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Evaluating Leonardite as a Crop Growth Enhancer for Turnip and Mustard Greens

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SUMMARY. The objectives of this study were to determine if the use of leonardite as a fertilizer supplement improved crop growth and if there was a residual effect from previous applications. Three planting sequences were established and leonardite applied at 0, 50, 100, 200, and 400 lb/acre (0, 56.1, 112.1, 224.3 and 445.6 kg·ha^{-1}). Subplots were treated at the first, the first and second, or all at three planting sequences. 'Purple Top White Globe' turnip (*Brassica rapa* L.) and 'Florida Broadleaf' mustard greens (*Brassica hirta* L.) were used as the indicator crops in the first two and last sequences, respectively. No differences in plant growth were observed among number of applications or treatment rate. Differences in soil potassium and iron were observed.

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The benefit of organic matter in soils is well known. Early agricultural systems relied on recycling plant residues and composting to increase soil fertility (Obrezza et al., 1988). As the world demand for food increases, practices that lead to increased yields on existing farm lands will continue to be important. Humates are reported to increase crop yields and reduce drought and high temperature stress (Russo and Berlyn, 1990). However, these compounds have not been researched extensively.

Humates occur in three chemical forms: humic acids, fulvic acids, and humins (Choudry, 1983). Humic acid is soluble in dilute alkaline solutions and is precipitated by acidification. Fulvic acid is the fraction that remains soluble after acidification, and cannot be precipitated. Humins are insoluble in dilute acid or base.

Commercial humate products are either mined or extracted from naturally occurring sources. Extracted humates are derived from peat moss, kelp and seaweed, from shale and oxidized coal (leonardite) deposits in Texas, Wyoming, New Mexico, North Dakota, Idaho, and Florida. The humic acid contents of these deposits usually range from 30% to 60%.

Hydroponic experiments have shown that when equal amounts of essential nutrients are supplied from humates or traditional sources, tomato (*Lycopersicon esculentum* Mill. 'Mountain Pride') seedlings grown with the nutrients supplied by humates out perform those receiving the same nutrient levels supplied by traditional sources (David et al., 1994). Conover and Poole (1979) suggested that the beneficial effects of humates in foliage plants could not be solely attributed to their fertilizer value.

Humates can have beneficial effects on plant growth by stimulating the plant to absorb greater quantities of nutrients and by inducing a more efficient use of the absorbed nutrients. Hydroponic experiments have shown that low concentrations of humic acids had a positive effect on nitrate and ammonium uptake in olive (*Olea europea* L. 'Maurino') (Tattini et al., 1990). Potatoes (*Solanum tuberosum* L.) (Kunkel and Holstad, 1968) and teak (*Tectona grandis* L.f.) seedlings (Fagbenro and Agboola, 1993) have responded similarly to humic acid applications. Increased levels of phosphorous in the tops of corn (*Zea mays* L.) have been attributed to humates (Lee and Bartlett, 1976). Micronutrient uptake by plants was found to be increased in the presence of humates (Tan and Nopamornbobi, 1979).

Karnok (1989) suggested humates increase the root mass of plants. An increase in the number of small lateral roots and in total mass of small and large roots by as much as 200% over nontreated plants, was shown in carrots (*Daucus carota* L.) (Sanders et al., 1990). Applications of humates to legume crops resulted in fewer nodules being formed on roots. However, nodules formed were significantly larger and had no difference in nitrogen content (Tan and Tantiwiramanond, 1983). Humates increased the root growth potential of *Juglans nigra* L. (Berlyn and Russo 1990).

Humates have increased the dry matter produced by plants, which may be attributed to the stimulation of auxins in the roots or the increased availability of essential nutrients (Tan and Tantiwiramanond, 1983). Treatments of 100 to 800 ppm fulvic and humic acid significantly increased the root dry weights of soybean (*Glycine max* L.), peanut (*Arachis hypogaea* L.), and clover (*Trifolium vesiculosum* Savi) In another experiment, a pronounced increase (187%) in shoot and root dry matter production in corn was observed (Lee and Bartlett, 1976). In the same experiment, foliar application of humates increased dry matter yield by 20%. Increases in root dry weight and in root to shoot ratios were observed in tomato (David et al., 1994). Similar increases in dry matter production have occurred in olive (Tattini et al., 1990). The objective of the field study was to determine if the use of humates as a fertilizer supplement increased yield or quality of turnips and mustard greens.

Materials and methods

A field test was conducted at the Texas Agricultural Experiment Station in Overton. Since leonardite contains a significant amount of humic acid, and is being sold as a plant growth enhancer, its effects in a vegetable production system must be evaluated. The effects of humic acid are more apparent in soils with low organic matter than in soils with high organic matter (Lee and Bartlett, 1976). Therefore a Bowie fine sandy loam, a fine-loamy, siliceous, thermic Plinthic Paleundult, with an organic fraction of <1% was chosen for the field experimentation in this study. 'Purple Top White Globe' turnip and 'Florida Broadleaf' mustard greens were used as the indicator crops.

A split-block design using leonardite application rates as the main plot and number of applications as the subplot used to test the effect of five leonardite rates, and the effect of three application sequences. Leonardite treatments consisted of 0, 50, 100, 200, and 400 lb/acre (0, 56.1, 112.1, 224.3, 445.6 $kg \cdot ha^{-1}$) applied in three sequences; the first planting only, the first and second planting, or at all three plantings. Plots were 120 ft (37 m) long × 100 ft (30 m) wide. Thirty beds 40 inches (1 m) × 120 ft (37 m) were made in the test area. Each main plot treatment was replicated four times. Each subplot was 15 ft (4.5 m) × 40 inches (1 m) with a 5-ft (1.5-m) buffer between subplots and replications within the same row. Treatment rows were bordered by a guard row on each side.

Treatments for the first planting on 25 May 1994, consisted of, applying the prescribed amount of leonardite in each subplot as a band. Ground leonardite (Table 1), that would pass a hundred mesh screen, was applied so that after bed preparation it would be 2 inches under the center of the seed bed. Fertilizer was applied at the rate of 120 lb/acre (133.7 $kg \cdot ha^{-1}$) of 20N–2.18P–8.3K that also contained (in %) 13 S, 0.5 Mg, 0.1 Fe, 0.05 Zn, 0.05 Cu, and 0.02 B. Fertilizer was incorporated into the bed surface before shaping. Two seed rows of 'Purple Top White Globe' turnip were sown 9 inches (23 cm) apart with the leonardite band centered between the seed rows. The seeds were placed ≈0.25 inches (0.6 cm) deep.

Immediately after planting, one drip irrigation line per bed was placed between the seed rows to supply crop water needs. The test plot was watered shortly after planting and as needed thereafter. Four weeks after sowing, the plants were thinned to 2 inches (5 cm) in-row plant spacing. Weeds were removed manually.

The middle two-thirds of the single application subplots were harvested 50 days after sowing. Total plant weight and root weights were recorded. Roots were graded for size. Five, 1.75 to 2.5-inch (4.5 to 6.4-cm) diameter turnip roots per subplot were sampled to determine soluble solids content. A 1-cm^3 sample was taken from the center of each root. These samples were squeezed in a garlic press to extract liquid. Liquid from all five roots was mixed thoroughly then placed in a refractometer (American Optical Corp., Keene N.H.) to measure the soluble solids content. A fresh sample of 10 to 15 mature leaves was taken from each subplot, weighed, placed in a brown paper bag, dried at 140 °F (60 °C) for 24 h and dry matter percentages were determined. The surface residue was incorporated using a tractor mounted rotovator.

For the second (18 Sept. 1994) and third planting sequences (21 Mar. 1995) plots were rebedded in the location that they had been previously. Plot preparations for the remaining sequences were the same as for the first planting. Data collection procedures for the second sequence were the same as for the first. Ground leonardite was banded in the subplots requiring multiple applications. Treflan (trifluralin) was applied preplant incorporated for pre- emergent weed control. Harvest of the second planting sequence was delayed due to excessive rain in late October and November. Consequently, a nitrogen deficiency was noted in the crop and N was applied on 30 Nov. via fertigation at a rate of 15 lb/acre (16.8 $kg \cdot ha^{-1}$) ammonium nitrate as N source. The single and double application subplots were harvested, sampled, and analyzed, as in the first study.

During the third planting sequence, an infestation of yellow margined black turnip beetles (*Microtheca ochrolma* Stal) destroyed the stand of plants 4 weeks into the test. The test area was refertilized with 120 lbs ammonium sulfate/acre (134.4 $kg \cdot ha^{-1}$). Dursban (chlorpyrifos) 1% granules were applied and incorporated for

Table 1. Analysis of leonardite from Walnut Creek Mining Co., applied to a Bowie fine sandy loam.

Constituent	Concn
Humic acid	79.5%[z]
pH	4.2[y]
Salinity (ppm)	1625.00
Element (ppm)	
Nitrogen	12.00
Phosphorus	13.00
Potassium	20.00
Calcium	8878.00
Magnesium	585.00
Zinc	0.18
Iron	296.88
Manganese	1.84
Copper	0.01
Sodium	636.00
Sulphur	303.00
Boron	2.02

[z]Analysis conducted by Pope Laboratories, Dallas, Texas.
[y]All other analysis conducted by Texas A&M University Soil Testing Laboratory, College Station, Texas.

systemic insect control at a rate (a.i.) of 1 lb/acre (1.12 kg·ha^{-1}). On 12 May 1995, a crop of Brassica hirta 'Florida Broadleaf' mustard greens was sown. This crop was selected because a difference in plant top growth was thought to be observed in the second planting. One seed line of 'Florida Broadleaf' mustard greens was planted down the middle of the row and thinned to 2 inch (5 cm) in-row spacing 4 weeks later. On 3 July 1995, the middle two-thirds of each subplot was harvested. A wooden spacer was used to maintain a constant cutting height of 1.75 inches (4.5 cm). Total yield and samples for dry weight analysis were taken. The process was repeated 1 month later.

After the last harvest, soil samples were collected and analyzed for nutrient content and humic acid. Three subsamples from the center line of the bed and three from 2 inches (5 cm) to either side of the center line were taken and thoroughly mixed.

Soil testing was performed using standardized test used by the Texas Agricultural Soil Testing Lab, College Station. Phosphorous, K, Ca, and Mg were extracted using an ammonium acetate extracting solution containing 0.25 M H_4EDTA in 1.4 M NH_4OAC and 1.0 M HCl at a pH of 4.2. A 0.5 g sample of pulverized soil and 30 mL of extracting solution were transferred into a 142-mL plastic cup and shaken on a horizontal rotary shaker for 1 h at 180 OPM. Samples were filtered through Whatman no. 42 filter papers. Extracts were analyzed using a Perkin Elmer inductively coupled plasma spectrometer.

Zinc, Fe, Cu, and Mn were extracted using a DTPA–TEA extracting solution that contained 0.1 M $(HOCH_2CH_2)_3N$, 0.005 M DTPA, 0.01 M $CaCl_2$, and 0.06 M HCl at a pH of 7.3. Twenty grams of dried soil, and 40 mL of the extracting solution were placed in a 142-mL plastic cup and shaken on a horizontal rotary shaker for two hours at 180 OPM. The suspension was filtered through Whatman no. 42 filter paper and placed in a 15 × 85 mm sample tube. Nutrient concentrations were determined using a Perkin Elmer inductively coupled plasma spectrometer.

Results

Results from first harvest were statistically analyzed using analysis of variance. No statistically significant differences ($P < 0.05$) in fresh weights of roots or leaves, soluble solids, percent dry weight or size distribution at any leonardite rate. Results were similar for the second harvest. Additionally, no significant interactions occurred among the number of applications and leonardite treatments in fresh weight of leaves or roots, soluble solids, percent dry weight, or size distribution. No statistically significant differences or interactions due to treatments were observed in the third sequence.

Of nine soil nutrients analyzed, differences occurred only in iron and potassium. Iron levels in the soil were higher with two or three applications than one application alone. Soil K levels increased with all treatments over the control.

Discussion

This experiment was designed to determine if leonardite applications had an effect on plant growth and if there was a residual effect after multiple leonardite treatments. Observed differences can be explained with factors other than a beneficial (or detrimental) effect of leonardite.

In the first planting sequence, there were no statistical differences of any observed responses. During the second sequence planting, a total of 13.5 inches (34 cm) of rainfall was received. Of this amount, 6.5 inches (16.5 cm) fell the twentieth day after sowing. Consequently, a significant amount of soil eroded. This also caused a nitrogen deficiency in the crop. This event probably confounded data for the rest of the experiment. Due to the nature of the experiment it was necessary to keep the plots in the same location. No trends were readily apparent in the data obtained from this planting sequence.

Detectable amounts of humic acid were not found in the soil after the experiment was concluded. This is probably due to the light, sandy soil, small amounts of leonardite applied, and excessive rainfall during the second sequence planting of the experiment. The soil organic matter content in the study site was less than one percent. At the highest rate only 672 ppm of Leonardite was added and of that only 79% was humic acid.

Differences in soil K levels among treatments are difficult to explain. The K concentration in the leonardite humate was 20 ppm. Increases in K in treatment plots over the control do not follow the incremental increases that would be expected with increasing amounts of K in leonardite applied. Humic acids contribute to the break down of soil minerals. This breakdown may have released some K to measurable forms (Brady and Weil, 1996). The high CEC of humic acid found in leonardite (Haynes and Swift, 1989) might have also held more of the additional K that was supplied to the crop in the form of fertilizer.

Soil Fe increased with the number of applications (Table 2). The leonardite had an Fe content of 296.9 ppm. As more Fe is added, an increase in the soil concentration is expected. It may also be associated with soil microclimate being affected by the lower 4.2 pH of the leonardite. While there is not enough leonardite present to affect the overall soil pH, it may increase the amount of Fe^{2+} present in localized

Table 2. Effect of leonardite treatments and number of applications on soil nutrient analysis of a Bowie fine sandy loam.

Leonardite	Soil nutrient analysis^z (ppm)								
(lb/acre)	P	K	S	Ca	Mg	Mn	Fe	Cu	Zn
0	10.5 a^y	31.5 a	13.5 a	463.7 a	46.5 a	24.1 a	9.6 a	0.183 a	0.263 a
50	10.8 a	43.3 b	15.0 a	436.8 a	55.3 a	26.0 a	10.8 a	0.277 a	0.288 a
100	10.6 a	46.0 b	14.9 a	429.9 a	46.9 a	25.3 a	13.2 a	0.254 a	0.293 a
200	10.5 a	49.0 b	15.5 a	450.2 a	58.6 a	27.6 a	11.8 a	0.244 a	0.295 a
400	10.9 a	46.2 b	17.5 a	421.3 a	53.6 a	22.9 a	10.9 a	0.219 a	0.286 a
Applications									
1	10.1 a	42.7 a	14.2 a	437.6 a	49.8 a	23.7 a	9.8 a	0.206 a	0.278 a
2	11.1 a	46.4 a	16.2 a	456.6 a	54.6 a	26.0 a	11.5 ab	0.246 a	0.287 a
3	11.0 a	40.6 a	15.4 a	427.4 a	52.2 a	25.9 a	12.5 b	0.254 a	0.290 a

^{z}Data represent subplot means.
^{y}Means in a column followed by the same letter are not significantly different by LSD at the 95% confidence level.

areas of the soil. Humic acid in the soil may also chelate soil Fe (Loepert et al., 1994). Soil humic acid can also hold iron in exchangeable or complexed forms (Brady and Weil, 1996).

In conclusion, no beneficial plant growth effects from number of applications or rates of leonardite were found under the conditions outlined in this study.

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Flower Quality, Flower Number, and Western Flower Thrips Density on Transvaal Daisy Treated with Granular Insecticides

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SUMMARY. Greenhouse studies were conducted to determine the efficacy of two granular systemic insecticides, acephate (Pinpoint 15G) and imidacloprid (Marathon 1G), against western flower thrips (*Frankliniella occidentalis* Pergande) on Transvaal daisy (*Gerbera jamesonii* H. Bolus ex. Hook. f). These studies were arranged in a randomized complete-block design with four blocks and four treatments per block. Two rates of acephate (0.75 g/16.5-cm pot and 1.0 g/16.5-cm pot) and one rate of imidacloprid (1.3 g/16.5-cm pot) were used in two studies. Plants were artificially inoculated with five adult western flower thrips at the prebloom stage. Plants were evaluated each week for flower quality (1 = complete injury or flower distortion to 5 = no injury), thrips density per flower, and number of plants flowering in each plot. Both studies showed that the acephate treated plants had the best flower quality, lowest numbers of thrips, and greatest number of plants flowering compared to imidacloprid and the check. These studies demonstrate that granulated acephate exhibits some activity in flower tissue and may assist growers in managing western flower thrips in floricultural crops.

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