Auburn University
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RESEARCH REPORT 11-03

RESPONSE OF LOBLOLLY AND SLASH PINE TO HUMIC, FULVIC ACIDS AND BIOLOGICAL STIMULANTS

by
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INTRODUCTION

In recent years there has been a renewed interest and awareness in maintaining a "green environment" through the use of organic products or products that by their content, or fate in the environment, have been deemed "green" by marketing associates. These products generally include either microorganisms, extracts of microorganism, plants or extracts of plants, or organic or inorganic products alone or in combination.

One of the most interesting things about understanding how to use these products is the terminology used to market them, especially to an environmentally conscious user community. In Research Report 09-05 we tested two products containing various microorganisms. These products were marketed as products "composed of a living consortium of microorganisms including photosynthetic strains proven to enhance plant growth." and "a formulation that includes actinomycetes, bacteria and other beneficial live soil microflora, to enhance depleted soils" and have been shown to "consistently validate improvements in the growth, yield, and quality of….. commercial crops".

There is no doubt that some or all of these microorganisms or other ingredients may have some effect on plant growth. Many of the microorganisms used affect plant quality by acting against soil pathogens through several methods: 1) the production of antibiotics, 2) by competing for space and utilization of substances needed for growth, 3) by directly parasitizing the soil pathogen, or 4) by the production of toxins or compounds needed by the microorganism for normal metabolic activity (Baker 1968, Parr et al. 1994). Microorganisms present in the root zone can also affect plant development. These organisms can increase the availability of nutrients to the plant, increase the ability of plants to take up nutrients, or produce plant hormones (IAA e.g.) thereby increasing plant growth (Vonderwell et. al. 2001). A commonly know effect is the presence of certain mycorrhizal fungi that make phosphorus more readily available to the plant. Not all research studies have shown positive growth responses but some unpredictable and inconsistent results (Parr et.al. 1994, Baker 1968).

The availability of these products in the market place has dramatically increased over the last several years. In 2009 a Google® search of the term "soil inoculants" yielded 6,100 hits or web pages. This same search in 2011 yielded 158,000 hits; a 2,500% increase in two years.

In order to apply these biological green products to either soil or crops, the active and inactive ingredients must be added to a carrier. One common liquid carrier is humic acid. Soil organic matter can be broken down into two components: humus and non-decomposed matter. The humus can be broken down further into humin and humic acids. Humic acids can be broken down into humic acid and fulvic acid. Due to the confusing terminology between the humic acids (from the breakdown from humus) and the final breakdown to humic and fulvic acids, in this paper, the humic acids derived from humus will be referred to as humic substances. Humic acids represent the largest component extracted from soil humic substances and are dark brown to black in color and are water soluble at pH above 2. Another substance extracted from soil humic substances are fulvic acids which are small molecular weight compounds light yellow to yellow-brown in color and soluble at all pH ranges.

Both humic and fulvic acid have been used in agriculture to increase soil and plant productivity by facilitating the uptake of essential nutrients (Rauthan and Schnitzer 1981) and chelate formation in the plant and increasing the cation exchange capacity (CEC) in the soil (Senn & Kingman 1973). Applications of humic substances to the soil seem to have the greatest benefits on crops grown in low organic matter soils which make their use in forest-tree nurseries a possibility.

When companies blend several biological organisms or other substances known to stimulate plant growth, it is difficult to determine which ingredient, carrier or combinations are causing the plant response or if all the listed ingredients are necessary. As the number and complexity of the ingredients increases, generally, so does the price.

The purpose of this research is to report the results of three studies: 1) the comparison of two products recommended for nursery use on loblolly and slash pine in a greenhouse, 2) the effects of granular humic acid applied to loblolly pine in a bareroot nursery and 3) and an experiment that examined rates of humic and fulvic acids on the growth loblolly and slash pine in the greenhouse.

METHODOLOGY

2009 Greenhouse Study. In 2009, two products were recommended to us for use in forest-tree nurseries. The first product, Hydromax®, was manufactured by North American Industries, Humboldt, AZ. It is described as a liquid extract from metal tailings from the Iron King Mine in Arizona used for production of Ironite®. Hydromax ® contains 22 elements, 10 of which are at sufficient concentrations to increase plant growth. Information on the remaining elements could not be found. The second product, Nature's NOG®, was manufactured by Senn, Senn & Senn LLC in Clemson, SC. This product is described as a totally organic, environmentally safe, completely non-toxic natural compound designed to enhance root formation, increase vascular strength, promote green color, and reduce stress on ornamental and agricultural plants. The MSDS describes this product as processed and modified seaweed extract and humate derivatives (humic, fulvic and ulmic acids). Forty elements and compounds are listed as ingredients.

In this experiment we also compared humic acid (Hydra-Hume®, 12% ai from Helena Chemical Company), fulvic acid (NutrAsyst®, 5% ai from Helena Chemical Company) and a water control treatment. Miracle Gro Fertilizer® 30-10-10 (The Scotts Company, Marysville, OH) was used in each treatment application except for the first.

The container set used in all greenhouse studies was the Hiko™ V-93; with a volume of 5.7 in^3 (93 cc) and seedling density of 49 ft^2 (526 m^2). Twenty cavities of loblolly pine and 20 cavities of slash pine were sown per container set and each set was an experimental unit with 15 container sets (replications) per treatment. Seeds of loblolly and slash pine were stratified for 45 and 21 days, respectively, and sown on May 19, 2009. The growing media (SunGro Sunshine Mix #8 Professional Growing Mix®) was composed of 70-80% Canadian sphagnum grower grade peat moss, coarse grade perlite, coarse grade vermiculite, dolomite limestone, gypsum and wetting agent. After sowing, the seeds were covered with a thin layer of coarse perlite and the treatments randomly assigned to one of three greenhouse benches.

At time of sowing, fertilizer was not applied to seedlings in any treatment. The amount of water and treatment are presented at each bi-weekly application in Table 1 and was applied to saturate the media. The fertilizer rate of 120 ppm N is approximately equal to 0.4 gm of 30-10-10 per liter of water.

Bi-weekly applications of treatments began on June 18 and consisted of: 1) Hydromax® plus fertilizer, 2) Nature's Nog® plus fertilizer, 3) Hydra-Hume® plus fertilizer, 4) NutrAsyst® plus fertilizer and 5) fertilizer alone. There were a total of 9 applications over the season. Normal seedling cultural practices were followed over the course of the season. On July 28, all seedlings greater than 7" were top clipped and the biomass of the clippings weighed. Twenty weeks after sowing, the study was completed and the RCD, height and seedling biomass was determined for each experimental unit, replication and treatment.

2009 Bareroot Humic Acid Study. A granular form of humic acid (Hydra-Hume DG®, 70% humic acid) was applied at 2 nurseries with coarse textured soils. In each nursery, bed-rows 3, 5 and 7 in two adjacent blocks of nine beds were designated as test plots. The treatments were: 1) 40 lb/acre 1 week after sowing, 2) 20 lb/acre 1 week after sowing, and 3) an applications of 20 lb/acre at 1 and 4 weeks post-sowing and 4) a non-treated control. The 40 lb/acre application rate is the label recommended rate. This study was a randomized complete block design with 6 replications and each bed- row included the four treatments. Each treatment bed was 40 foot long separated by a 40 foot buffer zone. A Gandy® cam gauge row applicator with 3 drops attached to a nursery tractor was used to apply the Hydra Hume DG®. Normal nursery management culture was applied to the treatment area. Just prior to nursery lifting, seedlings were collected from the middle 20 foot of each plot. Seedling quality was determined by measuring RCD, height, and shoots and root biomass for each treatment rate.

2010 Humic and Fulvic Acid Rate Study. Three rates (1.6, 4.0, 8.0 ml/l) of humic acid (HA) (Hydra-Hume®, 5% ai from Helena Chemical Company) and fulvic acid (FA) (NutrAsyst®, 5% ai from Helena Chemical Company) plus a water control were applied to loblolly and slash pine seedlings in a greenhouse. The study also included a control treatment that received only water. Miracle Gro Fertilizer® 30-10-10 (The Scotts Company, Marysville, OH) was used in each treatment application except for the application at sowing.

The amount of water and treatment used are presented at each biweekly application in Table 2. The amount of water applied to each treatment was sufficient to saturate the media. The fertilizer rate of 120 ppm N is approximately equal to 0.4 gm of 30-10-10 per liter of water. The lowest rate of both humic and fulvic acid (1.6 ml/l) approximates the suggested label rate for both products.

Hiko™ V-93 container sets were sown with loblolly and slash pine on May 17 as described in the previous greenhouse study. The media used was custom mixed using 65% Berger Peat Moss® (BM-1), 20% coarse vermiculite and 15% coarse perlite. Micromax® fertilizer was added at a rate of 1 lb/yd^3 of media with neither dolomite limestone nor gypsum added.

Bi-weekly applications of treatments began on June 7 and consisted of each treatment plus fertilizer (Table 2). There were a total of 9 applications over the growing season. On July 26, all seedlings greater than 7 in were top-clipped and the biomass of the clippings was weighed. Twenty weeks after sowing seedling RCD, height and dry biomass was determined for each experimental unit, replication and treatment.

RESULTS AND DISCUSSION

2009 Greenhouse study. The Hydromax® and NutrAsyst® treatments produced loblolly and slash pine seedlings with larger top biomass than the fertilizer control treatment (Table 3 and 4). The NutrAsyst® was the only treatment to have significantly greater RCD compared to the fertilizer control in both loblolly and slash pine seedlings. All four treatments increased loblolly pine root biomass when compared to fertilizer alone.

Both loblolly and slash pine seedlings treated with Nature's Nog® had significantly smaller RCD than the fertilizer control (Table 3 and 4). In this study, Nature's Nog® had little response on the seedling parameters measured in either loblolly or slash pine except for root biomass which was greater than the fertilizer control treatment.

When comparing Hydromax®, Nature's Nog®, Hydra-Hume®, and NutrAsyst® , Hydromax® and NutrAsyst® had more seedling growth characteristics that were significantly greater than the control (Table 3 and 4). Nature's Nog® only had one characteristic, root dry weight, significantly greater than the control in both loblolly and slash. In slash pine, Hydra-Hume® was not significantly different from the control for any measured parameter (Table 4). Nature's Nog®, was the only treatment where the seedling characteristic measured (RCD, height, top biomass) were significantly smaller than the control (Table 3 and 4).

Due to the lack of technical information on Hydromax®, it is difficult to determine what specific element, ingredient or combination of these resulted in the increased growth response observed. Therefore, this product will not be further studied or recommended for use. The estimated cost based upon study rates is $17/acre.

Nautre's Nog® is primarily composed of seaweed in a humic acid carrier. There are a large number of sources of this material on the internet along with user testimonials. Although studies with humic acid (Senn & Kingman 1973) and seaweed extract alone are available (Crouch &

Staden 1993), we could not find replicated scientific studies to confirm beneficial results of Nautre's Nog. The estimated cost for Nature's Nog® based upon study rates is $41/acre.

Hydra Hume® is composed of 12% humic acid has been used in many applications in agriculture and horticulture (Senn & Kingman, 1973, Lee and Barlett, 1976), but its use in forestry has been limited. Literature on the use of humic acid show both positive and negative results (Senn & Kingman, 1973, Lee and Barlett, 1976). Metzger (2003) attributes these inconsistent results to a lack of product standardization within the industry. In this study, Hydra Hume® had a larger root biomass than the fertilizer control, but there were no differences in the other seedling parameters. The lack of a response in our study may be due to the concentration of Hydra-Hume® used (Brad Brush, personal communication 2011).

NutraAsyst® is composed of 5% fulvic acid. This treatment produced seedlings with a larger RCD and shoot biomass than the fertilizer control. The uses of fulvic acid have produced increases in root biomass and/or shoot biomass in vegetable crops (Dunstone *et. al*. 1988, Rauthan and Schnitzer 1981, Mylonas and McCants 1980, Akinci *et. al*. 2009, Unlu *et. al*. 2011). A study by Rauthan and Schnitzer 1981) demonstrated that increases in cucumber (*Cucumis sativus*) biomass were accompanied by increases (compared to controls) of N, P, K, Ca, Mg, Cu, Fe and N in the shoots and N in the roots. The response appeared to be strongly related to fulvic acid concentrations used (Rauthan and Schnitzer 1981, Mylonas and McCants 1980). The estimated cost of NutraAsyst® based upon study rates is $13/acre.

2009 Bareroot Humic Acid Study. In both bareroot nurseries, none of the rates of granular humic acid affected loblolly pine seedling growth. The humic acid granules were applied (broadcast) after sowing which may have played a part in the lack of an effect on seedling growth. The product label suggested that this material can be applied anytime during the year with first preference being a broadcast application in the fall following deep tillage and second preference being a broadcast application. Different results may be expected if the material at the 40 lb/acre rate was first incorporated into the seedling bed, and it is possible that despite the coarse sandy soils that the material did not move into the rooting zone

2010 Humic and Fulvic Acid Rate Study. Because of the positive seedling growth responses observed in the studies mentioned above, as well as reports in the literature when using humic substances, a rate study of both humic acid and fulvic acid was conducted

Compared to the fertilizer control, the lowest rate of fulvic (FA1) and humic acid (HA1) in slash pine and the lowest rate of fulvic acid in loblolly pine produced significantly larger seedlings as measured by RCD and seedling biomass (Tables 5 and 6). The fertilizer control represents what a nursery would obtain without the use of fulvic or humic acid.

Loblolly pine seedling biomass was significantly greater than the controls for the FA1 and FA2 rates (Table 5). The highest rate of fulvic acid, FA3, did not affect seedling growth when compared to the control. In addition, the three rates of humic acid did not affect loblolly pine seedling growth.

All three rates of fulvic acid produced slash pine seedlings with larger RCD than the control (Table 6). Unlike loblolly pine, slash pine did respond to humic acid. Rates HA1 and HA2 produced larger root collar diameter and shoot and total biomass (Table 6) in slash pine.

Figures 1-3 show the dose response curves for the three rates of humic and fulvic acid on both slash and loblolly pine seedlings. For comparative purposes, the loblolly and slash pine graph for each seedling parameter are represented on the same scale. The first point on the Y-axis for each graph represents the control, i.e. no (0 ml/L) fulvic or humic acid. The next three points on each graph represent the three test rates of 1.6, 4.0, and 8.0 ml/L, respectively.

In slash pine, fulvic acid appears to reach a peak dose response for seeding growth at the lowest rate used (Figure 1-3) which was significant in the contrast statements (Table 7). The lowest rate of fulvic acid was significantly greater than the fertilizer control (Table 7). The middle rate (FA2) of fulvic acid produced slash pine seedlings with significantly less RCD and biomass than the lowest fulvic acid rate (FA1) (Table 7). The initial rate of humic acid was greater for all seedling parameters than the fertilizer control (Figure 1-3, Table 7). Both HA1 and HA2 treatments of humic acid were significantly greater for RCD than the fertilizer control (Table 7).

In loblolly pine, the seedling response for all growth parameters was greatest when treated with the lowest rate of fulvic acid (FA1) compared to the fertilizer control (Figures 1-3, Table 7). The peak response rate for root and total biomass occurred between FA1 and FA2 in loblolly pine and at FA1 for RCD (Table 7). Humic acid did not have any effect on seedling growth as did fulvic acid (Table 7). The response trend with humic acid in loblolly pine increased with increasing rates of humic acid (Figure 1-3).

The increase in biomass in this study with the use of fulvic acid is consistent with other reports in vegetable crops (Dunstone *et. al*. 1988, Rauthan and Schnitzer, 1981, Mylonas and McCants 1980, Akinci *et. al*.2009, Unlu *et. al*. 2011). There was a rate response with fulvic acid for all seedling parameters measured. A similar response was reported by Rauthan and Schnitzer (1981) for cucumbers where rates between 100 - 300 ppm of fulvic acid produced highly significant increases in plant biomass and rates above 500 ppm were less beneficial. Mylonas & McCants M437 demonstrated that fulvic acid concentrations of 50 - 100 ppm increased root length in tobacco (*Nicotiana tobacum* L. ‘Coker 254’) by 25% whereas higher concentration between 100 and 200 ppm had no effect. The lowest rate that produced the greatest response in our study was approximately 80 ppm. The higher rate (FA3) which was not significantly different from the control was approximately 400 ppm. With slash pine, it appears that the initial rate (FA1) of fulvic acid produced the most growth. What is not known from this study is if a lower rate than FA1 would be equally effective. In loblolly pine, the fulvic acid rate that produced the most seedling biomass was between FA1 and FA2. In both pine species it appears that the best rate of humic acid for increasing seedling biomass may be greater than the rates tested in this study.

MANAGEMENT IMPLICATIONS

In this study, we looked at the use of biological products to increase seedling growth and the use of compounds that facilitate nutrient uptake by seedlings. Care must be taken by nursery managers when using products that are marketed to increase seedling growth that have little or no scientific data to support their use. Although many of these products are generally safe to use when following the label directions, they may not be cost effective. Many of these products are combinations of compounds or elements, each of which may result in increased seedling growth. These products are difficult to recommend since we can generally not determine which product (in the case of multiple ingredients) is causing the growth response. Several questions should be asked of sales people wanting you to purchase their products:

1. Which element or combination of elements makes this product most effective? An answer of “That’s propriety information.” is not an acceptable response.
2. If it is one or a combination of elements, why are the other elements or compounds added? This simply raises the cost to you.
3. Have there been controlled replicated studies looking at the total product effect and then just effect attributed to the individual products?

Overall, these studies have shown that the use of fulvic acid or humic acid plus fertilizer at label rates produced larger slash pines than just fertilizer treatment alone. In loblolly pine, fulvic acid plus fertilizer produced larger seedlings than fertilizer alone. The rates of humic acid used did not affect loblolly pine growth significantly. The use of fulvic acid could be a consideration for nurseries that use water soluble fertilizer as their primary source to increase seedling growth.

Humic acid is a common carrier in many of these products. Humic substances like humic acid and fulvic acids are not fertilizers but rather act in the soil and on seedlings by facilitating the uptake of fertilizers. We generally use one or both of these in our testing program. If humic acid and fertilizer is effective with respect to seedling growth, why use a product that contains humic substances and/or several to many other ingredients in the product? The economical approach to increasing seedling growth, and subsequent seedling quality, may be to use humic substances and your standard fertilizer.

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Table 1. Amount of water and treatments applied to each of the 15 container sets per treatment at sowing (no fertilizer) and each bi-weekly application.

Treatment	Total Water (L)	Fertilizer (ppm N)	Treatment amount (ml/L)
Hydromax®	15.1	120	15.8
Natures NOG®	15.1	120	15.8
Hydra-Hume®	15.1	120	1.6
NutrAsyst®	15.1	120	1.6
Control	15.1	120	-------

Table 2. Amount of water and treatments applied to each 15 container sets per treatment at sowing (no fertilizer) and each biweekly application.

Treatment	Treatment Notation	Total Water (L)	Hydra-Hume® (ml/L)	NutrAsyst® (ml/L)	Fertilizer (ppm N)
Humic Acid	HA1	15.1	1.6	—	120
Humic Acid	HA2	15.1	4.0	—	120
Humic Acid	HA3	15.1	8.0	—	120
Fulvic Acid	FA1	15.1	—	1.6	120
Fulvic Acid	FA2	15.1	—	4.0	120
Fulvic Acid	FA3	15.1	—	8.0	120
Control	Control	15.1	—	—	120

Table 3. Treatment effects on loblolly pine seedling characteristics.

	October 2009 Final Seedling Characteristics			
	RCD (mm)	Height (cm)	Root Dry Weight (g)	Total Top Dry Weight (g)[1]
Hydromax®	2.8 b[2]	28.5 a	0.397 b	1.34 a
Natures NOG®	2.5 c	27.2 b	0.429 ab	0.98 c
Hydra-Hume®	2.7 b	26.4 b	0.398 b	1.09 b
NutrAsyst®	3.0 a	28.5 a	0.467 a	1.30 a
Fertilizer (control)	2.7 b	28.6 a	0.333 c	1.00 bc
lsd	*0.12*	*1.2*	*0.052*	*0.101*

[1]Total Top Dry = includes dry weight of top clippings from July

[2]Means (within a column) followed by the same letter are not significantly different based on Duncan's Multiple Range Test ($p \leq 0.05$).

Table 4. Treatment effects on slash pine seedling characteristics.

	October 2009 Final SeedlingCharacteristics			
	RCD (mm)	**Height (cm)**	**Root Dry Weight (g)**	**Total Top Dry Weight (g)[1]**
Hydromax®	3.1 b[2]	29.1 a	0.506 b	1.61 a
Natures NOG®	2.9 c	25.8 b	0.642 a	1.17 c
Hydra Hume®	3.1 b	26.2 b	0.522 b	1.36 b
NutrAsyst®	3.3 a	28.6 a	0.556 ab	1.52 a
Fertilizer (control)	3.1 b	26.5 b	0.522 b	1.33 b
lsd	*0.12*	*1.2*	*0.109*	*0.115*

[1] Total Top Dry = includes dry weight of top clippings from July

[2]Means (within a column) followed by the same letter are not significantly different based on Duncan's Multiple Range Test ($p \leq 0.05$).

Table 5. Comparison of three rates of fulvic and humic acid to the control treatment for loblolly pine root collar diameter (RCD) and biomass.

		Fulvic Acid			**Humic Acid**		
	Control	**FA1**	**FA2**	**FA3**	**HA1**	**HA2**	**HA3**
RCD (mm)	2.29	2.38 **	2.30	2.33	2.30	2.32	2.33
Root DW (g)	0.29	0.33 **	0.42 **	0.31	0.31	0.31	0.32
Shoot DW (g)	0.69	0.79 **	0.77 **	0.69	0.69	0.72	0.73
Total DW (g)	1.01	1.15 **	1.24 **	1.04	1.02	1.05	1.07

*** - Significantly different from Control at the 0.05 level using Dunnetts test*

Table 6. Comparison of three rates of fulvic and humic acid to the control treatment for slash pine root collar diameter (RCD) and biomass.

		Fulvic Acid			Humic Acid		
	Control	**FA1**	**FA2**	**FA3**	**HA1**	**HA2**	**HA3**
RCD (mm)	2.44	2.63 **	2.55 **	2.66 **	2.63 **	2.76 **	2.54
Root DWg)	0.31	0.40 **	0.32	0.35	0.39 **	0.32	0.37 **
Shoot DW (g)	0.67	0.91 **	0.75 **	0.72	0.79 **	0.83 **	0.83 **
Total DW	1.05	1.32 **	1.12	1.13 **	1.24 **	1.19 **	1.24 **

** - *Significantly different from Control at the 0.05 level using Dunnetts test*

Table 7. Statistical contrast statements comparing rates of fulvic and humic acid on loblolly and slash pine.

	Contrasts	Cntl vs F1	F1 vs F2	F2 vs F3	Cntl vs H1	H1 vs H2	H2 vs H3
Loblolly	**RCD**	2.29 vs 2.38 *(0.002)*	2.38 vs 2.30 *(0.0062)*	2.30 vs 2.33 *(0.3908)*	2.29 vs 2.30 *(0.8321)*	2.30 vs 2.32 *(0.4761)*	2.32 vs 2.33 *(0.6529)*
	Root DW	0.29 vs 0.33 *(0.0015)*	0.33 vs 0.42 *(0.0001)*	0.42 vs 0.31 *(0.0001)*	0.29 vs 0.33 *(0.1629)*	0.31 vs 0.31 *(0.6716)*	0.31 vs 0.32 *(0.4816)*
	Shoot DW	0.69 vs 0.79 *(0.0001)*	0.79 vs 0.77 *(0.5628)*	0.77 vs 0.69 *(0.0002)*	0.69 vs 0.69 *(0.9776)*	0.69 vs 0.72 *(0.1408)*	0.72 vs 0.73 *(0.8153)*
	Total DW	1.01 vs 1.15 *(0.0001)*	1.15 vs 1.24 *(0.0011)*	1.24 vs 1.04 *(0.0001)*	1.01 vs 1.02 *(0.8341)*	1.02 vs 1.05 *(0.1554)*	1.05 vs 1.07 *(0.5188)*
Slash	**RCD**	2.44 vs 2.63 *(0.0001)*	2.63 vs 2.55 *(0.0468)*	2.55 vs 2.66 *(0.0073)*	2.44 vs 2.63 *(0.0001)*	2.63 vs 2.76 *(0.0007)*	2.76 vs 2.54 *(0.0001)*
	Root DW	0.31 vs 0.40 *(0.0001)*	0.40 vs 0.32 *(0.0001)*	0.32 vs 0.35 *(0.0698)*	0.31 vs 0.39 *(0.0001)*	0.39 vs 0.32 *(0.0001)*	0.32 vs 0.37 *(0.0003)*
	Shoot DW	0.67 vs 0.91 *(0.0001)*	0.91 vs 0.75 *(0.0001)*	0.75 vs 0.72 *(0.1249)*	0.67 vs 0.79 *(0.0001)*	0.79 vs 0.83 *(0.1179)*	0.83 vs 0.83 *(0.8349)*
	Total DW	1.05 vs 1.32 *(0.0001)*	1.32 vs 1.12 *(0.0001)*	1.12 vs 1.13 *(0.8088)*	1.05 vs 1.24 *(0.0001)*	1.24 vs 1.19 *(0.1067)*	1.19 vs 1.24 *(0.1093)*

Number in parenthesis is the Prob > F

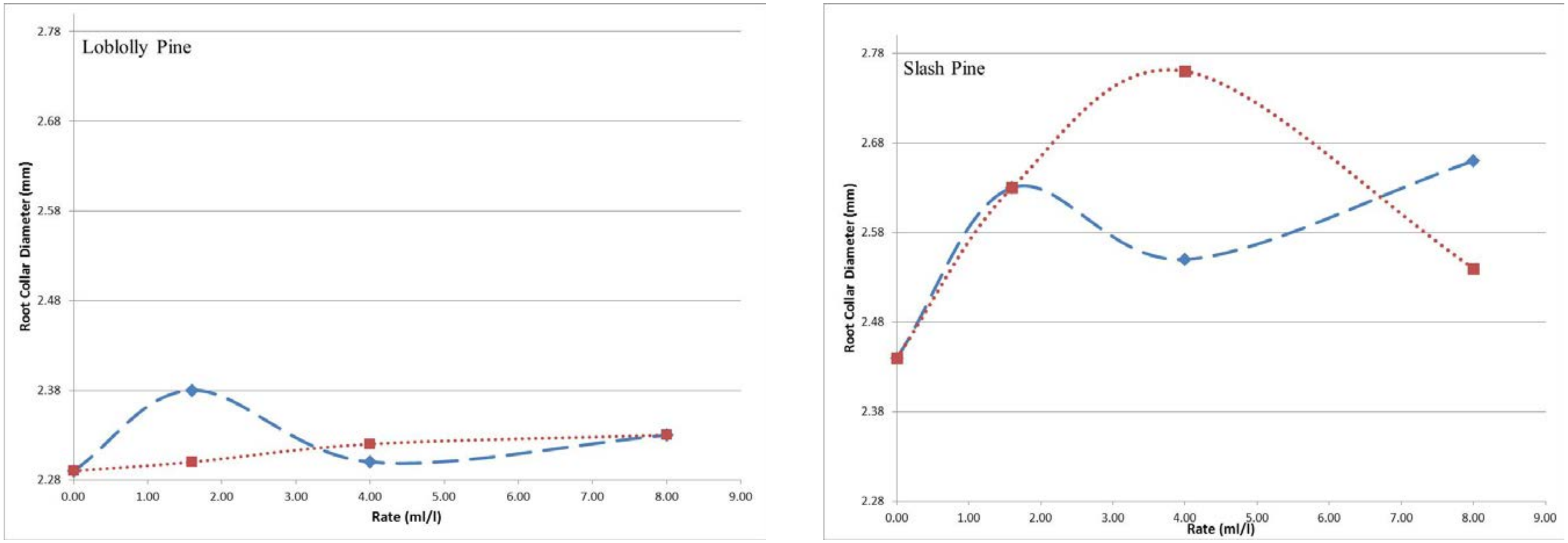

Figure 1. Comparison of root collar diameter for slash and loblolly pine.

Legend: — — — — — Fulvic Acid
•••••••••••••• Humic Acid

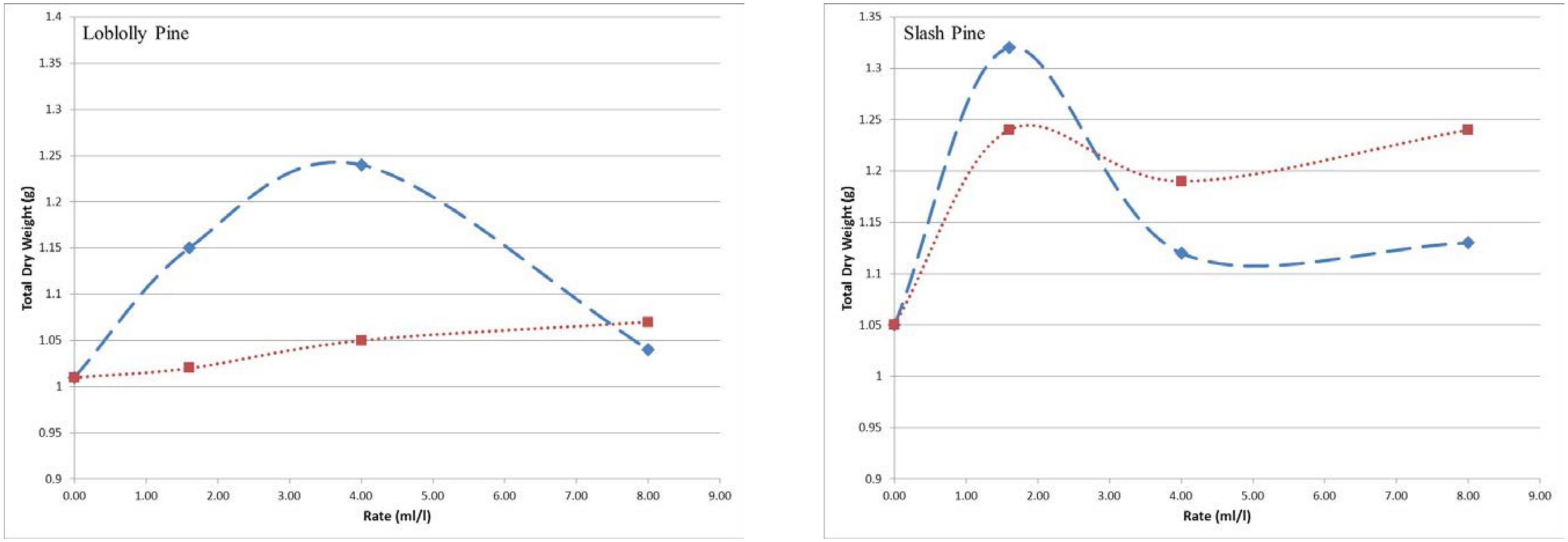

Figure 2. Comparison of total dry weight for slash and loblolly pine.

Legend: — — — — — Fulvic Acid
•••••••••••••• Humic Acid

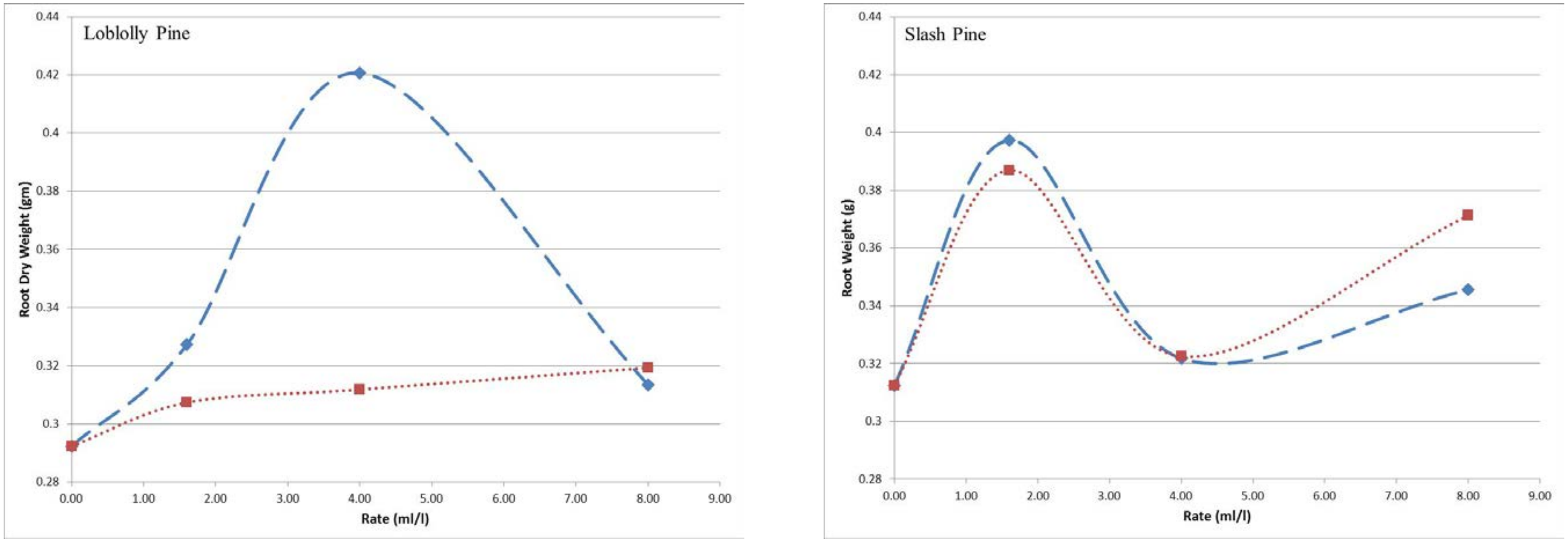

Figure 3. Comparison of root dry weight for slash and loblolly pine.

Legend:	— — — — — Fulvic Acid
	• • • • • • • • • • • • • • Humic Acid