Biostimulant Benefits from Biosolids

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Background

When domestic sewage is transported and conveyed to a wastewater treatment plant, it is treated to separate liquids from the solids, which produces a semi-solid, nutrient-rich product known as "sewage sludge". The terms "biosolids" and "sewage sludge" are often used interchangeably by the public; however, the U.S. Environmental Protection Agency (EPA) and wastewater treatment facilities typically use the term "biosolids" to mean sewage sludge that has been treated to meet the requirements in the EPA's regulation entitled, "Standards for the Use or Disposal of Sewage Sludge," promulgated at 40 CFR Part 503, and intended to be applied to land as a soil conditioner or fertilizer.

Biosolids are primarily composed of water and organic (carbon-rich) materials. Biosolids contain macronutrients like nitrogen, phosphorus and potassium as well as micronutrients like copper, zinc and iron. Additionally, biosolids contain inert (no carbon) solids like sand, trace elements and, depending on the level of treatment, low concentrations of microorganisms. Biosolids that comply with state and federal regulations are considered safe for the environment and protective of human health and may be beneficially used for land application as a fertilizer and soil amendment, as well as for use in composted products.

Biosolids are widely used as a soil amendment in agriculture, forestry, and land reclamation due to their beneficial macro- and micronutrient content, soil-conditioning properties, and carbon sequestration potential (Elgarahy et al., 2024; Xue et al., 2025).

Biosolids are recycled on farms and forests throughout the United States and in most developed countries worldwide. As of 2023, the EPA estimates about 60% of the total biosolids produced annually in the United States are applied for beneficial uses, while the remainder is either incinerated or disposed of in landfills.

In Virginia, the Department of Environmental Quality (DEQ), reports 37,786 acres received biosolids applications in 2024, an increase from 36,145 acres in 2023. Despite this, the acreage where biosolids are recycled represents less than 1% of all agricultural land in Virginia.

What are Plant Biostimulants

Plant biostimulants are promoted as an environmentally friendly alternative to chemical products. Biostimulants support sustainable agriculture by improving resource efficiency and productivity (du Jardin, 2015). A plant biostimulant is generally defined as "any substance or microorganism applied to plants with the aim to enhance nutrient efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrient content" (du Jardin, 2015).

Biostimulants were first described by Zhang and Schmidt (2000) as materials that, in minute quantities, promote plant growth. Until December 2018, no legal or regulatory definition for biostimulants existed in the United States. The 2018 Farm Bill provided the first statutory definition, stating that a plant biostimulant is "a substance or microorganism that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield."

Common Types of Biostimulants

The most common biostimulants include:

- Humic and fulvic acids
- Protein hydrolysates and amino acids
- Seaweed extracts and botanicals
- Chitosan and other biopolymers
- Inorganic compounds such as silicon

(Calvo et al., 2014; du Jardin, 2015). Many of these substances can also be produced by plant growth-promoting rhizobacteria and fungi.

Biostimulant Compounds in Biosolids

Biosolids contain several subcategories of biostimulants. Humic substances, hormones, amino acids, and vitamins have been identified and isolated from biosolids (Lemmer and Nitschke, 1994; Sanchez-Monedero et al., 1999; Zhang et al., 2005). Research on the biostimulant potential of biosolids has mainly focused on hormones such as auxins and on humic substances (humic and fulvic acids) (Pascual, 2011; Zhang et al., 2005, 2007, 2009, 2012, 2013; Zhang and Ervin, 2004).

Auxins are growth hormones that stimulate shoot elongation, control seedling orientation, encourage root branching, and promote fruit development. Most of these effects are attributed to the auxin indole-3-acetic acid (IAA) (Teale et al., 2006). Humic substances are heterogeneous compounds that make up a significant portion of organic matter. Historically, they are categorized into humins, humic acids, and fulvic acids based on molecular weight and solubility. Approximately 10–15% of the dissolved organic matter in biosolids consists of humic substances formed through anaerobic digestion and various thermal and chemical treatments of sludge (Xiao et al., 2020). Recent research has shown that humic substances can be extracted from biosolids as a concentrated fluid through membrane filtration and marketed as a value-added bioproduct (Nunez et al., 2022).

Evidence of Biostimulant Effects

Zhang et al. (2005) and Zhang and Ervin (2004) reported that humic acids in biosolids contain IAA and cytokinins (another class of phytohormones). The results of Zhang et al. (2007, 2009, 2012, 2013) suggest that applying biosolids can improve plant drought tolerance by enhancing hormone levels, antioxidant enzyme activity, and nitrogen metabolism. For turfgrass and Kentucky bluegrass (Chang et al., 2014), biosolids increased soil IAA levels, root length density, and root surface area under both drought stress and well-watered conditions. These effects were attributed to biosolids supplying hormones directly or stimulating microbes that produce hormones and growth-promoting substrates. Pascual et al. (2011) demonstrated that humic substances derived from composted biosolids significantly enhanced leaf, shoot, and root growth in pepper plants and led to earlier flowering and ripening.

Research Gaps and Future Needs

Despite these promising findings, there is limited literature on the biostimulant potential of biosolids. Recent research specifically examining the stimulant effects of biosolids on plant growth and yield has not attracted significant attention. Future studies are needed to investigate biostimulant mechanisms more deeply and to evaluate effects on a wider variety of crops, since most past research has focused on turfgrass.

References

1. Calvo, P., L. Nelson, and J.W. Kloepper. 2014. Agricultural uses of plant biostimulants. Plant and Soil 383:3-41.
2. du Jardin, P. 2015. Plant biostimulants: Definition, concept, main categories and regulation. Scientia Horticulturae 196:3-14.
3. Chang, Z., Zhuo, L., Yu, F., & Zhang, X. (2014). Effects of Biosolids on Root Growth and Nitrogen Metabolism in Kentucky Bluegrass under Drought Stress. HortScience, 49(9), 1205-1211.
4. Lemmer, H., and L. Nitschke. 1994. Vitamin content of four sludge fractions in the activated sludge wastewater treatment processes. Water Resources 28:737–739.
5. Nunez, D., P. Oulego., S. Collado, F.A. Riera., and M. Diaz. 2022. Separation and purification techniques for the recovery of added-value biocompounds from waste activated sludge. A review. Resource Conservation and Recylcing, 182.
6. Pascual, I., J. Aguirreolea, M. Sanchez-Diaz, J.M. Garcia-Mina, M. Fuentes, and I. Azcona. 2011. Growth and development of pepper are affected by humic substances derived from composted sludge. Journal of Plant Nutrition and Soil Science 174:916-924.
7. Sanchez-Monedero, Roig M.A., J.A. Cegarra, and M.P. Bernal. 1999. Relationships between water-soluble carbohydrate and phenol fractions and the humification indices of different organic wastes during composting. Bioresources Technology 70:193–201.
8. Teale, W.D., I.A. Paponov, and K. Palme. 2006. Auxin in action: Signalling, transport and the control of plant growth and development. Nature Reviews Molecular Cell Biology 7:847.
9. Xiao, K., G. Abbt-Braun., and H. Horn. 2020. Changes in the characteristics of dissolved organic matter during sludge treatment: a review. Water Research, 187.
10. Zhang, X., and E.H. Ervin. 2004. Cytokinin-containing seaweed and humic acid extracts associated with creeping bentgrass leaf cytokinins and drought resistance. Crop Science 44:1737–1745.
11. Zhang, X., and R.E. Schmidt. 2000. Hormone-containing products impact on antioxidant status of tall fescue and creeping bentgrass subjected to drought. Crop Science 40:1344-1349.
12. Zhang, X., E.H. Ervin, G.K. Evanylo, and K. Haering. 2007. Drought assessment of auxin-boosted Biosolids., pp. 150–165. In Proceedings WEF/AWWA Joint Residuals and Biosolids Management Conf., Denver, CO, 15–18 Apr.
13. Zhang, X., E.H. Ervin, G.K. Evanylo, and K. Haering. 2009. Impact of biosolids on hormone metabolism in drought-stressed tall fescue. Crop Science 49:1893–1901.

14. Zhang, X., E.H. Ervin, G.K. Evanylo, J. Li, and K. Harich. 2013. Corn and soybean hormone and antioxidant metabolism responses to Biosolids under two cropping systems. Crop Science 53:2079–2089.
15. Zhang, X., E.H. Ervin, G.K. Evanylo, C. Sherony, and C. Peot. 2005. Biosolids impact on tall fescue drought resistance. Journal of Residuals Science and Technology 2:173–180.
16. Zhang, X., D. Zhou, E.H. Ervin, G.K. Evanylo, D. Cataldi, and J. Li. 2012. Biosolids impact antioxidant metabolism associated with drought tolerance in tall fescue. HortScience 47:1550–1555.