actosol® Organic Humic-Fulvic Fertilizer for Increased Crop Yields, Quality and Improvement of Soil Health

A WHITE PAPER By
ARCTECH Inc. Centreville, Virginia USA
POC; Dr. Daman S. Walia dwalia@arctech.com 571 338-5005
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INTRODUCTION

Modern agriculture built with inputs of minerals and synthetic nutrition has resulted in the excessive mineralization of organic matter in soils and repeated turnover has caused loss of organic matter in farm lands, which is adversely impacting soil health and its fertility. Water and wind erosion and chemical and physical land degradations also contribute to the major loss of organic matter in soil. The eroded soil along with residual pesticides and fertilizers applied to farm lands, washes into water ways, including the area of this proposed project, the 64,000 square miles of the Chesapeake Bay that includes 6 States and Washington D.C. This sedimentation and pollution is damaging freshwater, marine habitats and the local communities that depend u them. *It is estimated that the total annual cost of erosion from agriculture in the US is about US $44 billion/year, i.e. ~US$247 per ha of cropland and pasture [*1*].*

The United Nations Food and Agriculture Organization (UNFAO) is raising concerns that global food production is being undermined by land degradation, loss of humus organic matter, shortages of farmland and water resources, making feeding the world's rising population – projected to reach nine billion by 2050 – a daunting challenge (Figure 1, [2]). In 2000 the UNFAO reported almost 25 billion tons of soil loss worldwide, six billion in US and made a case for the critical need to enhance soil fertility to feed world's growing population. In December 5, 2014 and at a forum marking World Soil Day, Maria-Helena Semedo, deputy director general of natural resources of FAO said that about a third of the world's soil has already been degraded. Ms. Semedo also warned that if current rates of soil degradation continue all of the world's top soil could be gone within 60 years. This is of great ecological concern as one inch of topsoil can take 500 years to form naturally [3].

Figure 1. Land Degradation, UNFAO 2011.

Prof Ratan Lal of Ohio State University and President of the **International** Union of **Soil** Sciences. Recently made a case for next agriculture revolution to be soil centric not seed centric. Note https://www.youtube.com/watch?v=KdiiG-Iwxgw&feature=youtu.be

To meet these challenges, the 68th UN General Assembly declared 2015 the International Year (IYS) of Soils. has been nominated to implement IYS, within the framework of the Global Soil Partnership and in collaboration with Governments and the secretariat of the United Nations Convention to Combat Desertification.

Approaches such as no-till farming and cover crops act as barriers against soil erosion and provide remedies for environmental protection and soil conservation. Cover crops can improve the soil by adding organic matter, nutrients, and stability and by acting as scavengers to trap leftover nutrients that otherwise might leach out. However, cover crops can interfere with growth of primary crops before emergence of the main crop. Commonly used methods to suppress main crop interference such as tillage, mowing, herbicides, or winter-kill species selection have a short life cycle [4]. These methods increase the cost of crop production. The addition of animal manures or compost as soil amendments to increase organic matter results in the spread of diseases to the plants and humans as well as increased emergence of weeds. The use of sewage sludge etc. requires caution to decrease the run off of unacceptable levels of toxic metals. Several other farm wastes and organic materials are used as soil amendment for disposal purposes.

Conservation and environmental impacts are directly related to soil health and protection of land degradation. Soil health is referred to as soil quality that is the ability of a specific soil to function, within natural or managed ecosystem boundaries, to maintain plant and animal productivity, enhance water and air quality. Soil does all of these activities through five essential functions [5]:

1. Regulating water
2. Sustaining plant and animal life
3. Filtering potential pollutants
4. Cycling nutrients
5. Supporting structures

The inherent and dynamic soil properties are indicators of the quality of soil. Inherent soil properties form over thousands of years and change very little [5 and 6]. Inherent soil properties result mainly from the soil forming factors including climate, topography, parent material, biota and time. Soil texture, type of clay, depth to bedrock, and drainage class are examples of inherent soil properties. Dynamic soil properties are affected by natural disturbances and human management over a single year or growing season.

The average content of the soil organic matter in fertile soils is 6% and about 35 - 55% of the non-living part of organic matter is humus [7]. Schulten and Schnitzer reported that soil organic matter contains humic acid plus carbohydrates plus proteins. They indicated that soil containing 3% organic matter has 2.5% humic acid plus 0.25% carbohydrates plus 0.25% proteins [8]. Research on radiocarbon dating [9] shows that organic matter comprises of two main components. A short lived, labile component is an energy source for soil microbes [10] from plant residues. The second component ($\geq$400 year old) namely humic substances is protected from microbial degradation. The ^{14}C data confirms that humic substances are long lived and represent the baseline of organic matter in soil [6]. A recent study on 24 agriculture top soil samples from 24 counties in Southern Idaho indicated that samples contain 0.31 to 9.8 % humic acid with a grand average of 1.9 ± 1.1% av. deviation (55 samples). Excluding the two samples with an average of 9.8% humic acid, the average for 53 samples drops to 1.6 ± 0.8% [11]. It is significant to note that worldwide the soil minerals have varied make up resulting from underlying varied rocks but contain same humic matter.

The soil conservation and environmental programs under NRCS, Agricultural Research Service (ARS) are leading efforts to improve the nation's natural resources and saving many soils by encouraging best management practices through multipronged approaches including use of amendments to improve the soil health. However despite the NRCS efforts, 1.8 billion tons of soil is still lost from cropland, and 120 million acres of cropland are eroding at a rate greater than tolerable soil loss rates (Figure 2, [10]).
Organic matter consists of plant and animal material and when it has fully decomposed it is called humus. This humus is important for soil structure because it holds individual mineral particles together in aggregates. Soil aggregates allow water to drain through it, and allow oxygen and carbon dioxide to move freely between spaces within the soil and the air above. Humus is also considered as nutrient bank and it helps soil hold important plant nutrients and improves the ability of the sandy soil to retain water. There are several ways to increase the amount of humus including the addition of (a). Compost (decomposed organic material); (b).Plant and animal material and waste; (c). Green manure. Humus content of the above-mentioned soil amendments is low and is not readily available.

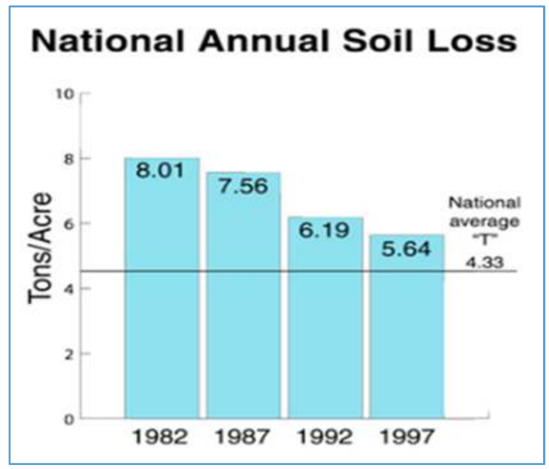


Figure2. National Annual Soil Loss

Agriculture experts in India are reporting that crop response to the fertilizers fell continuously from about 25 kg of grain kg-1 fertilizer during 1960's to 8 kg during 1990's (Kapur, 2011). They attribute this to decreasing organic matter in soils.

actosol® Organic Humic-Fulvic Products Solution: Soil organic matter or humus has been recognized by humans through the history of farming as the most important basis of soil health or soil fertility. The word Humus originated from the Greek language and was recognized by the Romans as the key marker for fertile soils and for cultivation for feeding its advancing armies. The ancient knowledge in the Ajurveda from the subcontinent of India states the cultivation of plants for health and nutrition depend up on the juice or soul of the soil. It states that it connects the non-living to living by deriving nutrition from the minerals in the soil for plant growth.

Humus is a relatively stable component formed by humic substances, including humic acids, fulvic acids, and humins [12]. The humic substances in soil are the fourth largest storehouse of carbon in our planet after sedimentary rocks, fossil fuels, and oceans [13]. One of the most striking characteristics of humic substances is their ability to interact with nutrient ions, hydroxides, and organic compounds, to form water-soluble and water-insoluble complexes. Through the formation of these complexes, humic substances can dissolve, mobilize, and transport nutrients and organics in soils and waters. This influences nutrient availability, especially those nutrients only present at micro concentrations. [14].

Humic acid is the largest and most active component of the soil organic matter along with minor fulvic acid and inert humin component. Role of humic acid in growing cycle of the plant--- three ways it helps.

<u>**Biological Benefits**</u>

- **Accelerates plant cell division and promotes growth**
- **Stimulates hormonal activity as a supplemental auxin**
- **Stimulates growth & proliferation of soil microorganisms**
- **Aids in photosynthesis**.

<u>**Chemical Benefits**</u>

- **Increases cation exchange capacity & chelation of plant nutrients**
- **Improves photosynthesis**
- **Converts phosphorus into plant available form**
- **Improves buffering properties of soils**
- **Increases water uptake in high salinity soils and irrigation water by modulating osmotic pressure**

<u>**Physical Benefits**</u>:

- **Increases moisture holding capacity and enhanced drought resistence**
- **Improves soil tilth & infiltration of compacted soils**
-

So even on application of small amounts of humic acid, the first benefits result from the biological and chemical activities and then on cumulative additions of humic acid especially in the soil results in imparting longer term chemical and physical benefits to the soils. Physical benefits result in agglomerating the soil (improves tilth and improves infiltration of soils) especially soils compacted with high Na and salt build up, by increasing moisture holding capacity- thus resistant to drought, decreases soil erosion. Chemical benefits result by increasing EC of soils, increasing nutrient up take especially P, increasing buffering capacity. It is being recognized that the use of humic acid products in water soluble liquid form provide economical benefits from use of only 1-5 gallons per acre as foliar and in soils then addition of powder/granular humic products in soils which require both right conditions and long periods for providing benefits. Today worldwide the use of HA products are being recognized as excellent natural biostimulant. But they do more by providing multiple benefits as described above by improving the soil health which imparts five essential functions :1. Regulating water 2. Sustaining plant and animal life 3. Filtering potential pollutants 4. Cycling nutrients 5. Supporting structures. Its these multifunctional benefits though being supported by science but still not well recognized compare to primarily single benefit use product inputs in use today. These benefits include slow release of the micronutrients for the plants. For example, humic acid increases the availability of phosphate to the plant by breaking the bond between the phosphate ion and iron or calcium. Phosphate is a stimulator of seed germination and root initiation in plants. In addition, humic acid is very effective in conversion of iron to suitable forms to protect the plants from chlorosis, even in the presence of high concentrations of the phosphate ion. Humic acid contributes to mineralization and immobilization of nitrogen in soil. The complexes formed between ammonium ions and humic acid are reported to release nitrogen slowly in to the soil. Humic acid serves as a slow release nitrogen carrier in the soil in this respect.

These properties are of great importance, not only in controlling the uptake of nutrients by the plant and their retention in the soil, but also in suppressing the deleterious effect of soil acidity. Humic acid mitigates the negative effect of high salinity on plants. **The Humic Acid optimum efficacy and its positive effect on increasing yield and quality of plants depends critically on its concentration at the time of application. At high concentration, humic acid has herbicidal effect and can cause phytotoxicity to the plants.** Optimum application rate ranges from 800 ppm for foliar applications and 1500 ppm for soil applications. Many scientific research studies show that the optimum application rates of HA for plant growth have been reported to range from 50 to 350 ppm.

Humic and fulvic acids enhance plant growth directly through physiological and nutritional effects. Some of these substances function as natural plant hormones (auxines and gibberillins) and are capable of improving seed germination, root initiation, uptake of plant nutrients and can serve as sources of N, P and S [12 and 14]. Indirectly, they affect plant growth through modifications of physical, chemical and biological properties of the soil. For example, enhanced soil water holding capacity and CEC, improved tilth and aeration through good soil structure [15]. About 35-55 percent of the non-living part of organic matter is humus. It is an important buffer, reducing fluctuations in soil acidity and nutrient availability. As shown in Table 1, these properties were demonstrated in several university studies as well as in ARCTECH's laboratory to confirm relationships of humic amendment with nutrient cycling, soil water availability, and plant growth.

Indicator	Impacts on Soil Health with Humic Acid Amendment
Biological Benefits: Tan, 1994 [12]; Schnitzer 1986 [14].	**<u>Increase plant growth by:</u>** • Accelerating plant cell division • Stimulating hormonal activity as a supplemental auxin • Stimulating growth & proliferation of soil microorganisms • Aiding in photosynthesis
Chemical Benefits: Stevenson, 1994 [15]; Bernard et. al., 2009 [16]; Kasim et. al., 2009 [17].	• **<u>Nutrient cycling by:</u>** • Increasing CEC and chelation of plant nutrients • Converting phosphorus into plant available form; • Reducing ammonia loss and retaining NH_4^+ for plants • Improving buffering properties of soils • Increasing water uptake in high salinity soils by modulating osmotic pressure
Physical Benefits: Stevenson, 1994 **(15)**	**<u>Water availability:</u>** • Increasing moisture holding capacity • Forming soil aggregation and improving aggregate stability, soil tilth and infiltration of compacted soils

Role of humic acid in nutrient cycling and soil water availability: The physicochemical characteristics of coal humic fraction was studied by Dr. Kim H. Tan, Messrs. John A. Rema and Juan Carlos Lubartini of University of Georgia, College of Agriculture. Coal humic acid sample was analyzed in its original state or after purification by dialysis. The humic acid fraction shows a carbon, hydrogen, nitrogen, and oxygen composition and a total acidity comparable with those of soil-humic acid. The NMR analysis indicated that the coal humic acid fraction was highly aromatic in nature, a feature similar to that detected in humic acids on Mollisols in the U.S. Corn Belt (Figure 3).

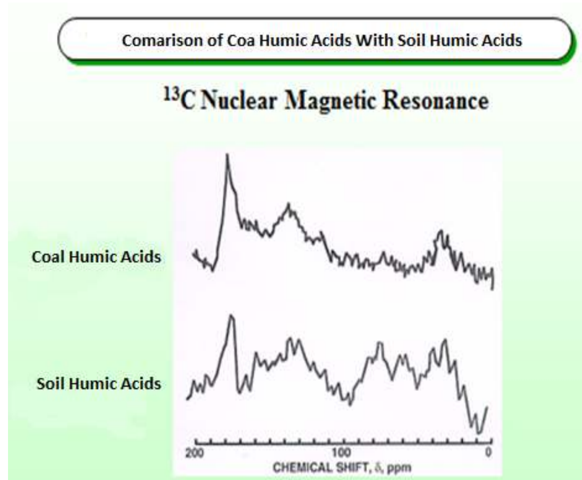


Figure 3. ^{13}C Nuclear Magnetic resonance.

Humic acid has several functional groups such as carboxyl and hydroxyl and considered as the most active component of organic matter in soil. As a nutrient binder, and absorbent, humic acid is essential to maintenance of fertile soils and can ***serve as sources of plant nutrients***. The versatile characteristic properties of humic acid include: a high cation exchange capacity, the ability to chelate nutrients. These properties were demonstrated in ARCTECH's laboratory with humic acid amendment. As shown in Figure 4, Humic acid binds to primary nutrients [N (24%), P (45%) and K (40%)], and micro nutrients [(Mn (60%); Cu, Zn and Fe (>90%)} and then release it slowly to plants. Therefore, the use of humic acid not only increase crop yield and quality, but also decreases the use of inorganic fertilizers and prevents leaching.

Humic acid increases soil moisture holding capacity. For example, in laboratory experiment humic acid increases water-holding capacity in sandy soil by 20% and in clay soil by 6%. In addition, humic acid improves soil texture through soil particles agglomeration, improving aggregates stability, soil tilth and infiltration of compacted soils (Figure 4).

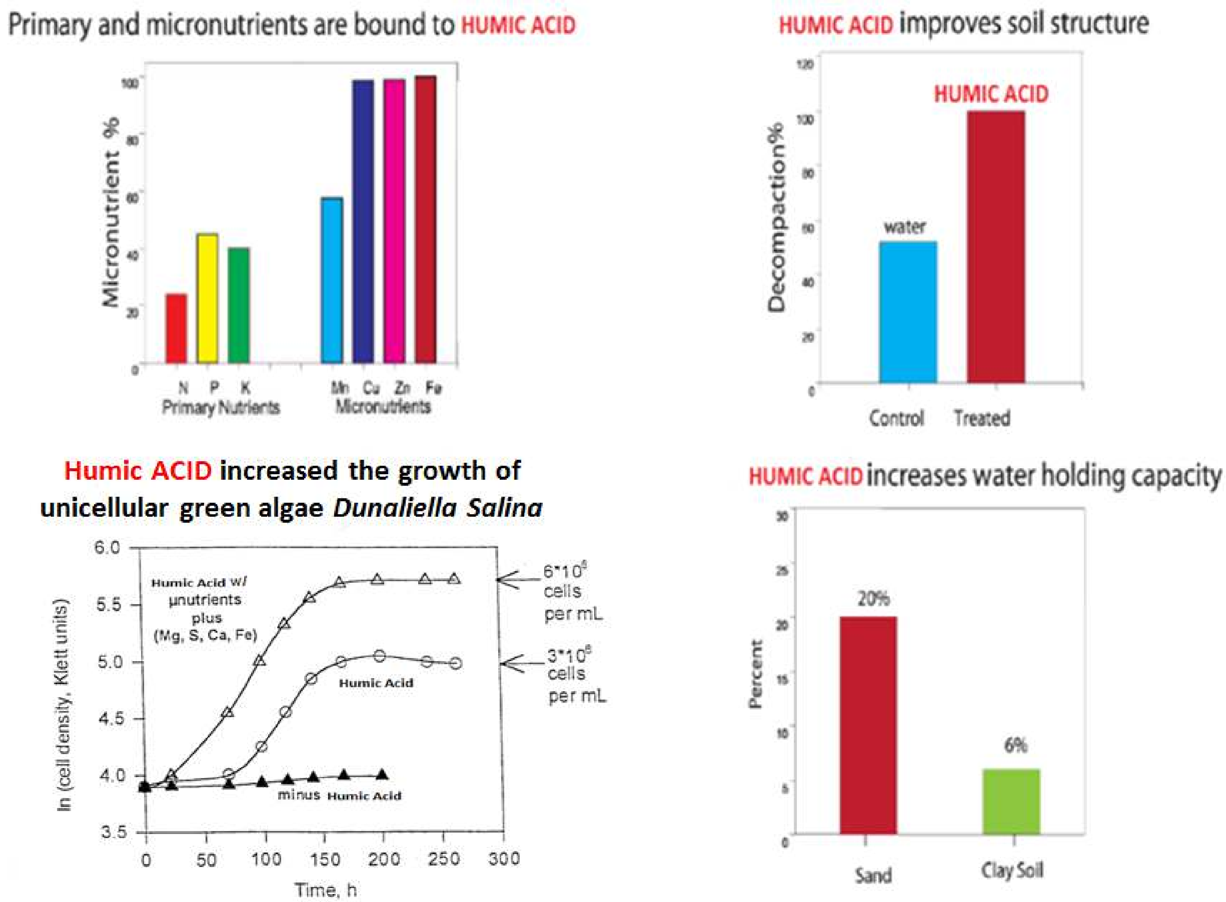


Figure 4. The Versatile Properties of Humic Acid Include: Ability to Chelate Nutrients, Improving Soil Texture Through Soil Particles Agglomeration, Increasing Water Holding Capacity, and Enhancing Microbial Population as Its role as an Electron Acceptor for

Role of humic acid in plant growth: Humic acid plays an important role of electron acceptor for enhancing microbial population (Figure 4). Also, Humic acid helps in accelerating plant cell division. The Effects of humic acid on the growth of the unicellular green algae *Dunaliella Salina* as a model organism to provide growth information on plant root and shoot was studied by Professor Anastasios Melis, Professor of Plant Biology, Department of Plant Biology, University of California, Berkely, CA. Professor Melis reported that the addition of both humic acid and humic acid plus micronutrients increased the algal growth by 25 to 50% over the control (Figure 4).

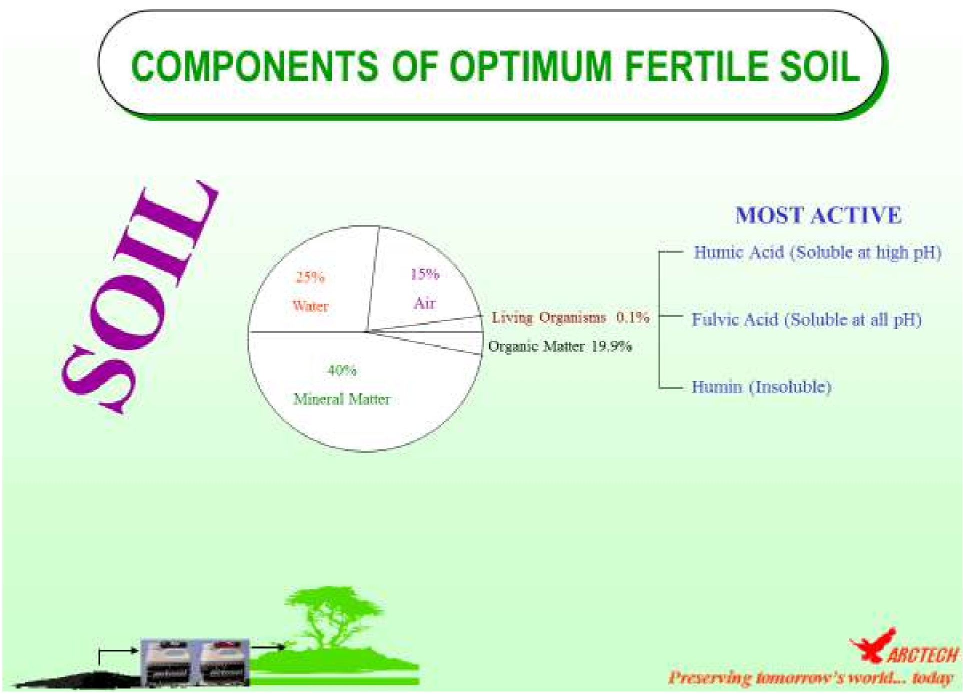
In 2012 and under conventional crop management in Iowa, Olk and Dinnes evaluated humic product derived from lignite for three years on corn fields. They reported an increase in corn (*Zea mays* L.) yield by 10-15 bushels after application of humic acid [18].

In order to demonstrate the need for building the long lived and representative of the baseline of organic matter in soil, we undertook a systematic effort to collect soil samples from the farms under cultivation for various crops in the farm lands in Virginia. The soil samples were analyzed by the Loss in Ignition Method for soil organic matter and for humic acid by the American Society of Soil Agronomy. The soil analysis presented in the table shows that not only the organic matter is lower today than historical averages of about 8- 20% for fertile soils but today the humic acid content is none to less than 1% or almost negligible.

Farm	SAMPLE LOCATION	Organic Matter, % Loss-On-Ignition*	Organic Matter, % Humic Acid**
Chad Francis Farm	Alpha Hay Field	2.2	0.04
	Sweet Corn Field	2.3	0.39
	Fescue Pasture	2.1	0.12
Rosemary Dairy	Fescue Hay Field	3.2	0
	Clover Hay Field	5.4	0.606
Wayne Kendrick Farm	Flue Cured Tobacco	2.3	0.17
	Burly Tobacco Field	2.2	0.39
	Soybean Field	2.5	0.14
	Corn Field	4.6	0.2
Bit By Bit Farm	Soybean Field	2.9	0.79
	Produce Field Tomato/ pumpkin	3.2	0.15
	Cornfield	1.1	0

**Loss-On-Ignition (LOI), a gravimetric, dry oxidation method, was used to estimate percentage of Soil Organic Matter by Virginia Tech.*

***Humic Acid Analysis Method by Alkali Extraction per American Society of Soil Agronomy analysis*



SOME EXAMPLES

USA

The effect of humic acid was tested on nutrient retention and organic matter content in sandy soils planted with tobacco (Figure 5). Over 90 days, the addition of humic acid doubled organic matter content in soil and retained more P, K , Mg , Ca, and Zn was than the control. In addition, there was increased root mass and 10% increase in height and corresponding weight.

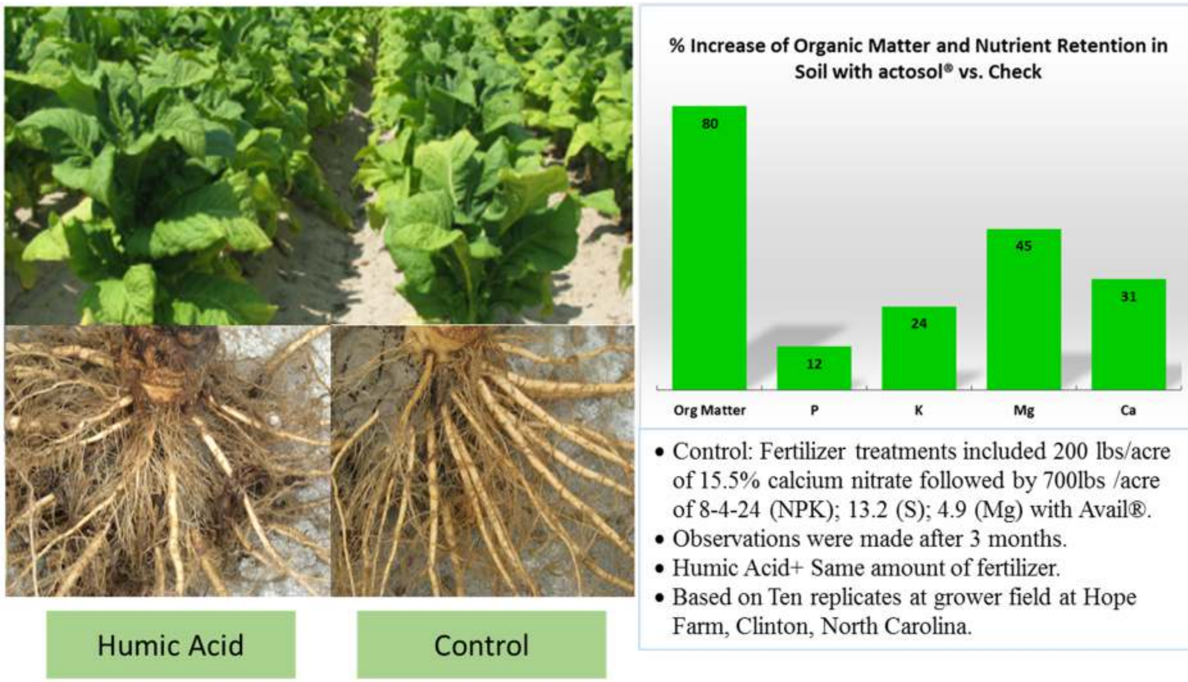


Figure 5. Humic Acid Amendment Increased Organic Matter and Nutrient Retention in the Soil and Plant Biomass.

At a 360 acres Lawson Farm in Gordonsville, Virginia , improved soil health has resulted with cumulative use of actosol organic humic and fulvic product over ten years along with only liquid based mineral nutrition and other inputs for growing Wheat, Soybean, Corn, Tobacco and Milo (Sorghum used for animal feed, bread making and whiskey. The resultant benefits observed at the farm are: improved regulation of water and increased drought resistance, nutrient recycling and reduction and markedly improved soil tilth. Yield increased from 50 bushels per acre to 100 bushels per acre with 1.5 gallons of actosol® per acre in fall and 1.5 gallons of actosol® per acre in spring along with other liquid inputs of mineral nutrition and protection chemicals. No granular fertilizers are applied. The protein increased by 3.5 percentage points. In case of Corn, resulted in 30 times values than the cost of actosol®. In case of Tobacco, gain is 12 times more than cost of actosol®. The impaired land was repaired with actosol® use in 18 months compared to generally it was taking him 5 to 10 years.

Lawson Farm Gordonsville, Virginia
900 +acres - Wheat, Soybean, Corn, Tobacco and Sorghum

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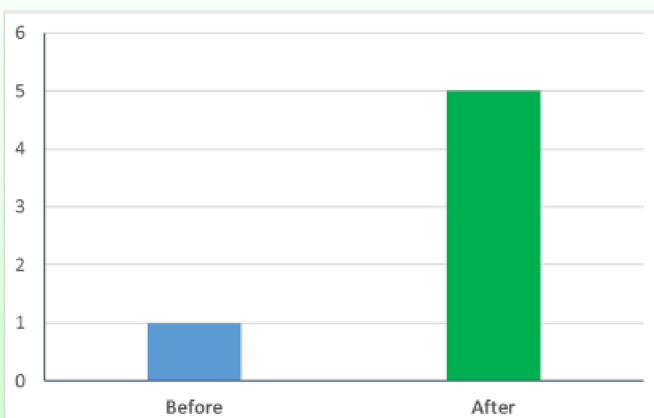
Preserving Tomorrow's World...Today

actosol® Gradually Increasing Organic Matter Over 10 Years – Based on Soil Quality Assessment



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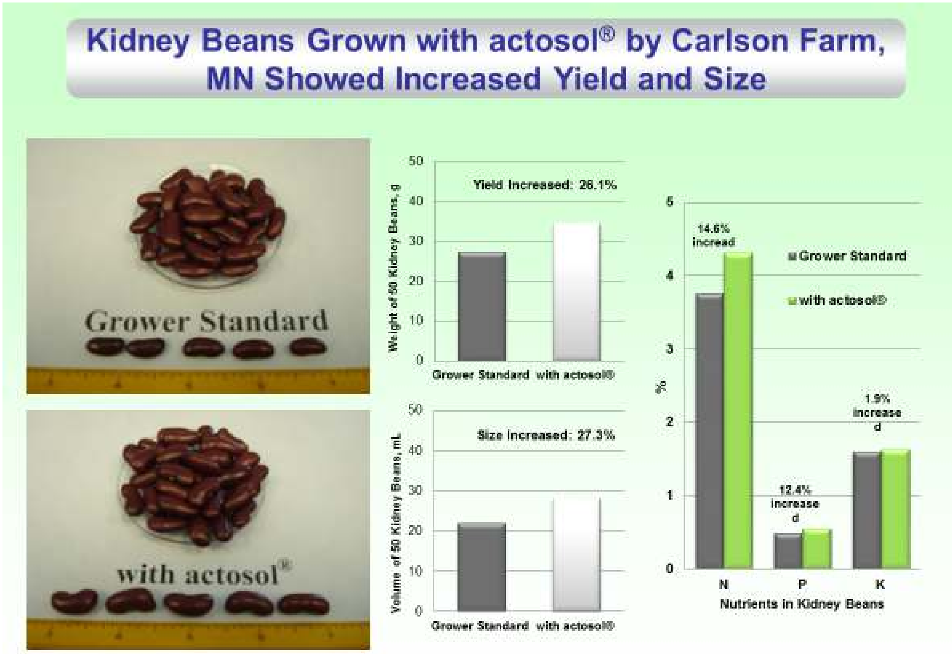

Egypt:

More than ten years of research experiments and fields trials show that actosol products have an effective role in solving some of the problems that faces the agriculture sector in Egypt, like reducing the amount of chemical fertilizers and irrigation water, increasing the yield, improving crop quality and increasing the storability of fruits and vegetables. In addition, the results show that the treated plants have a high tolerance for salinity and adverse weather conditions and a higher resistance to diseases especially to soil diseases. Moreover, the results confirmed that actosol can be used as a robust substitute to animal manures, which results in contaminating newly reclaimed desert lands since they contain weed seeds, nematodes, soil diseases and insects. Furthermore, actosol increases the soil fertility and enhances its physical, chemical and biological properties, which is a driving factor for increasing growth and production especially is calcareous soils.
These results were documents in more than 40 peer-reviewed articles in national and international journals, 2 PhD dissertations and 6 MSc theses. These research experiments were conducted in different soil types and different governorates in Egypt. The research work covered field crops, sugar crops, vegetables and fruits, aromatic and medicinal plants, ornamental plants, green areas and woody trees. This vast research work was conducted in different academic and research institutes in Egypt, which are the Agriculture Research Center, the National Research Center, Cairo University, Ain Shams University, Mansoura University, the African Studies Institute and the Desert Research Center. The following table summarizes the key results of more than ten years of research work on the actosol products in Egypt for some selected crops

Crop	Location (Soil Type)	Crop Increase [ton/acre]	Crop Increase [%]	Extra Revenue from Crop Increase [LE/acre]	Chemical Fertilizers Reduction [%]	Chemical Fertilizers Savings [LE/acre]	Cost of Organic manure [LE/acre]	Cost of actosol [LE/acre]
Wheat & wheat hay	Valley	0.39	14.4	1500	30	150	400	240
Rice	Valley	0.75	18.5	1500	50	250	400	240
Sugarcane	Valley	5.7	11.8	2300	25	300	800	400
Potatoes	Desert	2.5	17.8	2500	25	300	1500	480
Cucumber	Desert	2	20	2400	25	300	1500	480
Pears	Desert	1.8	12	2700	25	150	1000	400
Orange	Desert	2	11.1	2000	20	150	1000	400
Grapes	Desert	2	20	2500	20	150	1000	400
Apple	Desert	3.3	52	3000	20	100	1000	400
Mango	Desert	0.65	16.25	3200	25	150	1000	400

US 1$ = 7.14 LE (Egyptian Pound)

Ukraine:

Practical experience of humic-fulvic acid inputs has confirmed the following significance of harvest increase: wheat 13-25%, barley 15-17%, buckwheat and millet 25-50%, corn 30% with biomass 6-20%, potato, carrot, beet; radish 25-40%, cotton 10- 30%, cucumbers 34-38%, tomatoes 20-30%, cabbage 25-35%, apples 8-20%, grape 25-30%, all citrus 30-60%, pasture up to 100%. In case of flowers, results in increases in the quantity of roses and lilies 30-100%,' increased rooting, and a reduction in blossoming of 10-15 days.

What is also very significant is that use of humic-fulvic acid inputs not only increase only the quantity, but also the quality of agricultural products, they accumulate more nutritious elements. For instance, increased content of vitamin C: in beets up to 100%, in radish up to 30%; Carotene: in beets up to 100%, in cabbage up to 25%; Riboflavin: in the same vegetables 8-14%, Niacin: in beets up to 79%, in cabbage up to 42%, in radish 50%. Leaves of beets and cabbage increased content of protein 16-18%, phosphorus 26- 28%. Potatoes have a higher content of starch, flax got better quality of fiber and higher quantity of oil in seeds. Also, remarkable, is that humic substances sharply increased content of nuclear acids in cotton, content of oil in sunflower seeds, content of sugar and vitamin C in tomatoes up to 45%. Researchers conclude that stimulation of biochemical processes in the cell, which is connected with intensification of energetic exchange, provides high quality products with high content of nutritious elements.

In recent years' scientific research by academics and commercial users in the real world is resulting in increasing acceptance of use of humic acid as amendment, bio stimulant and for improved nutrient uptake by the regulators in the United States e.g. the USDA and the EPA approved laws administering the use of organic humic acid and its humate salts for agriculture application. Per the USDA National Organic Program, the input of humic acid is allowed for organic food production and is also listed in the Organic Materials Review Institute (OMRI). Humic acid is approved by US EPA under FIFRA for combining with pesticide formulations as UV protectant and adjuvant and is exempt from residue tolerance requirement. Recently, humic acid and humates are approved as part of the fertilizer by the Association of American Plant Food Control Officials (AAPFCO). This organization is the national organization of fertilizer control officials from each state, Puerto Rico and Canada responsible for administering fertilizer law and regulation. AAPFCO allowed the inclusion of humic acid and humates in labeling of fertilizers.

Both scientific research and real world applications are proving out that humic substances products derived from humic-rich low rank coals are beneficial in agriculture applications in US and other countries to restore soil health and improve crop yield. These coals, which are especially prevalent in the US coal fields, have very high content of humus and contain 20-80% extractable humic acid in water soluble liquid form. In this approach toxic metals contained in the mineral matter of coals remain part of the solid residue, the liquid extracted humic acid is free of these. The use of these amendments at low inputs of about 2-5 gallons per acre are available to farmers at very low costs averaging US $10 to US $30 per acre, with an increase in crop yields even during droughts. Many users are reporting realization of 3-10 times increased value. Today with decreasing crop prices and increased conservation mandates, adopting this added value generation approach even in one crop cycle will incentivize farmers to use these amendments for sustained soil health improvement and facilitate conservation practices.

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