

INFLUENCE OF HUMIC PRODUCTS ON SOIL HEALTH AND POTATO PRODUCTION

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Abstract

Since 1900, soil organic matter (SOM) in farmlands worldwide has declined drastically as a result of carbon turnover and cropping systems. Over the past 17 years, research trials were established to evaluate the efficacy of different commercial humates products derived from lignite and Leonardite in potato crop production. Data from humic acid (HA) trials showed that different cropping systems responded differently to different products in relation to yield and quality. Important qualifying factors included: source; concentration; processing; chelating or complexing capacity of the humic acid products; functional groups (Carboxyl $-CO_2H$; Phenol $-OH_p$; Hydroxyl $-OH_a$; Ketone $-C=O$; Ester $O=C-O-R$; Ether $-C-O-C-$; Amine $-NH_2, -NH, -N$), rotation and soil quality factors; consistency of the product in enhancing yield and quality of potato crops; mineralization effect; and influence on fertilizer use efficiency. Properties of humic substances, major constituents of soil organic matter, include chelation, mineralization, buffer effect, clay mineral-organic interaction, and cation exchange. Humates increase phosphorus availability by complexing ions into stable compounds, allowing the phosphorus ion to remain exchangeable for plants' uptake. Collectively, the consistent use of good quality products in our replicated research plots in different years resulted in a yield increase from 11.4 percent to the maximum of 22.3 percent. Over the past decade, there has been a major increase in the quality of research and development of organic and humic acid products by some well-established manufacturers. Our experimentations with these commercial products showed an increase in the yield and quality of crops.

Key Words: Soil Organic Matter (SOM), Humus, Humic Acids (HA), Lignite, Leonardite

Introduction

Soil is a living system. Soil organic matter (SOM) is derived from the chemical and biological degradation of residues of plants and animals in various stages of decomposition and from synthetic activities of microorganisms (Chen and Avid 1990; Stevenson 1994). The importance of SOM in crop production has been acknowledged in agricultural and soil sciences for over 150 years. Soil organic carbon (SOC), the major component of SOM, is a vital factor in every attribute of healthy, productive soil, including structural stability, permeability, water-holding capacity, plant nutrient storage and supply, erosion resistance, and pollutant binding. The rapid decline of SOM in farmlands over the past century due to carbon turnover and cropping systems has resulted in seriously low levels of SOM (Yang et al. 2003). As a result the world's arable lands are being lost to erosion, polluted and degraded through misuse of inorganic fertilizers, and soils are losing their ability to sequester carbon.

Soil may be defined as a biological entity similar to a "living tissue with complex biochemical reactions" (Lee and Quastel 1946), in which organic materials in the soil are consumed by soil macro- and microorganisms for use as substrate in a metabolic process known as humification. Biomolecules of plants and animals are cycled and recycled through physical, chemical and biological pathways of the *soil food web* (Bengtsson et al. 1996) until they reach the stage of stable humus resistant to further decomposition and bearing no resemblance to original plant or animal cellular organization (Brussaard and Juma 1996; Sanchez-Moreno and Ferris 2007).

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Humic substances (HS) constitute 65-80 percent of SOM and are ubiquitous in the environment, commonly occurring in soils, water, peat and carbon-containing minerals such as low-grade brown coals, lignite and Leonardite where they can remain unchanged for hundreds to thousands of years so long as conditions in which they have been formed remain unchanged. HS are composed of three main fractions operationally based on aqueous solubility: fulvic acids (FAs, soluble at all pH), humic acids (HAs, insoluble < pH 2), and humins (insoluble at all pH). (Stevenson 1994)

HAs and FAs are a family of organic molecules made up of very long carbon chains and numerous active radicals, such as phenols and aromatics. (Stevenson 1982) The biological center in soils, they possess properties of chelation, mineralization, buffer effect, clay/mineral/organic interaction, and cation exchange capacity that are essential to soil fertility and plant growth.

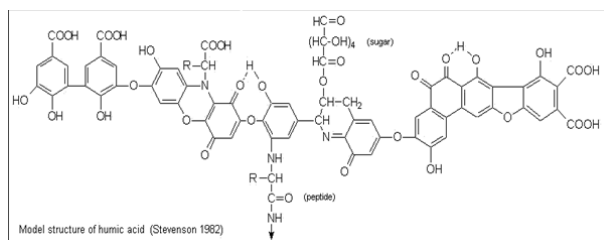


Fig. 1. Model structure of humic acid (Stevenson 1982)

Beneficial effects of HA direct modes of action on plant growth include: effects on membranes that result in improved transport of nutritional elements; enhanced protein synthesis; plant hormone-like activity; enhanced photosynthesis; and effects on enzyme activities. Indirect modes of action benefit plant growth through solubilization of microelements (e.g. Fe, Zn, Mn) and some macro elements (e.g. K, Ca, P); reduction of active levels of toxic elements; and increased microbial populations. Important attributes of HA are their ability to combine soil particles in structural aggregates, favor mineralization of chemical substances which release SO₄, PO₄, NH₄ and NO₃, and high cation exchange capacity. (Chen 1996)

Humic is important for its role in stable SOM by encapsulating small polar molecules (physical sequestration), binding functionalized biomarkers (chemical sequestration), and selective preservation of aliphatic biopolymers. (Stevenson 1990)

A fertile soil should contain from 2-8 percent organic matter; most soils contain less than 2%. (Schroth 2003) Most SOM in leached, acidic soils (usually sandy) is in the form of plant debris and fulvic acids (FAs). In neutral and alkaline soils SOM is mainly in the form of humic acids (HAs) and humin. Low SOM is a major contributing factor in poor soil structure and compaction, decreased infiltration, increased runoff, crusting, and erosion. (Collins et al. 1997) Over the last 40 years almost a third of the world's arable land has been lost to soil erosion. At a rate of more than 10 million hectares per year, soil erosion has become a major environmental threat to the sustainability and productive capacity of agriculture. (Pimentel, et al.1995).

While soil fertility is naturally reduced with erosion, fertility in itself is essentially a function of agricultural methods, soil type, and nutrient and SOM carbon content. Research shows the importance of microbial processes and their positive effects on soil and plant metabolism and

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sustainable cropping systems in protecting organic carbon in agricultural soils. (MacCarthy et al. 1990; Swift 2001) There is a strong need to add stable HS to enhance carbon sequestration in today's depleted soils.

The richest source of natural HAs is lignite (brown coal) and Leonardite (naturally oxidized lignite), the end product of a humification process lasting 70 million years. Leonardite is characterized by extremely high HA content (40-85%), and differs from lignite by a much higher HA content, higher carboxyl groups, and extraordinary bioactive properties. (Broughton 1972) Organo-mineral associations play an important function in soil health and productivity. (Fig. 2, 3, 4)

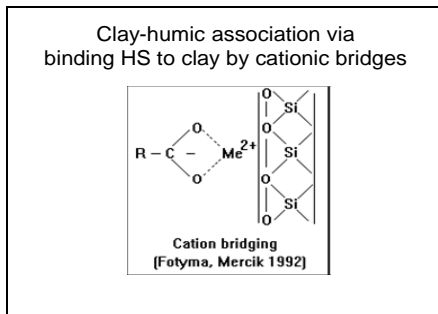


Fig. 2. Clay-humic association via binding to clay by cationic bridges.

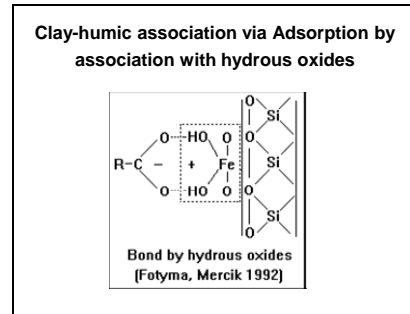


Fig. 3. Clay-humic association via HS adsorption by association with hydrous oxides.

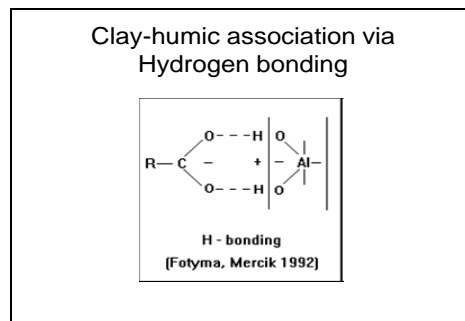


Fig. 4. Clay-humic association via hydrogen bonding

For 17 years we established research trials to evaluate the efficacy of commercial humic acid products derived from lignite and Leonardite on crop production in potato fields in western Idaho, USA.

Materials and Methods

HA treatments were arranged in a randomized complete block design with four replications. The products were applied as a foliar, side-dressed or top-dressed. For the top-dressed application of HA, hills above the potato seeds were opened prior to application for pre-emergence treatments. Liquid humic products were applied with solo pack sprayers to the opened furrow. Furrows were closed immediately after application of different treatments. In

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different trials, granular humates were weighed ($40.48 \text{ kg} \cdot \text{ha}^{-1}$) and spread as evenly as possible on treated rows, according to block design randomizations. Humic products were applied according to manufacturers' recommendations. At the end of the crop season, potatoes were harvested, graded, weighed, and quality parameters were evaluated.

Results and Discussion

Data from humic acids trials conducted over a seventeen-year period shows that the performance of different humic products varied in yield and quality. (Fig. 5; Table 1) Important qualifying factors were a) source; b) concentration; c) processing; d) chelating or complexing capacity of the humic acid products; e) functional group contents (carboxyl, phenol, hydroxyl, ketone, Ester, Ether, Amine; f) crop rotation and soil quality factors; g) consistency of the product in enhancing yield and quality of crops; h) mineralization effect; and i) influence on fertilizer use efficiency.

Conclusion

A comparison of statistical analysis of field data to determine the efficacy of twenty different humic acids products shows that collectively the consistent use of good quality products resulted in a yield increase from 11.4 percent to the maximum of 22.3 percent. In some poor quality products there was no yield increase and economic gain. In addition, the use of good-quality humates with complexing macro- and micro-nutrients in the solution enhanced fertilizer use efficiency and potato quality. Humic acid products enhanced nitrogen mineralization in early season by an average of 9.6 percent. As a cautionary measure, the C:N ratio should be evaluated early in the season to prevent higher mineralization after mid-June.

Humates increased phosphorous availability by complexing ions into stable compounds, allowing the phosphorus ion to remain exchangeable for plants uptake. A University of Idaho Aberdeen Research Station 3-year evaluation on the efficacy of HA on potato crop production shows that application of HA and liquid phosphorus in a concentrated band at potato hilling boosts yield and quality as compared with the application of phosphorus alone. (Fig. 6) Even though there were no statistically significant differences, there was an economic gain to the growers as shown by Table 2.

The dramatic increase in laboratory and applied research by well-established manufacturers over the past 10 years has resulted in the establishment of sound applied research summaries for use of their products. Our experimentations with these products have shown an increase in potato crop yield and quality.

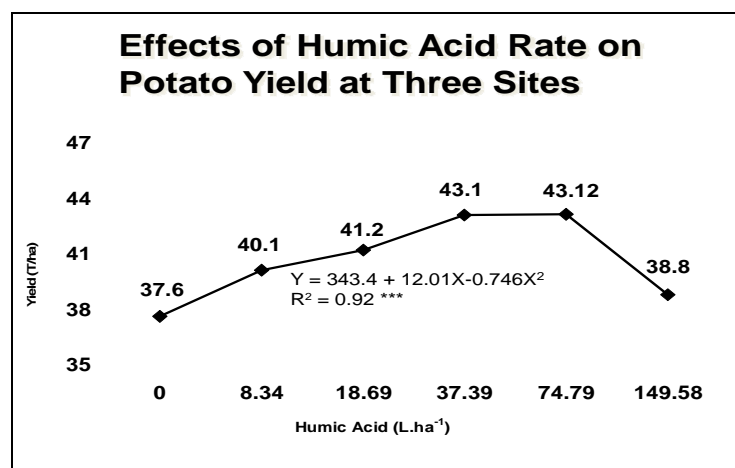


Fig. 5. Effects of humic acid rates on potato yield at three sites

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Table 1. Effect of humic acid on yield, 1999

Yield (MT.ha ⁻¹) ^a						
Mass, g Treatment ^b	0-113.4 g	113.4 – 220.8 g	226.8 – 340.2 g	>340.2 g	Culls	Total
#1: Control	10.2a	17.9a	8.2a	5.0a	3.4a	44.6a
#2: Granular Humate Only (Agri-Plus)	10.7a	16.7a	8.4a	5.5a	2.8a	45.1a
#3: Granular Humate (Agri-Plus) + 46.5 l.ha ⁻¹ Liquid Humic Acid (Quantum-H)	11.5a	16.7a	7.0a	5.0a	4.5a	44.7a
#4: Granular Humate (Agri-Plus) + 93.0 l.ha ⁻¹ Liquid Humic Acid (Quantum-H),	11.0a	15.3a	6.4a	4.2a	4.6a	41.5a

¹ MT=Metric ton
² Means followed by the same letter in the same column are not significantly different at the 0.05 level (Neumann-Keuls test)

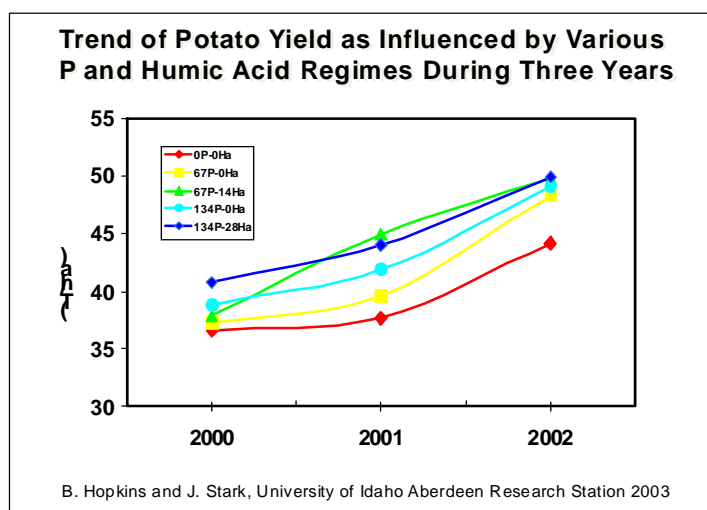


Fig. 6. Trend of potato yield as influenced by various P and humic acid regimes During 3- years (Hopkins and Stark 2003)

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Table 2. Yield, specific gravity, petiole P, and gross return in Russet Burbank Potatoes under different rates of 10-34-0 fertilizer (Hopkins and Stark 2003)

Yield, Specific Gravity, Petiole P, and Gross Return in Russet Burbank Potatoes Under Different Rates of 10-34-0 Fertilizer

P ₂ O ₅ (kg/ha)	Humic Acid (L/ha)	Total	US No.1	>283g	Sp. gravity	Petiole P (% dwt)	Gross Return (US\$/ha)
0	0	394	225	146	1.077	0.24	4523
67.36	0	431	260	177	1.079	0.29	5110
67.36	14	444	279	186	1.080	0.31	5390
134.7	0	438	261	179	1.079	0.30	5187
134.7	28	446	278	193	1.079	0.32	5402
LSD @ 1%		48	33	23	0.003	0.03	

B. Hopkins and J. Stark, University of Idaho Research Station 2003

* Horizon Ag.

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