Plant Health and Soil Changes with Humic Substance Applications

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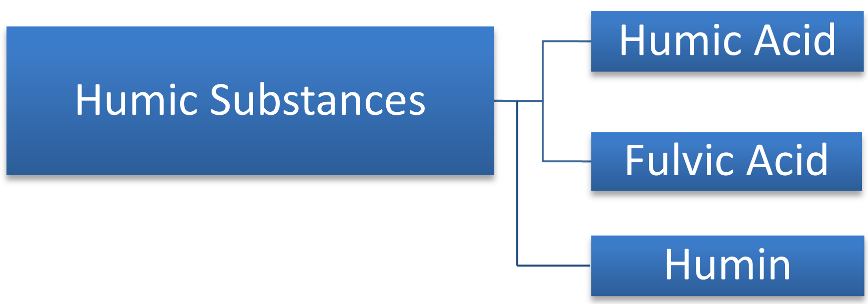
I. Introduction

Humic substances compose up to 80% of soil organic matter (Brady & Weil, 2008). Carbon, oxygen, hydrogen, nitrogen, and sulfur are the most common elements in humic substances (Pettit, 2004). As shown in Figure 1, there are three solubility-determined classifications of humic substances; fulvic acid, humic acid, and humin (Pettit, 2004). Humic acids and fulvic acids are soluble in sodium hydroxide, whereas humin is not (Brady & Weil, 2008). After solubilizing in sodium hydroxide, the humic substance mixture is treated with acid, which solubilizes the fulvic acid portion and precipitates the humic acid portion (Brady & Weil, 2008).

Figure 1: Humic Substance Classifications



Humic acids are considered to be the most abundant naturally occurring organic molecules on earth and are often described as being the "most important component of a healthy fertile soil" (Calvo, 2014; Pettit, 2004). Humic acids are water soluble in alkaline conditions, but not acidic conditions (Pettit, 2004). Approximately 35% of the humic acid's highly variable structure is composed of carbon rings, with the rest being made up of carbon chains (Pettit, 2004). Humic acids are typically composed of 53.8-58.7% carbon, 32.8-38.3% oxygen, 3.2-6.2% hydrogen, 0.8-4.3% nitrogen and 0.1-1.5% sulfur (Steelink, 2002).

Fulvic acids are water soluble under acidic, neutral and alkaline conditions (Pettit, 2004). Fulvic acids have a cation exchange capacity that is more than twice as great as that of humic acids (Pettit, 2004). Fulvic acids are very small, which allows them to enter plant roots, stems and leaves with more ease than humic acids or humins (Pettit, 2004). Fulvic acids are often included in foliar plant applications, as they are "the most effective carbon containing chelating compounds known" (Pettit, 2004).

The humin portion of humic substances is not soluble regardless of solution pH (Pettit, 2004). Humin has the greatest molecular weight of any humic substance and is extremely resistant to degradation (Pettit, 2004). The presence of humin in the soil improves the soil's water holding capacity, structure, and fertility, among other functions (Pettit, 2004).

Commercially available humic substances are extracted from composts, coal and peat (Quilty, 2011). They are available in liquid and granular forms. Liquid humic substances are applied to the soil or to the plant's foliage (Quilty, 2011). Granular humic substances are applied to the soil's surface or incorporated into the soil (Quilty, 2011). Suggested application rates for liquids range from 0.4-12 L per acre (Quilty, 2011). Suggested granular application rates range from 22-357 pounds per acre (Quilty, 2011).

II. Impact on Plant Growth

A. Nutrient Uptake

Laboratory studies indicate that the presence of humic substances may increase the uptake of nutrients; however, success in field studies is sporadic. The extent of impact on nutrient uptake may be related to the molecular size of the humic substance applied, in addition to other factors. A study conducted in 1992 observed that the application of humic substances with the smallest molecular size resulted in the greatest effect on plant nitrate uptake (Calvo, 2014). Humic acid molecules are small, which "allows them to reach the plant plasma membrane, where they effectively influence the assimilation of nutrients" (Quilty, 2011).

In a study conducted in 1998, humic acids were extracted from two commercial products that were prepared from peat and leonardite sources, labeled CP-A and CP-B, respectively (Adani, 1998). Upon the addition of humic acids from peat and leonardite sources to hydroponic solutions, tomato plants' uptake of nitrogen, phosphorus, and iron increased (Adani, 1998). In a greenhouse study conducted on strawberry plants grown in calcareous soil, the application of humic acid in solid and liquid forms did not significantly impact the nutrient content of the plants (Pilanali, 2003). Foliar application of 0.1% and 0.2% humic acid solutions to maize grown in calcareous soils resulted in a statistically significant impact on the uptake of copper, zinc, and manganese (Çelik, 2010). During a field study in which phosphorus and humic acid were applied to lettuce, the nitrogen content of the leaves increased (Cimrin, 2005). After application of humic acid, increased uptake of nitrogen, phosphorus, potassium, calcium, and magnesium was observed in peppers and cucumbers (Calvo, 2014). Increased uptake of nitrate was observed in beans, wheat and cucumbers after the application of humic acid (Calvo, 2014).

B. Total Plant Biomass

In a study conducted in 2006, humic acids extracted from vermicompost were added to planting medium at rates ranging from 250 to 1000 mg/kg (Arancon, 2006). "As a general pattern, plant growth increased in response to treatments of the plants with 50-500 mg/kg humic acids, but decreased significantly when the concentrations of humic acids in the container medium exceeded 500-1000 mg/kg" (Arancon, 2006). In a field study conducted on cucumbers, increased plant growth and fruit yield was observed when humic acid was applied (Calvo, 2014).

C. Root and Shoot Growth

As early as 1950, positive impacts from the addition of humic acids have been observed with regard to root growth (Cooper, 1998). When 4-5 mg/L humic acid was added to the solution in which corn was grown, the root length and number doubled, as compared to corn grown in a solution without humic acid (Cooper, 1998). A study conducted in 2008 attributed increased root elongation in germinating maize seed to "interaction between plant hormones and a humic substance treatment" (Quilty, 2011). In a study conducted in 1998, humic acids were extracted from two commercial products that were prepared from peat and leonardite sources, labeled CP-A and CP-B, respectively (Adani, 1998). Tomato plants treated with CP-A (from peat) had statistically significant increases in root growth, as compared to the control (Adani, 1998). Tomato plants treated with CP-B (from leonardite) had statistically significant increases in root and shoot growth, as compared to the control (Adani, 1998). In this study, root growth was more significantly impacted than shoot growth (Adani, 1998). Other studies have observed increases in shoot growth of cucumber, wheat, maize, and pepper (Calvo, 2014).

In a study conducted in 2006, humic acids extracted from vermicompost were added to planting medium at rates ranging from 250 to 1000 mg/kg (Arancon, 2006). A statistically significant increase in the dry weight of roots of marigolds and peppers grown in the planting medium resulted (Arancon, 2006). In other studies, humic acids extracted from vermicompost increased root growth in banana, strawberry and cowpea plants (Quilty, 2011).

The application of humic substances to creeping bentgrass resulted in an average of 26% increase in root mass in the top 10 cm, as compared to the untreated control (Cooper, 1998). Root masses also increased at depths greater than 20 cm when humic substances were applied, as compared to the untreated control (Cooper, 1998). The application of granular humic substances resulted in a greater maximum root length, as compared to the untreated control (Cooper, 1998). Greater root mass resulted when granular humate was incorporated into the growing medium, as opposed to when it was applied to foliage (Cooper, 1998). This "may have been a result of granular humate and its breakdown products being in more direct contact with roots compared with humic acid treatments that were applied to foliage" (Cooper, 1998).

D. Fruit Growth

In a study conducted in 2006, humic acids extracted from vermicompost were added to planting medium at rates ranging from 250 to 1000 mg/kg (Arancon, 2006). A statistically significant increase in the fruit weights of tomatoes grown in the planting medium was observed (Arancon, 2006). A statistically significant increase in the number of fruits of strawberries and peppers grown in the planting medium was also observed (Arancon, 2006). The number of flowers and fruits observed in peppers grown in the humic acid supplemented planting medium did not differ significantly from peppers grown in a planting medium supplemented with a plant growth regulator, which led the researchers to believe that "humic acid had a similar effect on pepper plants similar to the effects of a plant growth regulator" (Arancon, 2006). In a greenhouse study during which peppers were treated with soil and foliar humic acid applications, fruit firmness, fruit length, and fruit diameter were not significantly effected (Karakurt, 2009). A significant increase in mean fruit weight, sugar content and yield of peppers was observed after soil and foliar humic acid applications (Karakurt, 2009). In a greenhouse study in which humic acid was applied in addition to the recommended fertilizer regime, the number of fruits per okra plant significantly increased (Calvo, 2014). When the recommended fertilizer regime was decreased by 50% and humic acid was applied, there was not a significant increase in number of fruits per okra plant (Calvo, 2014).

III. Impact on Soil Characteristics

The addition of humic substances to soils can have important implications on the soil physical, chemical, and biological characteristics. The addition of organic matter, such as humic substances, increases soil aggregation, water retention, infiltration rate, and water-holding capacity (Brady & Weil, 2008). "Addition of humic substances has been shown to improve aggregation in soils with a range of texture grades and mineral suites" (Quilty, 2011). The impact on aggregation appears to vary by the source of the humic substances applied. When sandy and clay soils were treated with a peat-extracted humic substance, the number of small aggregates (<1000mm) increased (Quilty, 2011). When sandy and clay soils were treated with a manure-extracted humic substance, the number of large aggregates (1500–2500mm) increased (Quilty, 2011). Aggregation promotes high infiltration rates, which reduce runoff and erosion (Sylvia, 1998). The cation exchange capacity of the soil is also impacted by the application of humic substances. "Humus generally accounts for 50 to 90% of the cation-absorbing power of mineral surface soils. Like clays, humus colloids hold nutrient cations (potassium, calcium, magnesium, etc.) in easily exchangeable form, wherein they can be used by plants but are not too readily leached out of the profile by percolating waters" (Brady & Weil, 2008). From a biological perspective, humic substances enhance soil fertility by impacting the composition of microbial populations (Calvo, 2014).

The efficacy of humic substances is related to how similar the applied substances are to the humic substances in the native soil, which is impacted by the origin of the material and the processing methods (Senesi, 2007). "Since soil {humic substances] contribute essential functions to global soil fertility and health, the greater the amount and the more the compositional, structural and functional properties of [humic substance]-like fractions resemble those of native soil [humic substances], the more agronomically efficient, environmentally safe and economically valuable is the organic amendment" (Senesi, 2007). Processed humic substances typically have higher carbon, hydrogen, nitrogen and sulfur contents when compared to humic substances found in native soil (Senesi, 2007). When humic substances originating from the composting of municipal solid waste, sewage sludge, livestock waste, and food production waste were applied to various soil types, their molecular properties tended to change over time to more closely match the molecular properties of the humic substances found in the native soil (Senesi, 2007).

Just as the impact of humic substances varies by the source of the humic substance, plant species, and application method, it also varies by the type of soil (Seyedbagheri, 2010). In an experiment conducted in Saylor Creek, Idaho, several rates of humic acid were applied to plots in a randomized complete block. A 6% humic acid solution was applied at rates of 3, 7, 15, 30 and 60 L/humic acid/acre (Seyedbagheri, 2010). The plots were located in three different farmers' fields. The fields had calcareous soils (pH 8-8.2) and an organic matter content of approximately 1%. Potatoes were planted in plots and humic acid was applied via side dressing on both sides of the rows (Seyedbagheri, 2010). Stand and vigor increased in plots treated with humic acid, as compared to the control plots (Seyedbagheri, 2010). Potato yields increased with increasing rates of humic acid application up to 30 L/humic acid/acre, but were reduced at the highest treatment of 60 L/humic acid/acre (Seyedbagheri, 2010). The impacts on yield could be due to the effects of humic acid on the reactions that form organic-clay complexes (Seyedbagheri, 2010). “This reaction contributes to the creation of stable humus, which impacts soil physical, chemical and biological functions” (Seyedbagheri, 2010).

When Seyedbagheri applied granular and liquid humic acid to plots with calcareous silt clay loam soil, there was no statistical difference in yield between humic acid treatments and the control (Seyedbagheri, 2010). Granular humate was applied via top dressing at a rate of 16 kg per acre and liquid humate was applied via side dressing at the rates of 0, 18, and 37 L/humic acid/acre (Seyedbagheri, 2010).

IV. Conclusion

Based on laboratory experiments, humic substances show promise for commercial crop production; however, the extent of positive crop response is difficult to predict. To date, field research has shown mixed results. Humic substances may have an impact on plant growth and soil characteristics; however, the magnitude of the impact is determined by several factors, which include the source of the humic substance, plant species, method of application, and soil type. The efficacy of humic substances is also related to how similar the applied substances are to the humic substances in the native soil, which is impacted by the origin of the material and the processing methods (Senesi, 2007). With further field research, we will develop a greater understanding of how applied humic substances impact the plant and soil, which will allow us to more effectively integrate humic substances into fertilizer application regimes.

V. References

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