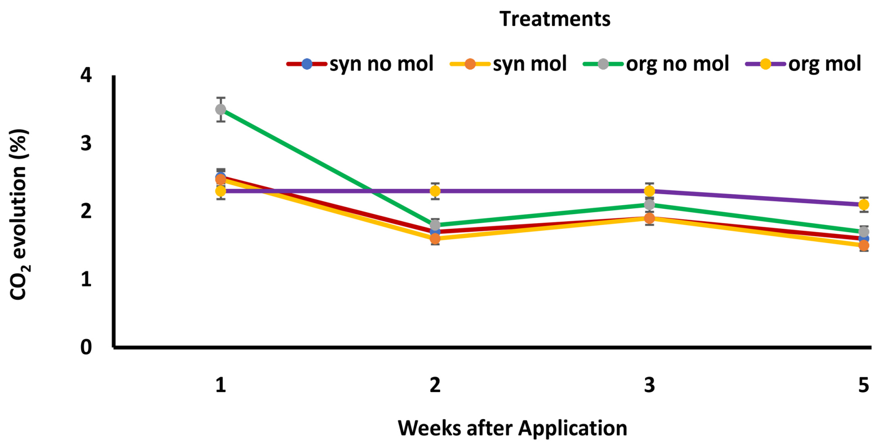

Figure 2. CO_2 evolution of different rates of organic molasses and different fertilizers after 5 weeks.

Organic fertilizer without molasses was greater than remaining treatments, which were statistically similar (**Figure 2**). After week 5, organic fertilizer with molasses was greater than all other treatments.

Plant Health: St. Augustinegrass N (**Figure 3**) and K (**Figure 4**) leaf levels were statistically similar between all treatments, however, P (**Figure 5**), Ca (**Figure 6**), Mg (**Figure 7**), and S (**Figure 8**) levels for organic fertilizer and organic

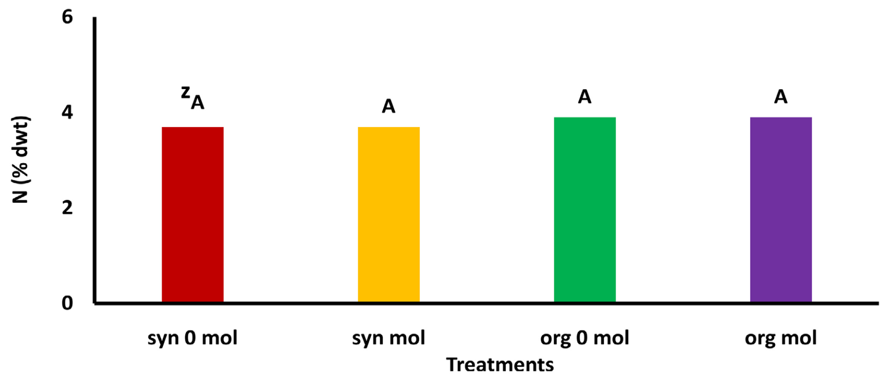

Figure 3. St. Augustinegrass N leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

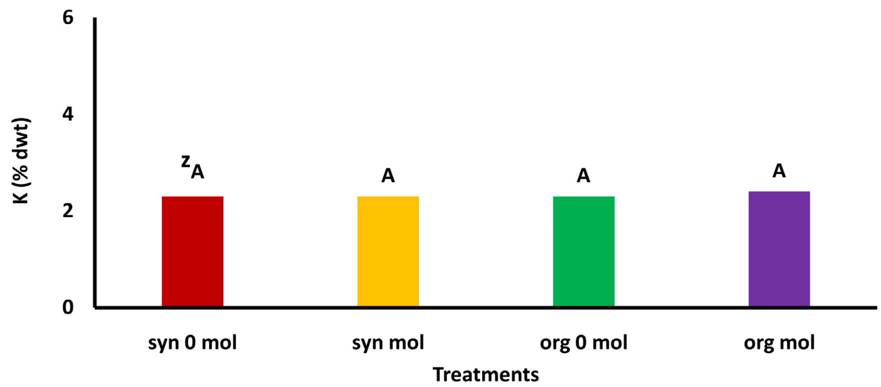

Figure 4. St. Augustinegrass K leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

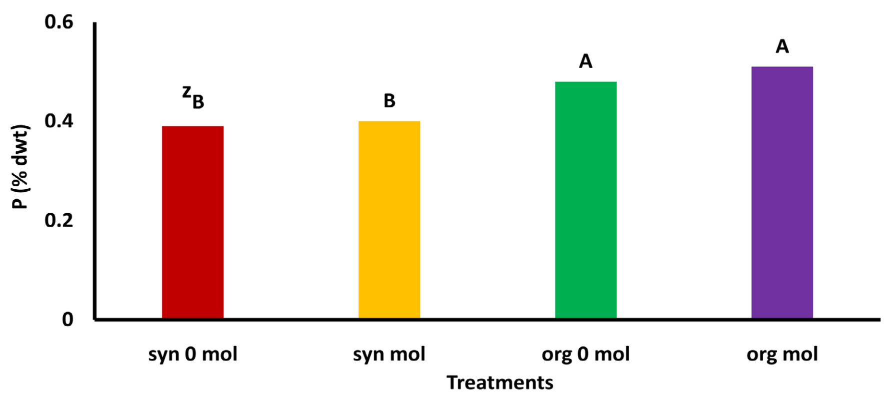

Figure 5. St. Augustinegrass P leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

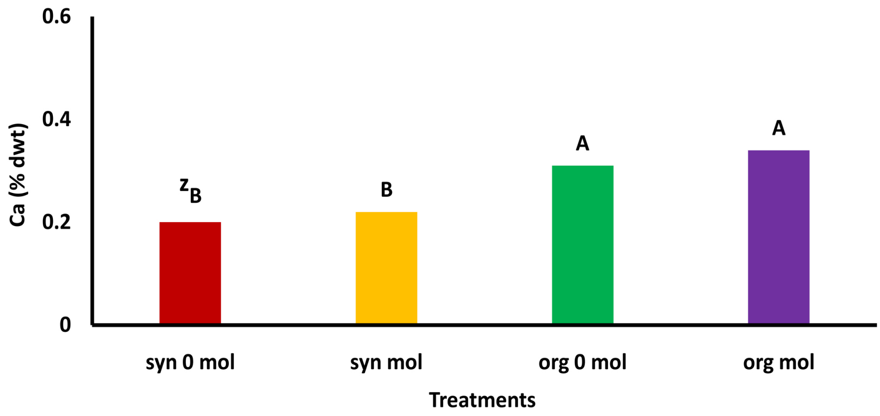

Figure 6. St. Augustinegrass Ca leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

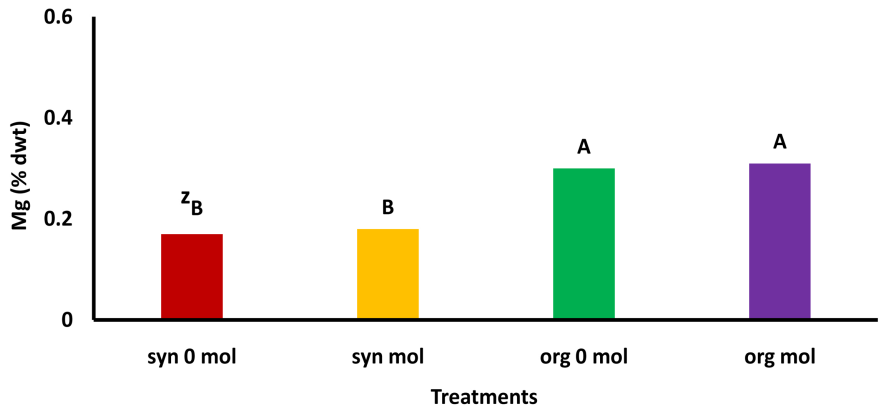

Figure 7. St. Augustinegrass Mg leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

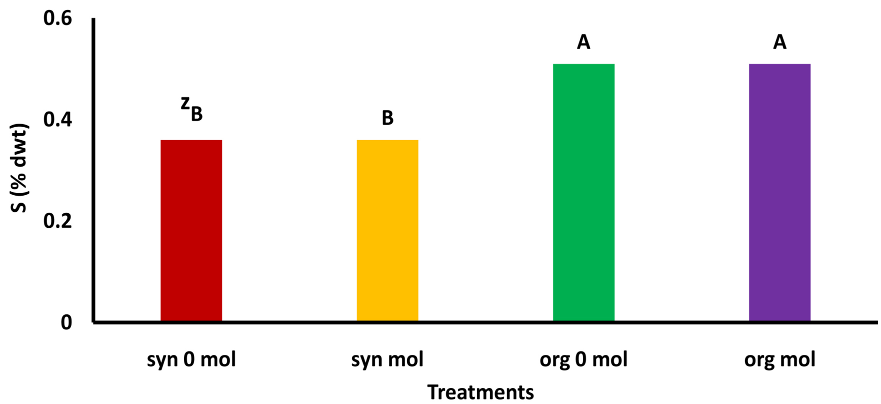

Figure 8. St. Augustinegrass S leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

fertilizer + 30 mL of molasses were significantly higher than the organic fertilizer treatments. All tissue levels met the minimum acceptable range except for synthetic fertilizer treatments for Ca leaf tissue levels, which were less than 0.3% [14].

Tomato N leaf tissue levels (**Figure 9**) were statistically similar between all treatments, however P (**Figure 10**), Ca (**Figure 11**), Mg (**Figure 12**), and S (**Figure 13**) levels for organic fertilizer and organic fertilizer + 30 mL of molasses were significantly higher in the organic fertilizer treatments. Potassium (**Figure 14**) tissue levels for synthetic fertilizer + molasses (30 mL/3.8 L of water)

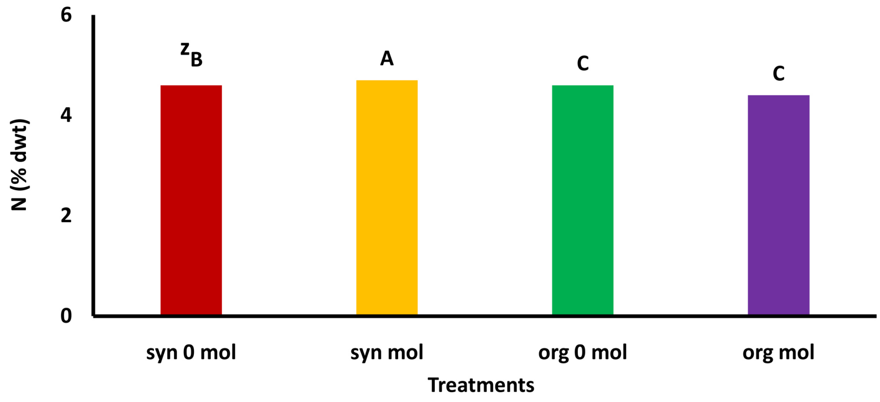

Figure 9. Tomato N leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

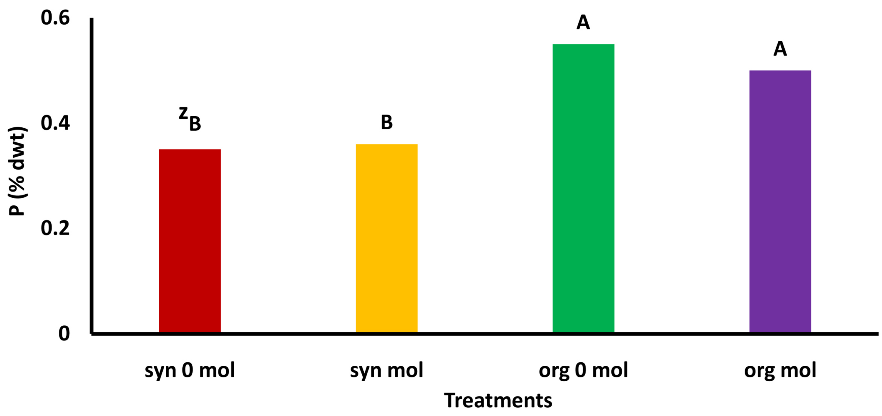

Figure 10. Tomato P leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

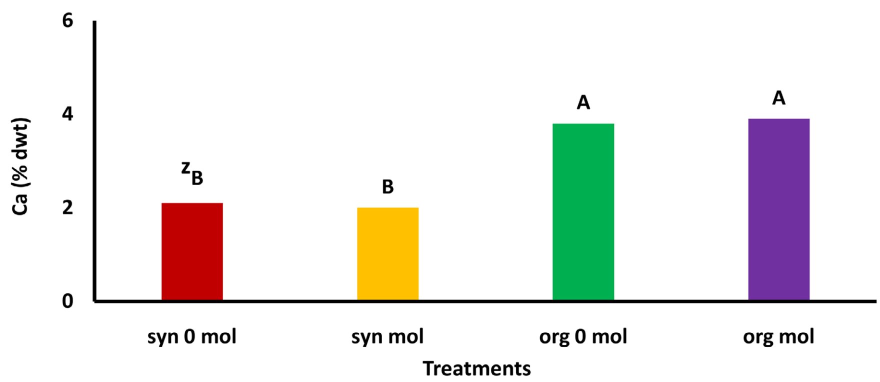

Figure 11. Tomato Ca leaf tissue nutrient content comparing fertilizer rate and source. [Z]Means with the same letter are not significantly different at the 0.05 level.

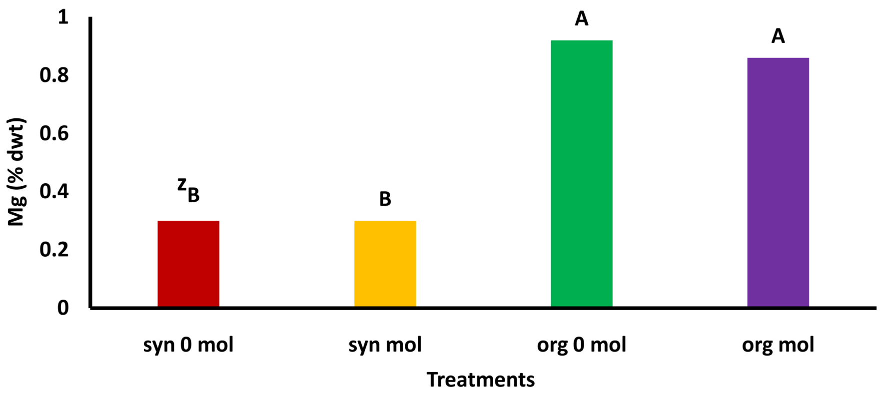

Figure 12. Tomato Mg leaf tissue nutrient content comparing fertilizer rate and source. ZMeans with the same letter are not significantly different at the 0.05 level.

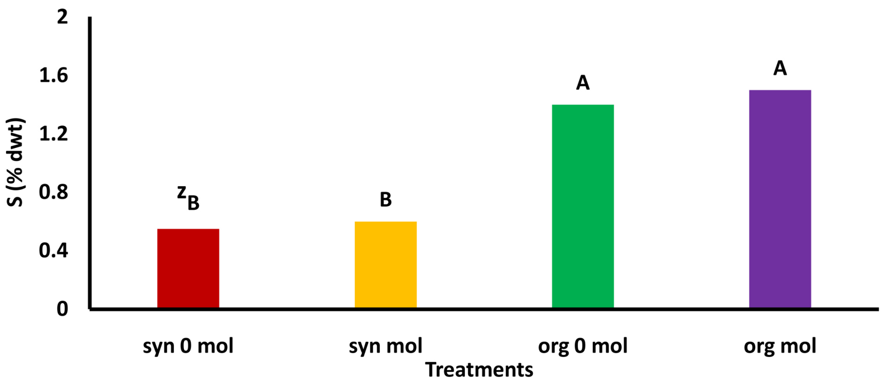

Figure 13. Tomato S leaf tissue nutrient content comparing fertilizer rate and source. ZMeans with the same letter are not significantly different at the 0.05 level.

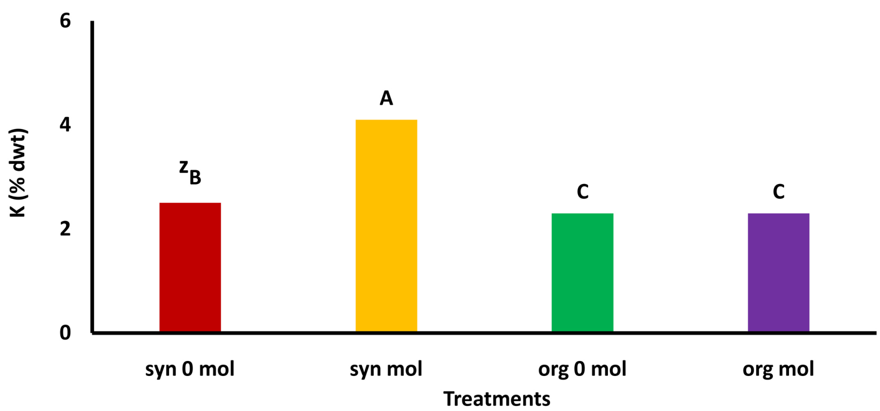

Figure 14. Tomato K leaf tissue nutrient content comparing fertilizer rate and source. ZMeans with the same letter are not significantly different at the 0.05 level.

maintained higher levels than all treatments, while synthetic fertilizer was greater than organic fertilizer levels compared to both organic fertilizer treatments. All tissue levels met the minimum acceptable range [15].

Growth Parameter: Although there were significant soil and plant health differences, there were no significant differences measured for grass and tomato plant height and biomass accumulation (graphs not shown).

Nutrient Effluent: Potassium concentrations were below 1 ppm which was below detection for both fertilizers (data not shown). Analysis revealed significant differences between nutrient levels, pH, and EC levels between fertilizer sources. Soil pH was greater for the organic fertilizer source effluent as expected (**Figure 15**). Electro-conductivity (EC) and nutrient levels were significantly greater in the synthetic granular fertilizer compared to the organic fertilizer (**Figure 16** and **Figure 17**). These results relate to the nutrient results in plant tissue where there were increases in organically fertilized plants (**Figures 18-22**).

Increased soil microbial activity was observed with the use of biostimulants. This has been reported by several researchers previously [6]. Additionally, organic fertilizer alone increased soil health. This has also been shown in prior research [2] [13]. Essential plant elements were shown to increase significantly when using biostimulants. Maintaining the acceptable ranges of essential elements

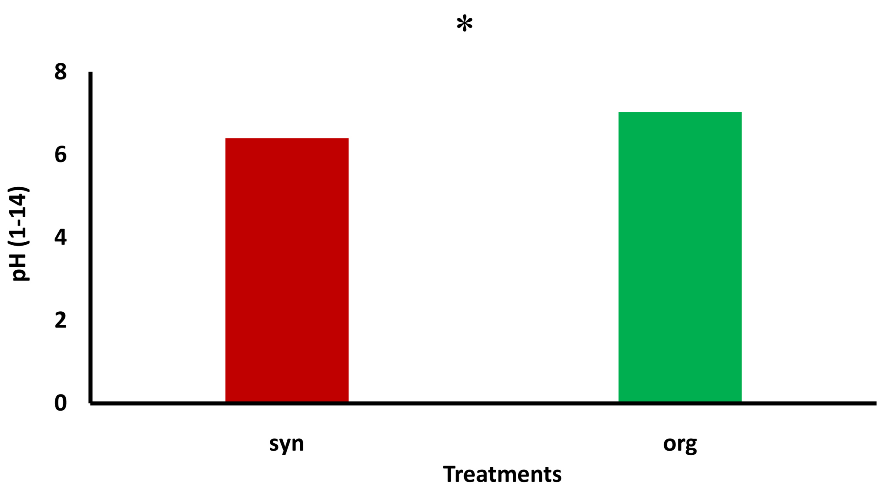

Figure 15. Soil water effluent comparing synthetic and organic fertilizers after 7 days of watering. ^{Z*} = Significant at the 0.05 level.

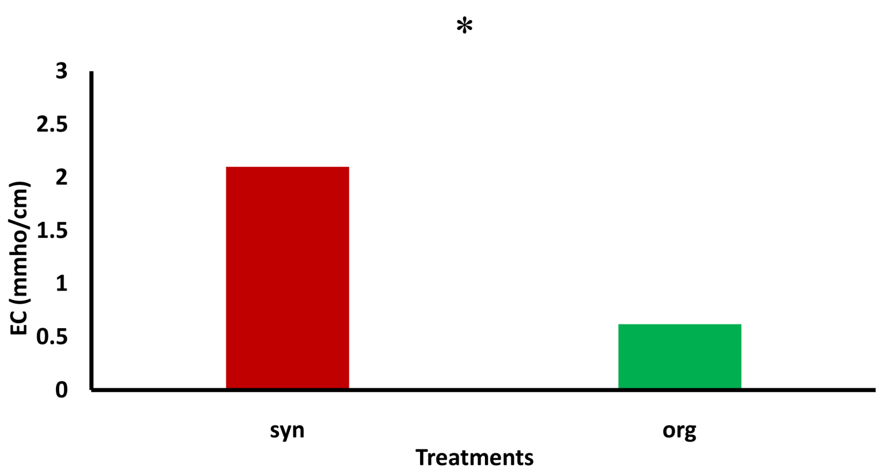

Figure 16. Soil water effluent electroconductivity comparing synthetic and organic fertilizers after 7 days of watering. ^{Z*} = Significant at the 0.05 level.

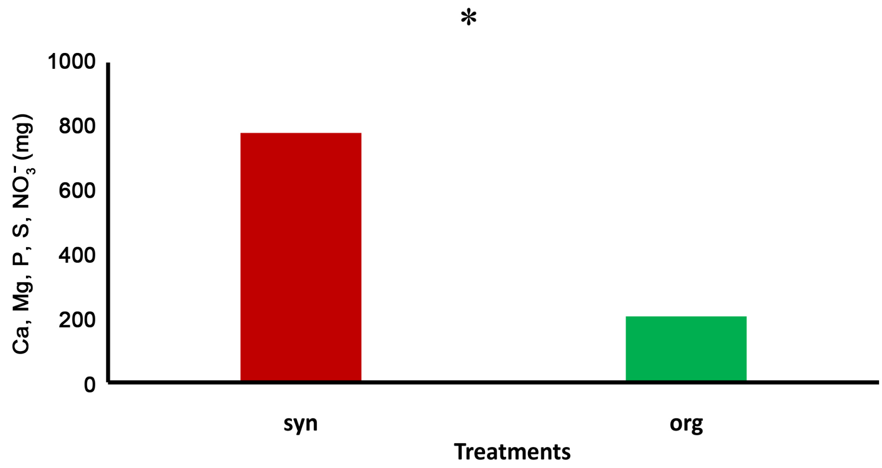

Figure 17. Total nutrient load concentration of soil water effluent. Z* = Significant at the 0.05 level.

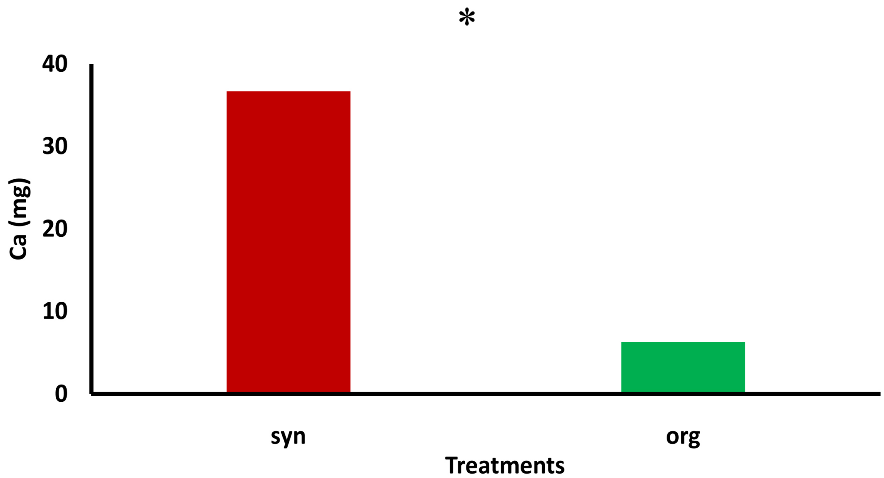

Figure 18. Soil water Ca comparing synthetic and organic fertilizers after 7 days of watering. Z* = Significant at the 0.05 level.

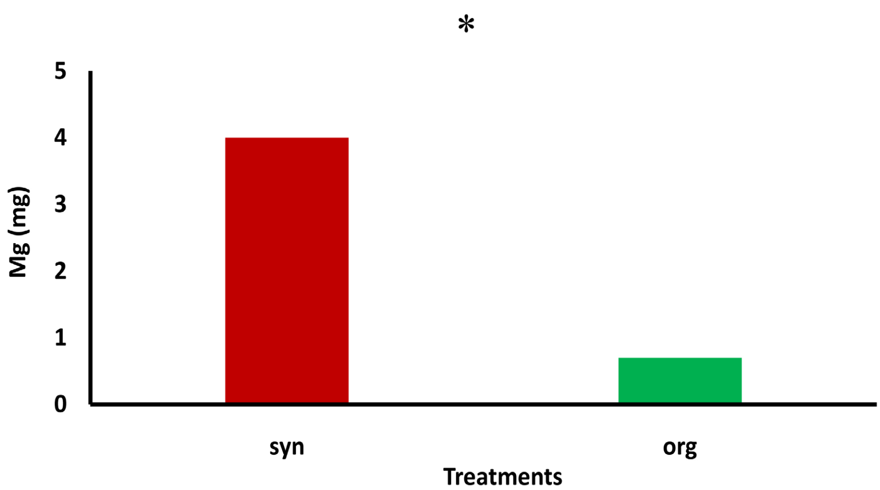

Figure 19. Soil water Mg comparing synthetic and organic fertilizers after 7 days of watering. Z* = Significant at the 0.05 level.

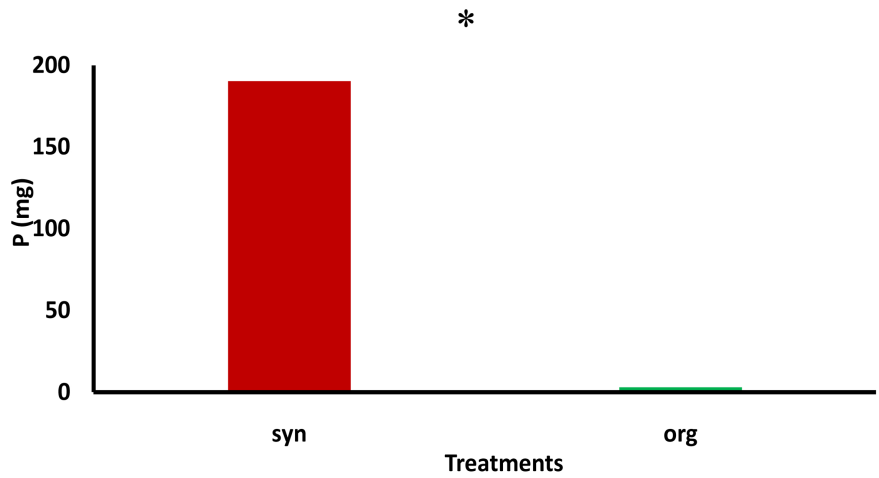

Figure 20. Soil water P comparing synthetic and organic fertilizers after 7 days of watering. Z* = Significant at the 0.05 level.

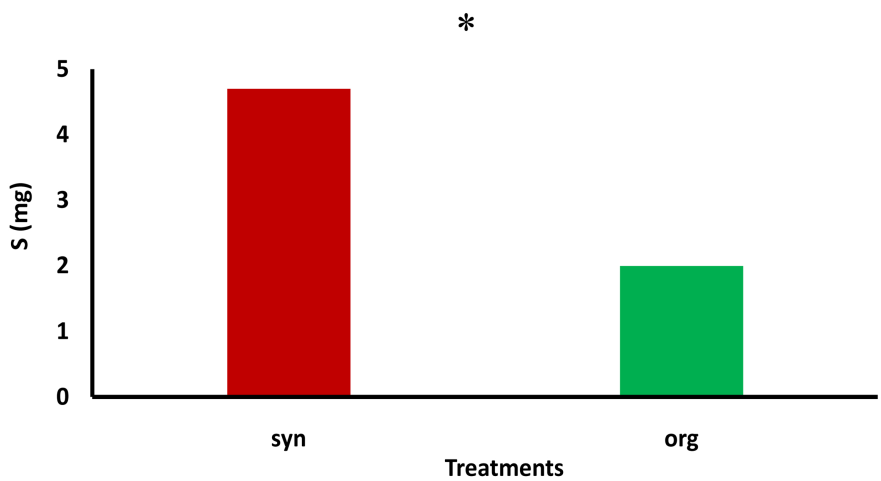

Figure 21. Soil water S comparing synthetic and organic fertilizers after 7 days of watering. Z* = Significant at the 0.05 level.

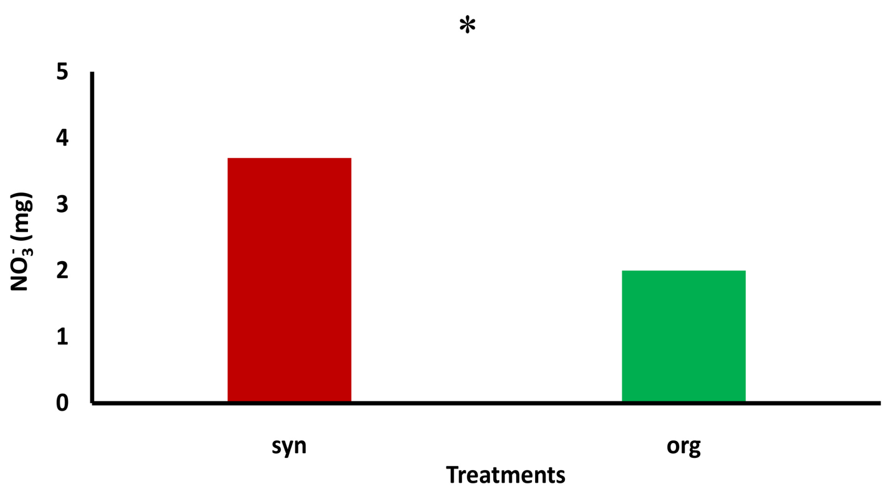

Figure 22. Soil water NO_{3-} comparing synthetic and organic fertilizers after 7 days of watering. Z* = Significant at the 0.05 level.

is necessary for proper plant health. Although in our study there were no growth differences measured, proper nutrition is vital for plant growth and development. Reducing nutrient runoff is an important best management practice. Increased nutrient losses can result in increased off-site runoff and aquifer contamination. Increasing plant usage can also improve plant growth and yield resulting in improved nutrient efficiency [7]. Best management practices strive to improve crop production, lower cost, and reduce environmental impacts. Organic fertilizer seemed to approach best management practices more closely compared to the synthetic fertilizer source.

4. Conclusions

Soil biostimulants did significantly increase the microorganism activity. In study 1, the higher rates of molasses solution had significantly higher rates of CO_2 evolution. The higher rate had increased activity after 1 week by more than 100%. This increase persisted for 4 weeks. Overall, blackstrap molasses increased microbial activity. In study 2, there were significant differences between fertilizer sources and molasses treatments. The benefit of molasses was dependent upon fertilizer source and dependent variables. Organic fertilizer with molasses maintained the highest activity after 5 weeks for all treatments. Although there was increased microbial activity and fertility interaction, there was no measured increase or decrease in plant growth. Further research should be considered to elucidate the full impact of molasses and the use of organic fertilizers. Blackstrap molasses does have a significant, beneficial effect on plant health and microbial growth. Blackstrap molasses combined with fertilizers may have horticultural benefits for crop production. However, more research needs to be done to determine if the use of blackstrap molasses is economically feasible for commercial production.

In conclusion,

- Biostimulants increased microorganism activity;
- Biostimulants with organic fertilizer had the highest rate of microorganism activity;
- Biostimulants had a positive effect on plant health.

Application to Society

Blackstrap molasses does have a significant, beneficial effect on plant health and microbial growth. Blackstrap molasses combined with fertilizers may have horticultural benefits for crop production. Organic fertilizers combined with molasses did increase essential element uptake, which can improve crop growth. However, more research needs to be done to determine if the use of blackstrap molasses is economical feasible for commercial production. Fertilizer management can reduce pollution and increase plant growth.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Soppelsa, S., Kelderer, M., Casera, C., Bassi, M., Robatscher, P. and Andreotti, C. (2018) Use of Biostimulants for Organic Apple Production: Effects on Tree Growth, Yield, and Fruit Quality at Harvest and During Storage. *Frontiers in Plant Science*, **9**, Article 1342. https://doi.org/10.3389/fpls.2018.01342

[2] Rouphael, Y., Colla, G., and De Pascale, S. (2018) Plant Biostimulants: Innovative Tool for Enhancing Plant Nutrition in Organic Farming. *European Journal of Horticultural Science*, **82**, 277-285. https://doi.org/10.17660/eJHS.2017/82.6.2

[3] Weil, R.R. and Brady, N.C. (2017) The Nature and Properties of Soils. Pearson Education, Bostons.

[4] Neff, J., Townsend, A. and Gleixner, G. (2002) Variable Effects of Nitrogen Additions on the Stability and Turnover of Soil Carbon. *Nature*, **419**, 915-917. https://doi.org/10.1038/nature01136

[5] Mahmoud, S.H., El-Tanahy, A.M.M. and Fawzy, Z.F. (2020) The Effects of Exogenous Application of some Bio Stimulant Substances on Growth, Physical Parameters and Endogenous Components of Onion Plants. *International Journal of Agriculture and Earth Science*, **6**, No. 2.

[6] Adoko, M., Sina, H., Amogou, O., Agbodjato, N., Noumavo, P., Aguégué, R., Assogba, S., Adjovi, N., Dagbénonbakin, G., Adjanohoun, A. and Baba-Moussa, L. (2021) Potential of Biostimulants Based on PGPR Rhizobacteria Native to Benin's Soils on the Growth and Yield of Maize (Zea mays L.) under Greenhouse Conditions. *Open Journal of Soil Science*, **11**, 177-196. https://doi.org/10.4236/ojss.2021.113010

[7] Martínez-Alcántara, B., Martínez-Cuenca, M.-R. Bermejo, A., Legaz, F. and Quiñones, A. (2016) Liquid Organic Fertilizers for Sustainable Agriculture: Nutrient Uptake of Organic versus Mineral Fertilizers in Citrus Trees. *PLOS ONE*, **11**, e0161619. https://doi.org/10.1371/journal.pone.0161619

[8] Brinton, W.F. (2020) Laboratory Soil Handling Affects CO_2 Respiration, Amino-N and Water Stable Aggregate Results. Research Article, Vol. 24, Article No. 556262. https://doi.org/10.19080/ARTOAJ.2020.22.556262

[9] Bush, N. (2020) Studying the Poetic Function and Scientific Accuracy of Ancient Agricultural Treatises. Honors Thesis, Baylor University, 1-14.

[10] Olajire-Ajayi, B.L., Dada, O.V., Wahab, O.M. and Ojo, O.I. (2015) Effects of Fertilizers on Soil's Microbial Growth and Populations: A Review. American Journal of Engineering Research, **4**, 52-61.

[11] Stulina, G., Verkhovtseva, N. and Gorbacheva, M. (2019)Composition of the Microorganism Community Found in the Soil Cover on the Dried Seabed of the Aral Sea. *Journal of Geoscience and Environment Protection*, **7**, 1-23. https://doi.org/10.4236/gep.2019.78001

[12] Vel Murugan, A. and Swarnam, T.P. (2013) Nitrogen Release Pattern from Organic Manures Applied to an Acid Soil. *Journal of Agricultural Science*, **5**, 74-184. https://doi.org/10.5539/jas.v5n6p174

[13] Guidroz, A. (2020) Soil Health on a Small-Scale Sustainable Vegetable Farm in South Louisiana. Master's Theses, Louisiana State University, 5053. https://digitalcommons.lsu.edu/gradschool_theses/5053

[14] Bryson, G.M., Mills, H.A., Sasseville, D.N., Jones, J.B. and Barker, A.V. (2014) Plant Analysis Handbook III: A Guide to Sampling, Preparation, Analysis and Interpretation for Agronomic and Horticultural Crops. Micro-Macro Publishing, Inc., Athens, GA.

[15] Hochmuth, G., Maynard, D., Vavrina, C., Hanlon, E. and Simonne, E. (2018) Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida. *UF/IFAS Extension*, **964**, 1-48.

[16] Moore, D.B., Guillard, K., Geng, X.Y., Morris, T.F. and Brinton, W.F. (2019) Predicting Cool-Season Turfgrass Response with Solvita Soil Tests, Part 2: CO—Burst Carbon Concentrations. *Crop Science*, **59**, 2237-2248.
https://doi.org/10.2135/cropsci2018.11.0707