Humic Substances
and Their Potential for Improving Turfgrass Growth

Richard J. Cooper, Ph.D.
Department of Crop Science,
North Carolina State University

One aspect of turfgrass management which seems constant from year to year is the introduction of new products which aim to allow turfgrass managers to grow better quality turfgrass. Many of these products are designed primarily for high use, intensively managed areas such as putting greens, athletic fields and other closely-mown areas growing on sand-based rootzones. Indeed, these types of areas often require the most management input and are subject to great environmental and use stresses. It is not easy to maintain them at peak quality, especially during the summer stress period.

During recent years, many commercial products containing humic substances have been promoted for use on turfgrasses. While the effects of humic substances on cereal grasses and numerous other plants have been studied for some time they are a relatively new addition to the management arsenal of the turfgrass manager. The following material is meant to provide a thorough introduction to humic substances and their potential use on turfgrass.

Introduction

It has been recognized for centuries that soils containing ample organic matter are usually more fertile and productive than sandy soils. Organic matter has been shown to improve soil water holding capacity, cation exchange capacity (CEC), nutrient retention, soil microbial activity and other properties (Tate, 1987). Although it often composes only 1 to 4% of the dry weight of a soil, it has been estimated that organic matter is responsible for about one-half of a soil's CEC and water-holding capacity.

In recent years, scientists have begun to study specific components of soil organic matter to determine their influence on plant growth. In particular, much research has focused on evaluating the humic substances present in soil.

Interest in humic substances is not a recent phenomenon. In 1786, Achard extracted a substance from peat that we now know as humic acid. Achard's procedure is still the basis for common methods of extracting humic substances from soil today. In the 1800s, plant scientists believed that plants obtained the carbon they needed for growth from carbon present in soil organic matter, including humus. This theory was known as the humus theory of plant nutrition. Of course, we now know that plants obtain the carbon they need through the process of photosynthesis, not from fertilizers or the soil. Even so, soil organic matter remains very important for plant nutrition.

Humic substances can be generally described as "naturally occurring, highly decomposed organic substances with very complex structures." They are derived from plant and animal residues and are usually dark in color. Humic substances can be divided into humic acids (HA), fulvic acids (FA) and humins based upon their solubility in acidic and basic solutions. Aiken et al. (1985) have characterized the fractions as:

Humic acid – The fraction of humic substances that is not soluble in water at a pH less than two, but is soluble at higher pH values.

Fulvic acid – The fraction of humic substances that is soluble in water at any pH.

Humin – The fraction of humic substances not soluble in water at any pH.

Humic substances are essentially a component of organic matter and can be found almost anywhere: streams, lakes and virtually any soil which contains organic matter, animal or plant residues. Some common sources of HAs and humates are coal, Leonardite (a coal-like material) and peat.

Table 1 lists several commonly used soil organic amendments, their humic and fulvic acid content and their CEC. Reed-sedge peat is often used in high sand content rootzones because of its higher CEC and humic content compared to the other sources.

Extracting and producing humic and fulvic acids from various naturally occurring materials often results in a material too acidic for use on many turfgrass areas. To produce a more usable commercial product, HA can be treated with a basic compound to produce a soluble salt with a near neutral pH referred to as humate. It is also possible to mine soil deposits which contain a high percentage of HA or humate. Humic acids and humates are the most commonly marketed types of humic substances currently available for use on turfgrass.

The Composition of Humic Substances

Because humic substances are highly complex organic molecules, their structure varies widely from source to source and no characteristic structure can be described. Even though it is not possible to accurately detail the structure of a typical humic substance, it is known that the major functional groups in humic substances include carboxyl, alcohol, carbonyl and phenolic hydroxyl groups. Also, the general nutrient composition of many soil humic substances has been evaluated. Table 2 lists the average nutrient content for some typical humic substances.

Although several of the possible benefits of humic substances are associated with improved nutrition, it is important to recognize that humic substances themselves are not fertilizers and do not supply appreciable amounts of the major nutrients needed by turfgrasses. It is interesting to note that while research has shown that humic substances can affect a range of plant growth responses, they do not elicit a response because of their fertilizer value. Indeed, carbon, hydrogen, oxygen and sulfur often account for almost all of their composition with only slight and variable amounts of the macroelements N, P and K. Since humic substances are organic in origin, it is not surprising that carbon and oxygen generally make up over 80% of their mineral composition. Generally, humic acids have a greater carbon content and a smaller oxygen content than fulvic acids. (MacCarthy, et al., 1990).

TABLE 1: HUMIC & FULVIC ACID CONTENT OR AMENDMENTS

Humic and fulvic acid content and cation exchange capacity of four commonly used soil organic amendments (adapted from Dixon, 1990).

Amendment	Humic acid (%)	Fulvic acid (%)	CEC (meq /100g)
Reed-sedge peat	21.1	12.0	118.0
Sphagnum peat	8.3	8.6	74.8
Rice hull compost	5.8	6.9	16.5
Fir bark	3.1	5.8	18.3

How Humic Substances Influence Plant Growth

It has been well documented that humic substances may have both indirect and direct effects on plant growth. Indirect effects generally involve a change in soil properties such as: increasing the nutrient holding capacity (CEC) or water holding capacity of the soil; enhancing the population of desirable soil microbes in the soil; improving soil aggregation, aeration, or permeability; and improving micronutrient availability and transport into roots. In addition to these indirect soil-related effects, it is thought that humic substances might also have the ability to directly impact plant growth. Direct effects are those which require uptake of humic substances into the plant tissue resulting in various biochemical effects.

There are several hypotheses as to how humic substances may function in plants to produce positive changes in growth. Some possible mechanisms indicated by past research include: enhanced absorption of mineral nutrients; reduction in soil levels of toxic elements; enhancement of soil microbial populations; increased photosynthesis and protein synthesis; increased plant hormone activity; and alteration of cell membranes resulting in improved transport of nutrients from the soil.

Several researchers have noted an increase in the transport of nutrients (P, K, calcium, magnesium, iron and manganese) from roots to shoots following HA application to various crops (Fortum and Lopez-Fando, 1986). Application of HA has also been shown to reduce aluminum toxicity to plants by chelating available aluminum and rendering it unable to compete with P uptake, thus increasing P availability in acidic soils (Tan and Binger, 1986). Kreij and Basar (1995) reported that humic substances lowered the uptake of manganese, zinc and copper for several herbs with the response being more pronounced at low pH. Reduced uptake at low pH may be due to increased complexation by humic substances and lower availability in complexed form.

Increased iron uptake in response to HA application has also been reported (DeCock, 1955) and it has been suggested that the increase in iron uptake might be due to increased cell membrane permeability. Chen and Aviad (1990) have also speculated that humic substances may interact with the phospholipids in cell membranes to facilitate nutrient transport.

Humic substances may also influence plant growth as a result of their effect of various aspects of plant metabolism (Vaughan and Malcolm, 1985). HA has been reported to increase both photosynthesis and respiration in a wide range of plants (Chen and Aviad, 1990), as well as leaf chlorophyll content (Sladky, 1959 a,b). Increases in these processes might be expected to result in increased plant growth. Miroslava (1960) reported that HA increased root respiration with increased respiration linked to greater growth.

TABLE 2: CHEMICAL COMPOSITION OF HUMIC SUBSTANCES

Average chemical composition of selected humic substances. (From Steelink,1985).

Element	Humic Acid	Fulvic acid
	%	
Carbon	54 - 59	41 - 51
Hydrogen	3 - 6	4 - 7
Oxygen	33 - 38	40 - 50
Nitrogen	1 - 4	1 - 3
Sulfur	0 - 2	0 - 4

Plant Growth in Response to Humic Substances

While scientists have not conclusively determined the exact mechanism(s) responsible for influencing plant growth, the positive effect of humic substances on the growth of numerous plants in the Gramineae family has been well documented (Chen and Aviad, 1990). Dixit and Kishore (1967) reported enhanced germination in corn, barley and wheat treated with humic or fulvic acids.

Many studies have associated improved rooting with the application of humic substances. Kononova and Pankova (1950) compared the root development of corn growing in solution culture with or without added humic acid and found that root length and number doubled in response to humate added at 4 to 5 mg/litre. Lee and Bartlett (1976), also working with corn grown in solution culture, found that rooting was enhanced significantly at a humate concentration of 8 mg/litre. Tattini et al. (1990) reported that HA improved the root:shoot ratio and increased the production of lateral roots in olive (*Olea europaea* L.). They also observed increased partitioning of carbohydrates to the roots and an increase in whole plant dry weight.

Vaughan and Malcolm (1985) compared root and shoot growth of wheat grown in water alone, in a complete (Hoagland's) nutrient solution and in each solution supplemented with 50 mg/litre humic acid. The results showed a 58% increase in root growth when humic acid was added to water alone. This was less than the increase in growth when plants were grown in a solution with adequate mineral nutrition but no humic acid. The greatest response, however, occurred with the addition of humic acid to plants growing in nutrient solution. These plants increased root growth approximately 25% compared to plants which were growing in nutrient solution alone. While the use of humic substances cannot substitute for proper nutrition, they do seem to improve nutrient uptake and utilization.

In a review of research evaluating humic substances, Chen and Aviad (1990) cite many studies demonstrating the influence of humic materials on nutrient uptake by plants. Dormaar (1975) reported an increase in N uptake by rough fescue (*Festuca scabrella* Torr.) in response to application of humic substances extracted from three soils while P, K, calcium, magnesium and sodium were unaffected. Guar (1964) found increased N, P, and K uptake in perennial ryegrass (*Lolium perenne* L.) grown in sand amended with humic acid extracted from compost. Varshovi (1991) found no increase in N uptake by bermudagrass (*Cynodon dactylon* L.) following application of a commercial humate material at 0, 268 and 803 kg/ha. Dorer and Peacock (1997) reported no increase in leaf tissue concentration of N, P or K following applicartion of liquid or granular humate to a creeping bentgrass putting green. Whether nutrient uptake increases, decreases or remains constant in response to humic substances appears to depend in large part on the plant species and humic materials used.

It is important to keep in mind that humic substances are classified primarily according to their solubility, not upon chemical structure. In fact, it is sometimes said that if you can identify a the structure of a particular compound, it is not a humic substance. It is difficult to make comparisons among different humic materials.

Two products may contain identical amounts of humic or fulvic acid, but they may have come from completely different sources and produce very different results when applied to a turf area. Therefore, it is important to gain as much information about a specific product as you can before using it yourself. Good sources of information include: independent research results from unbiased labs, university research, impressions from superintendents who have used a particular product and small test plots on your own golf course. While the positive effects of humic substances on cereal grasses and other plants have been documented, the growth response of turfgrass has not been studied extensively.

In an upcoming issue, we will summarize current research results dealing specifically with the effects of humic substances on turfgrasses.

Richard J. Cooper, Department of Crop Science, North Carolina State University, Raleigh. He can be reached at (919) 515-7959 or e-mail at rich_cooper@ncsu.edu.

REFERENCES

Aiken, G.R., D.M. McKnight, R.L. Wershaw and P. MacCarthy. 1985. Introduction to humic substances in soil, sediment and water. Pp. 1-9 *In* Aiken,G.R. *et al.*, ed. Humic substances in soil, sediment and water: geochemistry, isolation and characterization. Wiley-Interscience, New York, NY.

Chen, Y. and T. Aviad. 1990. Effects of humic substances on plant growth. Pp. 161-186 *In* MacCarthy, P. *et al.*, ed. Humic substances in soil and crop science: selected readings. SSSA and ASA, Madison, WI.

DeCock, P.C. 1955. Influence of humic acids on plant growth. Science. 121:473-474.

Dixit, V.K. and N. Kishore. 1967. Effect of humic acid and fulvic acid fraction of soil organic matter on seed germination. Indian J. Sci. Ind. 1:202-206.

Dixon, C.R. 1990. Evaluating organic amendments for sand-based turf systems. Golf & Sports Turf. Sept. p. 23-25.

Dorer, S.P. and C.H. Peacock. 1997. The effects of humate and organic fertilizer on establishment and nutrition of creeping bent putting greens. J. Int. Turf. Res. Soc. 8:437-443.

Dormaar, J.F. 1975. Effects of humic substances from Chernozemic Ah horizons on nutrient uptake by *Phaseolus vulgaris* and *Festuca scabrella.* Can. J. Soil Sci. 55:111-118.

Fortum, C. and C. Lopez-Fando. 1986. Action of peat compost humic acids on growth and mineral content of ryegrass. Agrochemica. 30(1):83-92.

Guar, A.C. 1964. Influence of humic acid on growth and mineral nutrition in plants. Bull. Assoc. Fr. Itude Sol. 35:207-219.

Kononova, M.M. and N.A. Pankova. 1950. Action of humic substances on growth and development of plants. Doklady Akad. Nauk. SSSR. 73:1069-1071.

Kreij, C. and H. Basar. 1995. Effect of humic substances in nutrient culture on nutrient uptake. J. Plant Nutrition. 18:793-802.

Lee, Y.S. and R.J. Bartlett. 1976. Stimulation of plant growth by humic substances. Soil Sci. Soc. Am. J. 40:876-879.

MacCarthy, P., R.L. Malcolm, C.E. Clapp and P.R. Bloom. 1990. An introduction to soil humic substances. Pp. 1-12 *In* MacCarthy, P. *et al.*, ed. Humic substances in soil and crop sciene: selected readings. SSSA and ASA, Madison, WI.

Miroslava, J.L. 1960. Influence of humic acid on respiration of plant roots. Biol. Plant. 2:152-164.

Sladky, Z. 1959a. Effect of extracted humus substances on tomato growth. Biol. Plant. 1:142-150.

Sladky, Z. 1959b. The application of extracted humus substances to overground parts of plants. Biol. Plant. 1:199-204.

Steelink, C.A. 1985. Implications of elemental characteristics of humic substances. Pp. 457-476 *In* Aiken, G.R. *et al.*, ed. Humic substances in soil, sediment, and water: geochemistry, isolation and characterization. Wiley-Interscience, New York, NY.

Tan, K.H. and A. Binger. 1986. Effect of humic acid on aluminum toxicity in corn. Soil Sci. 141(1).

Tate III, R.L. 1987. Soil organic matter. John Wiley and Sons, Inc. New York, NY.

Tattini, M.A., A. Chiarini, R. Tafani and M. Castagneto. 1990. Effects of humic acids on growth and nitrogen uptake of container grown olive. Acta Horticulture. 286:125-128.

Varshovi, A.A. 1991. Humate: properties and influence on the growth and nitrogen uptake of bermudagrass. M.S. Thesis. Univ. of FL, Gainesville.

Vaughan, D. and R.E. Malcolm. 1985. Influence of humic substances on growth and physiological processes. Pp. 37-75 *In* Vaughan, D. and R.E. Malcolm, eds. Soil organic matter and biological activity. Martinus Nijhoff/Dr. W. Junk Publ., Dordrecht.