New Best Management Practices For Coastal Citrus

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Executive Summary

Virtually all of Florida's 833,701 acres of citrus are located within the coastal zone and therefore, are subject to "management measures" for NPS pollution. Agricultural NPS pollution is the leading source of water quality impacts to rivers and lakes and the third largest source of impairments to estuaries. The primary sources of agricultural NPS pollutants are nutrients and in particular, Nitrogen and Phosphorus. Best Management Practices (BMPs) are deemed to be the best available technology for reducing pollutants while avoiding increased costs. Unfortunately, very little work has been done recently towards developing and testing new BMPs for Florida's citrus groves. Accordingly, new proven BMPs that reduce the amount of discharged nutrients into surface water are now essential. The purpose of this project was to demonstrate and help validate two new BMPs for coastal citrus groves--foliar fertilization and the application of organic matter to help reduce nutrients discharged into coastal water bodies while maintaining economic profitability for coastal citrus growers.

Foliar fertilization is the application of small amounts of appropriate fertilizers to a plant's foliage for assimilation and use by the plant as a source of nutrients. Foliar fertilization as a BMP could reduce the amount of ground applied fertilizers to citrus, particularly phosphorus fertilizers. This application methodology was found to be effective as a candidate BMP using foliar spray applications of nitrogen and phosphorus fertilizers with conventional citrus sprayers.

The addition of organic matter to Florida's typical sandy soils increases the cation exchange capacity, increases nutrient retention, increases soil moisture retention, improves soil structure, and perhaps most importantly nitrogen is released to the plant relatively slowly and, therefore, more efficiently. The strategy developed in this project used placement technology to decrease the application area by targeting an application strip located along the tree row, thereby dramatically increasing the amount of organic matter per unit of area. To perform this type of application a suitable side-delivery compost spreader was located and purchased and was shown to be capable of placing a uniform band of compost to citrus trees. Modifications were made to increase the capacity and strengthen the drive line. The modified compost spreader performed effectively and reliably applying compost as prescribed even under harsher conditions and terrain at the MINWR groves than are typically found in commercial citrus groves.

Both the Foliar and Compost candidate BMP fertility programs were shown to be capable of providing adequate nitrogen and phosphorus levels to citrus trees without ground applications of conventional phosphorus fertilizers. Both candidate BMP fertility programs, when applied at similar fertility levels, were equivalent in cost assuming favorable application conditions. However, they were twice as expensive as the conventional fertility program using ground applied chemical fertilizer. No significant differences between the three fertility programs were observed based on the nutrient status of the trees.

While we were not able to quantify the amount of nutrients discharged in storm water for each fertility program, we were able to identify trends based on nutrient levels detected in the storm water. Our data did demonstrate a reduction in phosphorus levels in storm water where fertilizers not containing phosphorus were applied. Storm water nitrogen levels at all sites were

below the E.P.A. drinking water standard of 10 mg/liter. Further research efforts are deemed necessary to determine the precise environmental impact, if any, for these different nutrient application methods. In addition, continued efforts towards using foliar and organic matter applications to citrus is warranted to discover, develop, and improve the methodology and infrastructure for these important BMPs if coastal citrus is to remain viable.

Introduction

There are standing concerns of Non-Point Source (NPS) pollutants derived in part from agricultural operations impacting major water bodies throughout the United States. In response to this and other NPS problems, Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) requires coastal states to address NPS pollutants impacting coastal waters. Based on the geography of Florida and by authority of the CZARA, virtually all of the State's 833,701 acres of citrus are located within the coastal zone and therefore, are subject to "management measures" for NPS pollution. According to the *National Water Quality Inventory*, agricultural NPS pollution is the leading source of water quality impacts to rivers and lakes and the third largest source of impairments to estuaries. The primary sources of agricultural NPS pollutants are nutrients and in particular, Nitrogen and Phosphorus. The current "management measures" or Best Management Practices (BMPs) are deemed to be the best available technology for reducing pollutants while avoiding increased costs. Unfortunately, very little work has been done recently towards developing and testing new BMPs for Florida's citrus groves. As a result, farmers must wait for government agencies to develop and assess new management practices and determine if they are economically viable. Without these management measures as BMPs to reduce NPS pollutants, farmers run the eventual risk of having regulatory measures imposed; thereby jeopardizing their farming operations. If coastal citrus groves are going to be productive economically without exceeding mandated Total Maximum Daily Loads (TMDLs), new, proven BMPs that reduce the amount of discharged nutrients into surface water will be essential. The purpose of this project is to demonstrate and help validate two new BMPs for coastal citrus groves--foliar fertilization and the application of organic matter to help reduce nutrients discharged into coastal water bodies while maintaining economic profitability for coastal citrus growers.

Foliar fertilization is the application of small amounts of appropriate fertilizers to a plant's foliage for assimilation and use by the plant as a source of nutrients. Foliar fertilization as a BMP could reduce the amount of ground applied fertilizers to citrus, particularly phosphorus fertilizers. Substituting foliar applied phosphorus for ground applied phosphorus would be feasible in coastal soils that typically exhibit elevated phosphorus levels. Since a majority of coastal citrus is grown for the fresh fruit market, foliar sprays are widely and routinely applied to protect the fruit crop from fungal and insect damage. The addition of foliar fertilizers to these crop protectant sprays represents a cost efficient means of application. This will enable growers to utilize existing spray equipment to implement a new agricultural practice without increasing equipment costs or learning new methodologies. This project will collect agricultural, economic, and environmental data from a grove using foliar applications of phosphorus fertilizers and ground application of chemical fertilizers lacking phosphorus to evaluate this fertility practice as a candidate BMP.

The incorporation of organic matter as a fertility source for citrus is currently listed as a BMP to minimize nutrient loading in surface waters according to the Water Quality/Quantity BMPs for Indian River Area citrus groves. The addition of organic matter to Florida's typical sandy soils increases the cation exchange capacity, increases nutrient retention, increases soil moisture retention, improves soil structure, and perhaps most importantly nitrogen is released to the plant relatively slowly by a biological mineralization process. Unfortunately, the water-holding capacity, soil structure, and cation exchange capacity are probably not significantly increased unless about 9 tons/acre of organic matter are broadcast annually to a citrus grove for several years (Obreza and Ozores-Hampton, 2000). The application of this amount of matter would be economically prohibitive for most citrus growers. However, this high rate assumed a general broadcast application, from tree trunk to tree trunk or approximately 25 ft. Our strategy was to use placement technology to decrease the application area by targeting an application strip located along the tree row, thereby dramatically increasing the amount of organic matter per unit of area. For example, in a citrus grove with tree rows 25 ft apart and a tree spacing of 15 ft or 116 trees per acre (Appendix 1), a 9 tons/acre broadcast application trunk to trunk would represent 0.4 lb/sq ft of organic matter whereas a 2 ft band applied to both sides of the tree row at 4.5 tons/acre would render 1.3 lb/sq ft The second candidate BMP evaluated by this project used banded applications of organic matter at 4-5 tons/acre placed along the dense feeder root area occurring at the tree's drip edge. This required locating and assessing the capability of a suitable side-delivery compost spreader to place a uniform band of compost to citrus trees that is also durable, affordable and available to the grower.

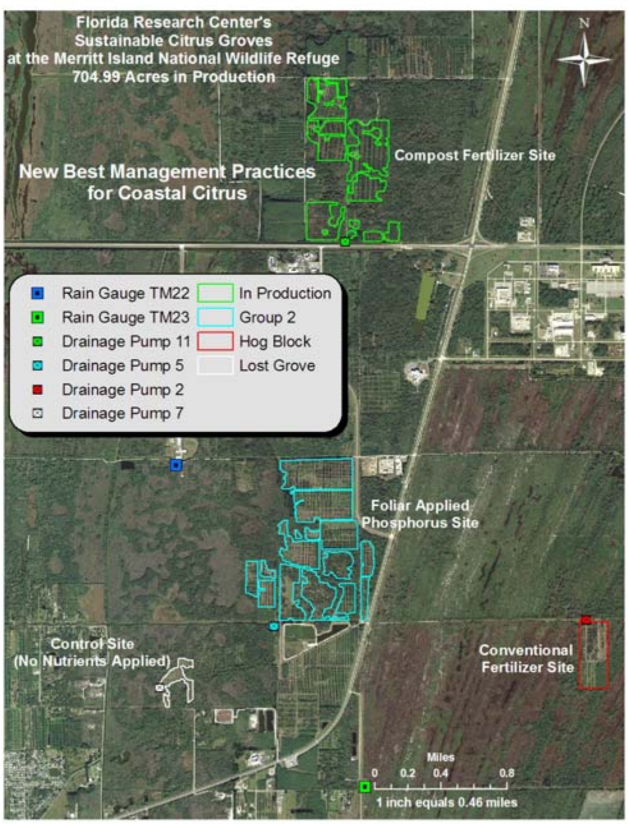
Methodology

<u>Study Sites and Programs</u>

Four fertility management programs-- control (no fertilizer applications), conventional ground applied fertilizer (with phosphorus), and two candidate BMPs were assigned to individually managed grove sites at the Merritt Island National Wildlife Refuge (MINWR). The candidate fertility BMPs were: 1) Foliar BMP, where foliar fertilizer applications with phosphorus were used in conjunction with ground applied chemical fertilizers not containing phosphorus and 2) Compost BMP, where banded compost applications were used with ground applied chemical fertilizer not containing phosphorus. The acreage for each site was determined by employing a Geographic Information System (GIS), ArcView 3.2 (Environmental Systems Research Institute, Inc., Redlands, CA). The same software was used to project the locations of citrus trees, grove boundaries, drainage pumps, and drainage ditches onto high resolution aerial images obtained from NASA at the Kennedy Space Center (GIS Image 1). The citrus grove study sites ranged from 14 to 262 acres and each was drained separately with its own engine powered drainage pump. The storm water discharged from each of the four drainage pumps was sampled and analyzed quarterly for nutrient levels. The pump run times were monitored and start/stop times were recorded. Rainfall was recorded daily from two nearby sites (within 1-1.6 miles of each site) by the Kennedy Space Center. This information was used to determine the environmental impact for each fertility management program in terms of the amount of nitrogen and phosphorus applied to each grove site as fertilizer and removed from each site as discharged storm water. Nutrient application rates and costs were recorded for each site to determine the economic feasibility for each fertility management program. The environmental impact and the total fertilization cost per acre together served as the selection criteria to determine the relative merit for each fertility program as a BMP.

The names and a brief description of the four fertility programs evaluated in this project were:

1. Control Site- A semi-abandoned citrus grove (Lost Grove, Tract No. 4333) received no fertility inputs was the designated Control Site and was 13.9 acres. (GIS Image 2)
2. Conventional Fertilizer Site- A conventionally managed citrus grove (Hog Block, Tract No. 4508) received only ground applications of chemical based fertilizer (containing phosphorus using industry standard analyses and rates) was the designated Conventional Fertilizer Site as was 45.7 acres. (GIS Image 3)
3. Foliar BMP Site- A candidate Nutrient BMP citrus grove (Group 2) received a ground application of chemical based fertilizers (without phosphorus) and foliar applications of phosphorus containing fertilizers was the designated Foliar BMP Site and was 262.2 acres. (GIS Image 4)
4. Compost BMP Site- A candidate Nutrient BMP citrus grove (Group 4) received ground applications of compost based fertilizers (derived from UPD and chicken manure) and a single ground application of chemical based fertilizer without phosphorus was the designated Compost BMP Site and was 154.4 acres. (GIS Image 5)



GIS Image 1. Aerial image of all four study sites

The citrus caretaking program for each study site is described in detail and pictured below via a GIS map using a high resolution aerial image featuring grove and drainage structures.

1. Control Site (no fertilizer)

Site Name- Lost Grove, Tract No. 4333

Description- A 13.9 acre semi-abandoned, grapefruit grove receiving no fertility inputs is the designated control site.

Purpose- The purpose of the control site is to establish a background level of phosphorus in surface water discharge originating solely from resident soil phosphorus in a coastal citrus grove.
Drainage System- A PTO powered 24 inch diameter drainage pump having a 10,000 gpm capacity (NASA pump no. 7).

Spray Program- No sprays were applied

Fertilizer Program- No applications of any fertilizers are to be applied.

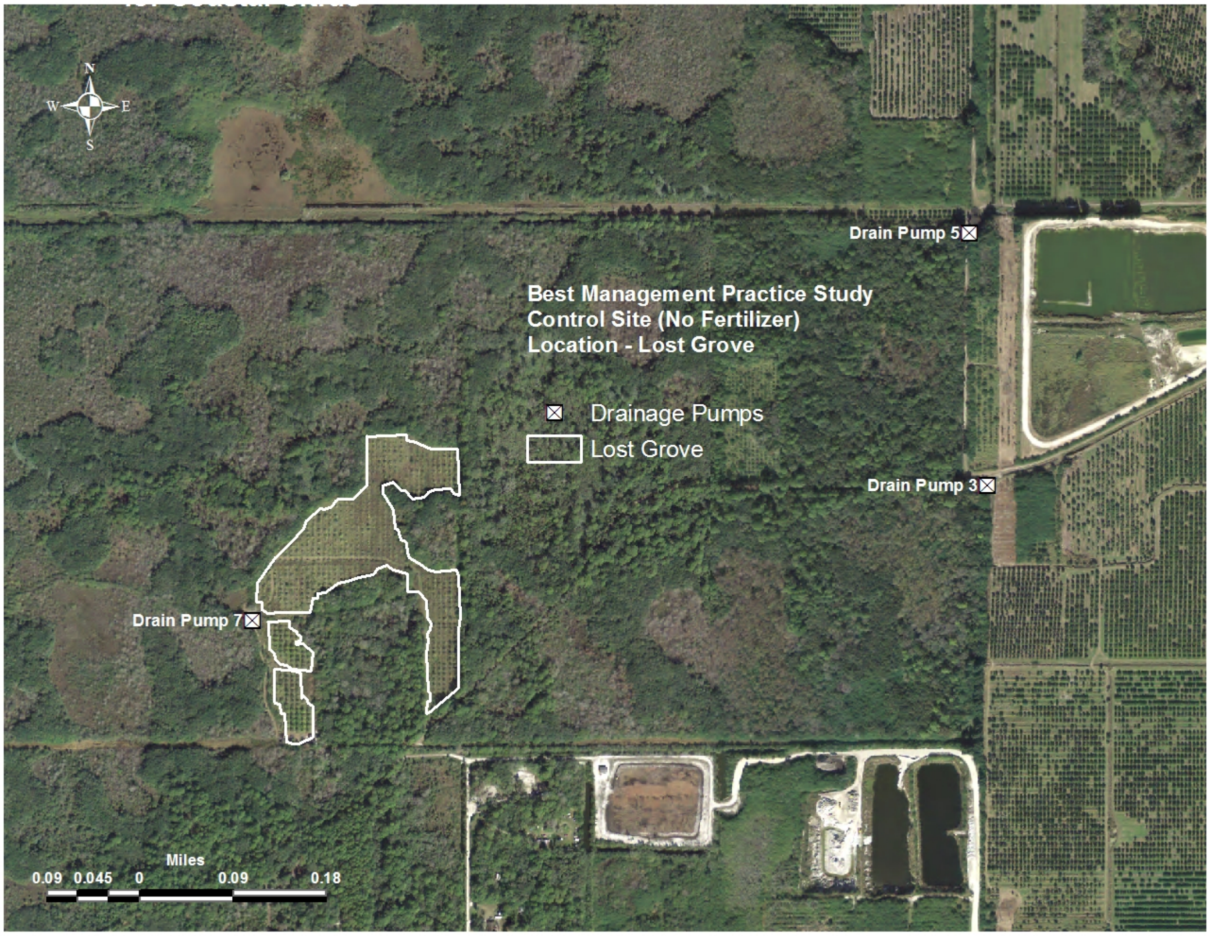
Weed Control Program-

Date	Materials	Rate/Tr. Acre	Spray Vol/Acre	Cost/Tr. Ac
May 7-11	Round-Up Ultra	3.0 qt	35 gal	$27.90
	Ammonium Sulfate	17 lb/100 gal*		.58
Aug. 19-23	Round-Up Ultra-Max	2.4 qt	33 gal	23.25
	Ammonium Sulfate	17 lb/100 gal*		.58
		Total Annual Cost/TREATED Acre:		$52.31

* Qty. Of Adjuvant/ 100 gal tank   1 Treated Ac = .50 Grove Ac
(Cost of Roundup Ultra @ $37.20/gal)
(Cost of Roundup Ultra-Max @ $38.75/gal

TOTAL ANNUAL HERBICIDE COST /GROVE ACRE: $26.16

Mow grove three times per year and chemical mow two times per year.



GIS Image 2. The Control Site a.k.a. Lost Grove demarked by white borders.

2. Conventional Fertilizer Site (receiving ground applied phosphorus)

Site- Hog Block, Tract No. 4508

Description- A 45.7 acre conventionally managed, mixed orange and grapefruit grove receiving two ground applications of a chemical based fertilizer containing phosphorus using industry standard analyses and rates is the designated conventional fertilizer site.

Purpose- The purpose of the conventional fertilizer site is to establish the level of phosphorus in surface water discharge originating from both ground applied fertilizer and resident soil phosphorus in a coastal citrus grove.

Drainage System- A diesel powered 18 inch diameter drainage pump having a 5,000 gpm capacity (NASA pump no. 2).

Spray Program (No foliar fertilizer sprays are applied)-

Spray Timing	Materials	Rate/Acre	Cost/Acre
Post Bloom 1	Kocide 101	5.0 lb	9.50
Pea Size	KeyPlex 445	2.0 qt	7.66
(167 gpa)	455 9E Spray Oil	0.25 gal	0.54
Post Bloom 2 †	Kocide 101	6.0 lb	11.40
~April	KeyPlex 445	2.0 qt	7.66
(167 gpa)	455 9E Spray Oil	0.5 gal	1.08
Summer Oil 1	KeyPlex 250	3.0 qt	12.30
~July 1	455 9E Sun Oil	5.0 gal	10.75
(167 gpa)	Agri-Mek 0.15 EC	10 oz.	49.50
Total Spray Materials Cost/Acre			$110.39

Fertilizer Program- Use a single ground application of a chemical based fertilizer containing phosphorus using Industry standard analysis and rates.

Fertilizer Analysis: 14-2-14 3 Mg derived from the following:

Material	Analysis	Weight lbs.
Ammonium Nitrate	34-0-0	778
Di-Ammonium Phosphate	18-46-0	87
Muriate of Potash	0-0-60	467
Super Mag	0-0-0 14 Mg	429
Manganese Sulfate		25
Borax	14.9B	8
Akzo Iron	13.0Fe	8
Sludge, New York		199
	Total Weight	2,000

Chemical Fertilizer Source and Price: Diamond R Fertilizer Co. ($193.25/ton)

Application Date	Rate per Acre	Cost/Ac
Feb. 16-19, 2001	700 lb/acre of Chemical Fertilizer	$ 67.64
Aug. 2001	400 lb/acre of Chemical Fertilizer	$ 38.65
		$106.29

Fertilizer Type	Per Cent Available 1st Yr.	Nitrogen Lbs N	Phosphorus Lbs P_2O_5	Potassium Lbs K_2O
1st Ground Applied Chemical Fertilizer		98	14	98
2nd Ground Applied Chemical Fertilizer		56	8	56
Total NPK/Ac/yr		154	22	154

Weed Control Program-

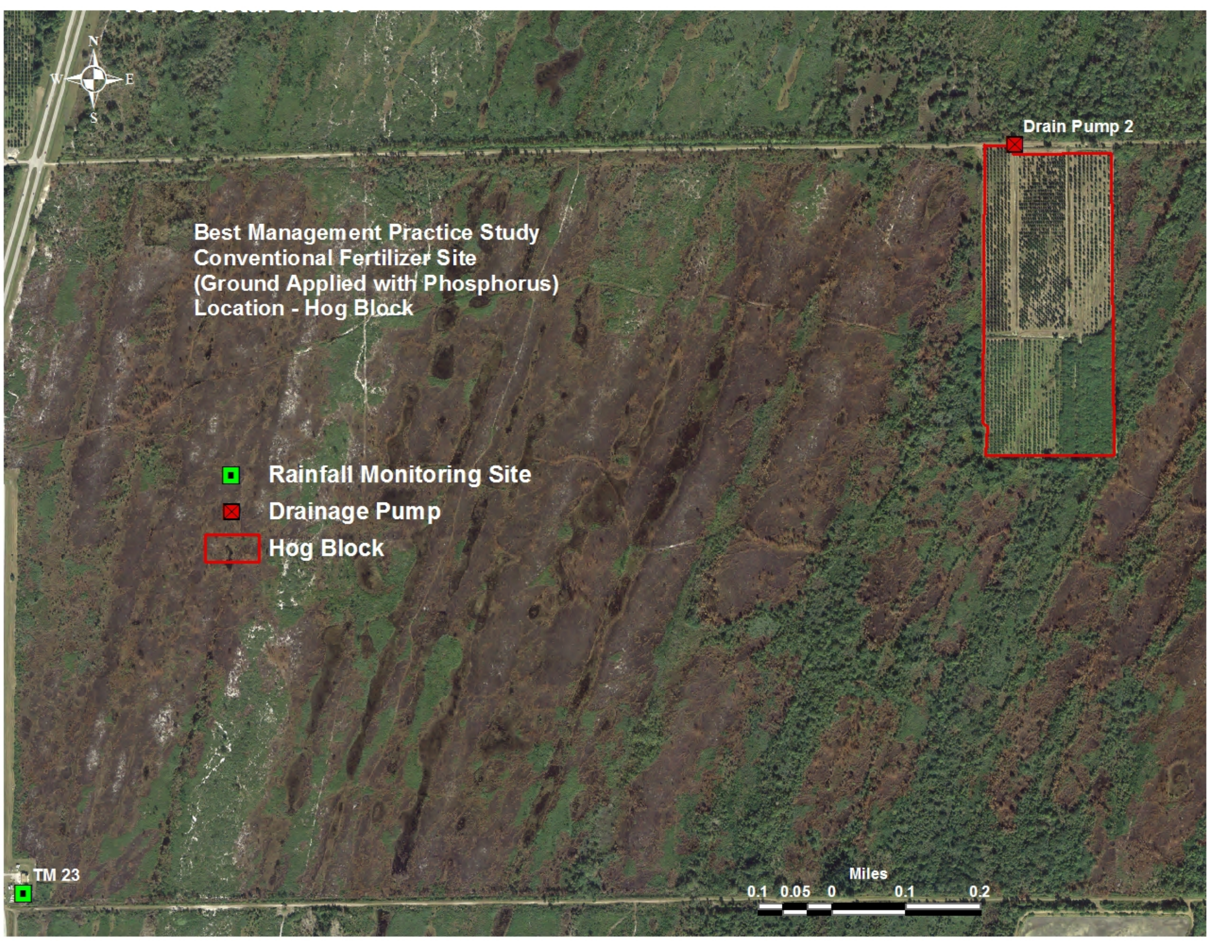
Date	Materials	Rate/Tr. Acre	Spray Vol/Acre	Cost/Tr. Ac
Feb.	Round-Up Ultra	1.0 qt	20 gal	$10.42
	LandMaster II	1.0 qt		4.63
	Ammonium Sulfate	17 lb/100 gal*		.58
May	Round-Up Ultra	3.0 qt	33 gal	31.26
	Ammonium Sulfate	17 lb/100 gal*		.58
Sept.	Round-Up Ultra	2.0 qt	20 gal	20.84
	Ammonium Sulfate	17 lb/100 gal*		.58
		Total Annual Cost/TREATED Acre:		$68.89

* Qty. Of Adjuvant/ 100 gal tank — 1 Treated Ac = .50 Grove Ac

(Cost of Roundup Ultra @ $41.67/gal)

Total Annual Herbicide Cost /Grove Acre: $34.45

Mow grove three times per year and chemical mow two times per year.



GIS Image 3. The Control Site a.k.a. Hog Block demarked by red borders.

3. Foliar Applied Phosphorus Site (1st Candidate Nutrient BMP)

Site- Group 2

Description- A 262.2 acre mixed orange and grapefruit citrus grove receiving split ground applications of chemical based fertilizer without phosphorus and foliar applications of phosphorus containing fertilizers as a candidate nutrient BMP for citrus is the designated foliar applied phosphorus site.

Purpose- The purpose of the foliar applied phosphorus site is to establish the level of phosphorus in surface water discharge originating from ground and foliar applied fertilizer as well as resident soil phosphorus in a coastal citrus grove.

Drainage System- A diesel powered 24 inch diameter drainage pump having a 15,000 gpm capacity (NASA pump no. 5).

Spray Program (Fertilizer sprays are <u>underlined</u>)-

Spray Timing	Materials	Rate/Acre	Cost/Acre	lbs./Ac
Post Bloom 1	Kocide 101	5.0 lb	9.50	
Pea Size	<u>N-Sure 28-0-0</u>	<u>2.0 gal</u>	<u>10.00</u>	<u>6 lbs. N</u>
	KeyPlex 445	2.0 qt	7.66	
	455 9E Spray Oil	0.25 gal	0.54	
Post Bloom 2 †	Kocide 2000	4.0 lb	5.20	
~April	<u>K-Phos 0-18-20</u>	<u>1.5 gal</u>	<u>6.00</u>	<u>3.1 lbs P_2O_5</u>
	455 9E Spray Oil	0.5 gal	1.08	3.5 lbs P_2O_5
Post Bloom 3	<u>K-Phos 0-18-20</u>	<u>1.5 gal</u>	<u>6.00</u>	<u>6.0 lbs P_2O_5</u>
~May 15	<u>Phos Might 0-22-20</u>	<u>0.5 gal</u>	<u>12.50</u>	<u>6.3 lbs K_2O</u>
Summer Oil 1	<u>N-Sure 28-0-0</u>	<u>1.0 gal</u>	<u>5.00</u>	<u>3 lbs N</u>
~July 1	KeyPlex 250	2.0 qt	8.20	
(167 gpa)	455 9E Sun Oil	3.5 gal	7.53	
Fall Flush	<u>K-Phos 0-18-20</u>	<u>1.5 gal</u>	<u>6.00</u>	<u>6.0 lbs P_2O_5</u>
~September 15	<u>Phos Might 0-22-20</u>	<u>0.5 gal</u>	<u>12.50</u>	<u>6.3 lbs K_2O</u>
Total Spray Materials Cost/Acre (not including foliar fertilizer)			\$39.01	
Total Foliar Fertilizer Cost/Acre			\$58.00	

Fertilizer Program- Apply a single ground application of a chemical based fertilizer without phosphorus and foliar applications of phosphorus containing fertilizers (see spray program above).

Ground Fertilizer Analysis: 14-0-14 3 Mg derived from the following:

Material	Analysis	Weight lbs.
Calcium Nitrate	15.5-0-0	500
Ammonium Nitrate	34-0-0	595
Sulfate of Potash	0-0-50	323
K-Mag	0-0-22 11.5 Mg	538
Sludge, New York		44
	Total Weight	2,000

Chemical Fertilizer Source and Price: Diamond R Fertilizer Co. ($214.25/ton)

Application Date	Rate per Acre	Cost/Ac
Feb. 16-19, 2001	700 lb/acre of Chemical Fertilizer	$ 74.99
See spray program above	(Foliar Fertilizer)	$ 58.50
		$133.49

Amount of Available Nutrients per Acre

Fertilizer Type	Per Cent Available 1st Yr.	Nitrogen Lbs N	Phosphorus Lbs P_2O_5	Potassium Lbs K_2O
Foliar Applied		**27***	**15**	**16**
Ground Applied Chemical		**98**	**0**	**98**
Total NPK/Ac/yr		**125**	**15**	**114**

* Foliar applied nitrogen is three times more effectively taken up by the plant than ground applied nitrogen and this rate has been elevated accordingly.

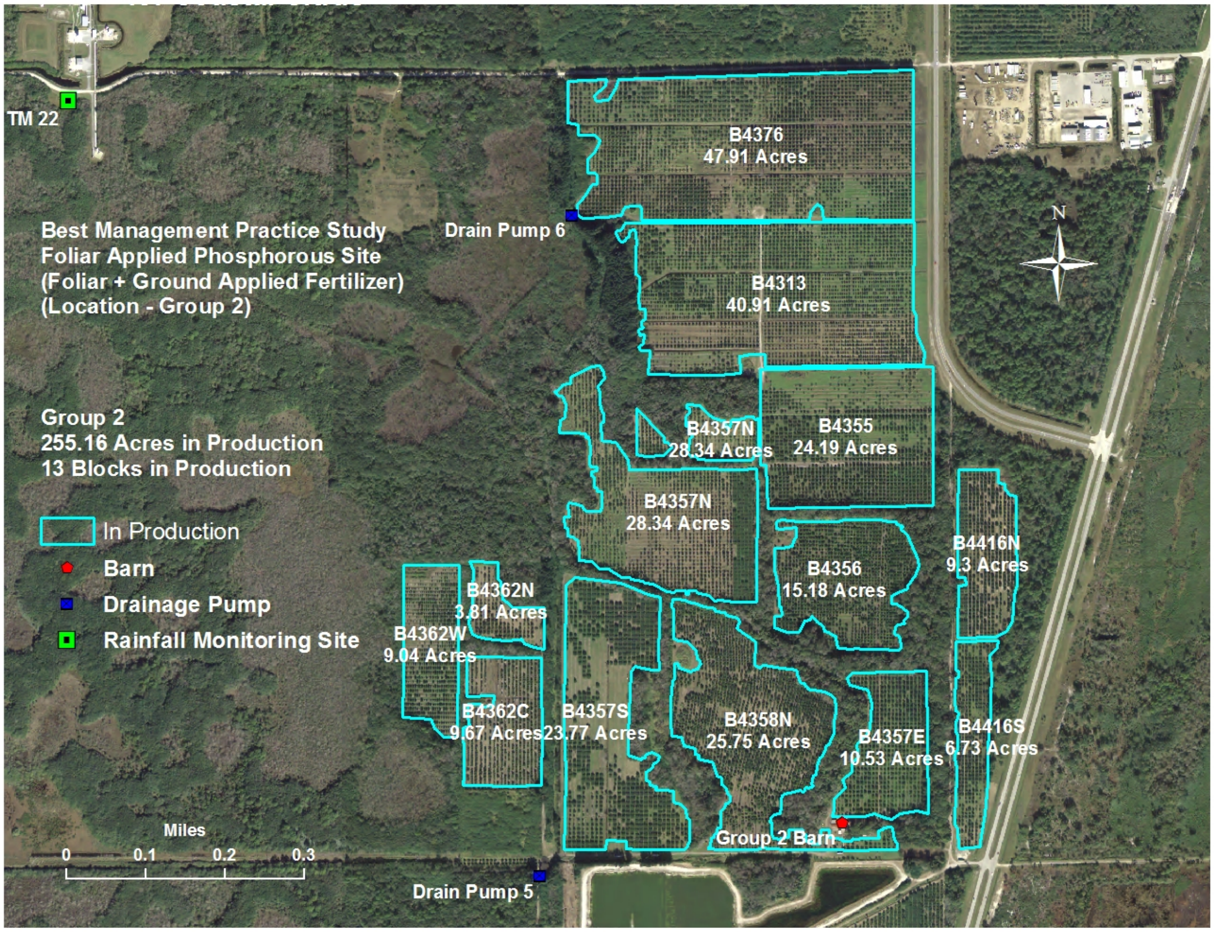
Weed Control Program-

Date	Materials	Rate/Tr. Acre	Spray Vol/Acre	Cost/Tr. Ac
Feb.	Round-Up Ultra	1.0 qt	20 gal	$10.42
	LandMaster II	1.0 qt		4.63
	Ammonium Sulfate	17 lb/100 gal*		.58
May	Round-Up Ultra	3.0 qt	33 gal	31.26
	Ammonium Sulfate	17 lb/100 gal*		.58
Sept.	Round-Up Ultra	2.0 qt	20 gal	20.84
	Ammonium Sulfate	17 lb/100 gal*		.58
		Total Annual Cost/TREATED Acre:		$68.89

* Qty. Of Adjuvant/ 100 gal tank — 1 Treated Ac = .50 Grove Ac
(Cost of Roundup Ultra @ $41.67/gal)

TOTAL ANNUAL HERBICIDE COST /GROVE ACRE: $34.45

Mow grove three times per year and chemical mow two times per year.



GIS Image 4. The Foliar Applied Phosphorus Site a.k.a. Group 2 demarked by blue borders.

4. Compost/Chemical Fertilizer Site (2nd Candidate Nutrient BMP)

Site- Group 4

Description- A 154.4 acre mixed orange and grapefruit citrus grove receiving ground applications of compost based fertilizers (derived from UPD and chicken manure) and a single ground application of chemical based fertilizer without phosphorus as a second candidate nutrient BMP for citrus is the designated compost fertilizer site.

Purpose- The purpose of the compost fertilizer site is to establish the level of phosphorus in surface water discharge originating from both ground applications of chemical and compost fertilizers as well as resident soil phosphorus in a coastal citrus grove.

Drainage System- A diesel powered 24 inch diameter drainage pump having a 12,000 gpm capacity (NASA pump no. 11).

Spray Program (No foliar fertilizer sprays are applied)-

Spray Timing	Materials	Rate/Acre	Cost/Acre
Summer Oil	N-Sure	1.0 gal	4.50
August 10	KeyPlex 250	3.0 qt	12.30
(167 gpa)	455 9E Sun Oil	5.0 gal	10.75
Total Spray Materials Cost/Acre			$27.55

Fertilizer Program- Apply a single ground application of a chemical based fertilizer without phosphorus in the Spring and a banded compost application in layers consisting of composted chicken manure (bottom layer) and composted urban plant debris (top layer).

Chemical Fertilizer Source and Price: Diamond R Fertilizer Co. ($224.25/ton)

Analysis: 9-0-14 3.0 Mg

Derived from the following:

Material	Analysis	Weight lbs.
Calcium Nitrate	15.5-0-0	1226
Sulfate of Potash	0-0-50	442
K-Mag	0-0-22 11.5 Mg	269
Ermathlite		64
	Total Weight	2,000

Composted Chicken Manure Source and Price: Boyd Bros. ($30.65/ton)

Analysis: 2.23-2.38-1.88 0.34 Mg

Composted Urban Plant Debris Source and Price: Overland Services ($15.20/ton)

Analysis: 0.60-0.22-0.22 0.08 Mg

Application Dates	Rate per Acre	Cost/Ac
May 16-19, 2001	850 lb/acre of Chemical Fertilizer	$ 95.31
Sept. 4-21, 2001	1.9 tons/acre of Composted Chicken Manure	$ 58.24
Sept. 20-24. 2001	2.4 tons/acre of Composted UPD	$ 36.48
	Total Fertilizer Cost/Acre	$190.03

Amount of Available Nutrients per Acre

Fertilizer Type	Per Cent N Available 1st Yr.	Nitrogen Lbs N	Phosphorus Lbs P_2O_5	Potassium Lbs K_2O
Composted Chicken Manure	**50***	**42†**	**72†**	**60†**
Composted UPD	**50***	**11†**	**6†**	**7†**
Chemical Fertilizer	**100**	**77**	**0**	**119**
Total NPK/Ac/yr		**134**	**78**	**148**

†Adjusted for the release rates for applied organic matter (N x 50%, P_2O_5 x 80%, K_2O x 85%). U.S. Department of Agriculture. Soil Conservation Service, 1992. Agricultural Waste Management Field Handbook.

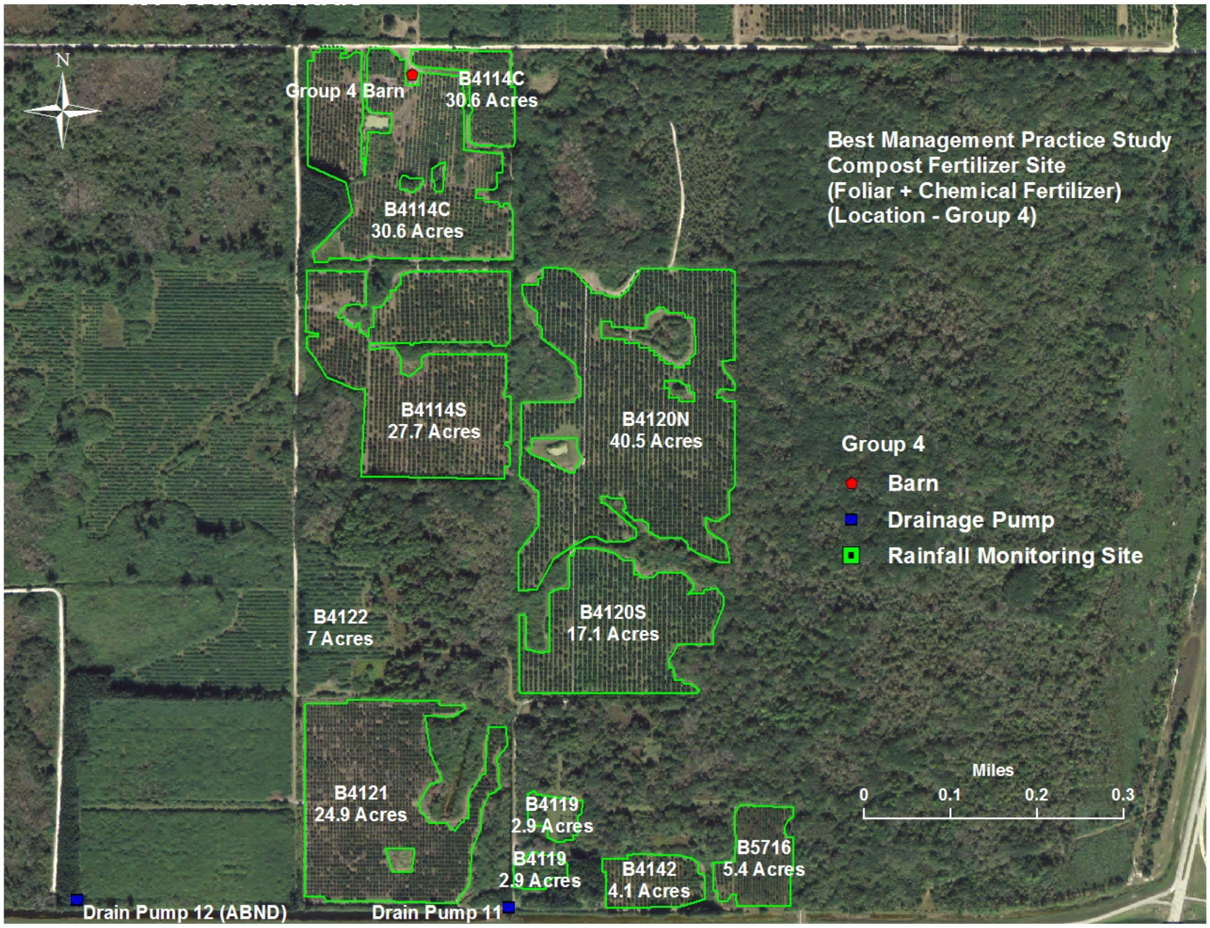
Weed Control Program-

Date	Materials	Rate/Tr. Acre	Spray Vol/Acre	Cost/Tr. Ac
May 7-11	Round-Up Ultra	3.0 qt	35 gal	$27.90
	Ammonium Sulfate	17 lb/100 gal*		.58
Aug. 19-23	Round-Up Ultra-Max	2.4 qt	33 gal	23.25
	Ammonium Sulfate	17 lb/100 gal*		.58
		Total Annual Cost/TREATED Acre:		$52.31

* Qty. Of Adjuvant/ 100 gal tank 1 Treated Ac = .50 Grove Ac
(Cost of Roundup Ultra @ $37.20/gal)
(Cost of Roundup Ultra-Max @ $38.75/gal

TOTAL ANNUAL HERBICIDE COST /GROVE ACRE: $26.16

Mow grove three times per year and chemical mow two times per year.



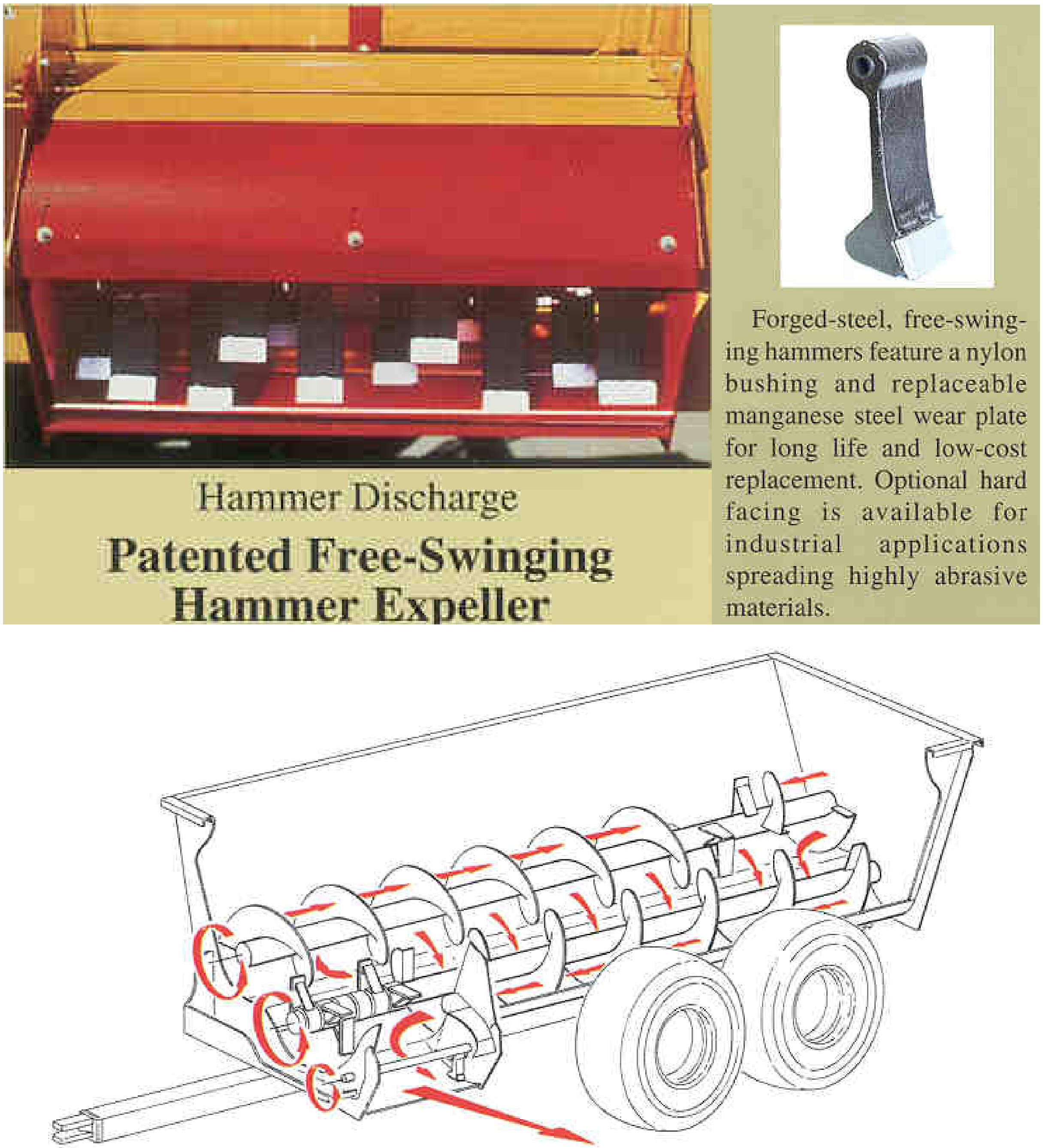
GIS Image 5. The Compost/Chemical Fertilizer Site a.k.a. Group 4 demarked by green orders.

<u>Compost Spreader & Modifications</u>

The candidate BMP using applications of organic matter required a search for a suitable side-delivery compost spreader possessing the following requirements: capability of maintaining a uniform spread pattern of organic matter to citrus trees, durability to handle both rough terrain and harsh foreign objects and rocks frequently found in poultry litter and UPD, capacity sufficient for at least 2 acres, a design that eliminates material bridging and packing, a reliable means to adjust the application rate and control the spread width, fast, efficient, and simple operation, and most importantly, affordability. Several models of compost spreaders were considered for our application. After speaking with several implement dealers and visiting the Ag Expo trade show in Moultrie, GA we selected the model 8014 ProTwin Slinger® Spreaders manufactured by Knight Manufacturing, Brodhead, WI for use in this project (Fig. 1).

Fig. 1. The Knight 8014 ProTwin Slinger Spreader as delivered by the manufacturer before modifications.

It featured a side discharge equipped with forged-steel, free swinging hammers that can pulverize large chunks of debris (Fig. 2). This spreader model possessed all the above requirements except capacity. We spoke with the company's engineers and they indicated that with low density materials (approximately 1,000 lb/cu yd) like compost, we should be able to extend the capacity from 6.1 cu yd to 13 cu yd by raising the sides up 36 inches. Using eleven-gauge corten steel plates and 1 3/4 inches x 3/16 inch angle iron, we constructed and bolted the hopper to the top of the spreader (Figs. 3-4). A steel pipe was welded to a 2 inch x 1/4 inch steel strap and attached via bolts to strengthen the top of the hopper (Fig. 5). Two cross members using the same pipe were bolted across the hopper for structural support. Aircraft tires were mounted to provide extra floatation in soft soils and to increase the load carrying capacity (Fig. 6). A "V" shaped side rail was bolted to each side to further increase the lateral support along the long axis of the hopper (Figs. 7-9). The hopper was sand blasted, primed, and painted before attachment to the spreader body. Silicone caulk was applied to the mating surfaces and grade 8 bolts and lock nuts were used to fasten the hopper to the spreader. The spreader complete with all the modifications is illustrated in Fig 9.   The retail cost for the spreader was approximately $12,400 and the labor and materials for the modifications amounted to $3,400 for a total cost of $15,800 (Table 1).



Cut-away view showing Patented Material Flow

Fig. 2. Design features of the compost Spreader. The free swing hammers pulverize and expel compost in a fine even pattern.

Fig. 3. A 36" high steel hopper was constructed out of 11 gauge "corten" steel to increase the capacity of the spreader to 13 cubic yards.

Fig. 4. The steel hopper was attached with angle iron (1 ¾" x 1 ¾" x 3/16") bolted with 3/8" diameter Grade 8 bolts (left) with a ¼" flat steel strap for reinforcement (right).

Fig. 5. Inside view of spreader (left) with the hopper installed showing the increased capacity. Steel pipe (1¼" dia.) was welded to the top hopper edges and as cross members for extra strength.

Fig. 6. Aircraft tires (40" x 14.5") were used to replace standard truck type tires to provide greater floatation in soft soils encounter in citrus groves.

Fig 7. Final version of modified compost spreader designed for application of organic matter to citrus. Lateral support to the sides was accomplished by means of attaching side rails constructed out of the same 11 gauge corten steel used to fabricate the hopper sides.

Fig. 8 Close-up of the construction details of the side rails added to the hopper sides for strength. Grade 8 bolts (3/8" diameter) were used to bolt the rails in place.

Fig. 9. The completed compost spreader with all the modifications. The addition of the hopper increased the spreader's capacity from 6.1 cubic yards to 13 cubic yards. (Pictured in the center is Mr. David Connell who made and designed the hopper.)

Table 1. Compost Spreader & Modifications Costs

Compost Spreader

Supplier	Cost	Description
Pedrick Enterprises Quitman, GA	$12,400.00	8014 Knight Spreader (currently comes with wide implement tires)

Modifications

Category	Cost(s)	Description
Metal	$ 839.59	Angle iron steel: 37.5 ft Flat iron steel: 50 ft Steel pipe: 26.25 ft Sheet/plate: 3 sheets, 4' x 10' Cutting & Bending Steel

Category	Cost(s)	Description
Hardware	$ 162.49	Nuts, bolts, washers, locknuts, c-clamps (to make a jig for welding pipe border on spreader), drill bits

Modifications (continued)

Category	Cost(s)	Description
Labor	$1,200.00	Changed tires & wheels on spreader to aircraft tires; Designed 3' high hopper for spreader to increase load capacity; Supervised & coordinated outside fabrication and painting of hopper body for spreader; Installed 8 cu yd capacity hopper to compost spreader; Strengthened hopper body sides and installed cross members on hopper; and installed stronger drive clutch to compost spreader
Welding Supplies	$ 63.90	10 lbs of low hydrogen welding rod ($30) ½ tank oxygen ($19.65) ¼ tank acetylene ($14.25)
Paint and primer	$ 182.57	1 gal Knight Yellow Paint & 1 gal Primer
Labor	$ 790.60	Sandblast, prime, and paint hopper
Tools	$ 23.94	Nylon Sling to lift hopper
Hydraulics	$ 42.92	Hydraulic Hoses & Hose Ends
Total Modification Costs	**$3,378.29**	

Repairs

Supplier	Cost(s)	Description
Miller Bearings	$ 273.88	Roller Chain and roller link
St. Lucie Battery & Tire	$ 104.54	Repair tire/Spreader
Pedrick Enterprises	$ 174.56	Clutch, Separator, Spring
Turner Machine	$ 152.03	Replace tube and bar on PTO shaft

Category	Cost(s)	Description
Apple Machine	$ 98.16	Spacer kit, air tank
Hogan Grove Care	$ 315.56	Repair tires, tire tube
Total Repair Costs	**$1,118.73**	

Compost Sources and Evaluation

Poultry manure originates from either broiler or caged layer operations and can be obtained as either the fresh form (manure alone) or litter form (combined with bedding material such as sawdust, wood shavings, or peanut hulls) (Obreza and Ozores-Hampton, 2000). The preferred source is broiler litter because it is composted with pine sawdust and has a relatively low odor. Good quality composted broiler litter requires a well-designed composting facility that is covered and turned regularly. Compost meeting these requirements is available in the region around Live Oak, FL. This is largely due to cooperative projects with the local poultry producers, the Natural Resource Conservation Service (NRCS) and the Suwannee River Water Management District to build composting facilities with cost-shared monies to reduce leached nitrates from improperly handled poultry manure. Prices ranged from $33 to $35 per ton delivered (200 miles, one-way) to the citrus groves at the MINWR (Appendix 2). Samples (8 oz) of broiler litter were taken from piles according to the method described in Fig. 10 and sent to A&L Analytical Laboratories, Inc., Memphis, TN, for their Basic M2 ($30 each) laboratory analysis (Appendix 3).

Urban Plant Debris (UPD) is derived from many possible organic sources including ground yard waste or vegetation from land clearing projects. It is the most variable of the sources of organic matter available to the grower and should be carefully evaluated before purchasing. First, we visually inspected the UPD looking at the aggregate size of the chips or debris. We required that the UPD be well ground and screened to ½ inch or less with no hard wood present. Smaller sized woody debris increases the composting rate which produces better compost. Avoid sources that contain plastic, metal, and other trash. Smell the UPD. Good composted UPD should smell like fresh soil or humus. Next, samples were taken from the piles meeting these criteria using the methods indicated in Fig. 10 and placed in plastic Ziplock bags labeled with the source and location. To determine how much sand was present in the compost, we developed a simple compost evaluation method based on the sediment density of the different materials present. One cup (8 oz) of UPD was weighed and recorded with a triple beam balance. Next, it was mixed with 450 ml of water using a plastic 500 ml graduated cylinder, and is described in detail in Fig. 11. The different sediment layers resulted from differences in density of the various materials present in the UPD. The volumes of each was determined visually and recorded. The densest material was sand which quickly fell to the lowest layer. The better UPD had the lower amounts of sand and floating debris (Table 2). Eight oz of the UPD sample was sent to the laboratory for the same analysis (Appendix 4). The remainder of the UPD sample was kept sealed in the Ziplock bags while the samples were processed by the lab. After about ten days the samples were inspected for germinating/ed seeds (Fig. 12) If seedlings were observed, that particular source was rejected, since noxious weeds could be brought into the citrus groves via the application of that source of UPD.

Fig. 10. A good sampling procedure for compost is shown above.

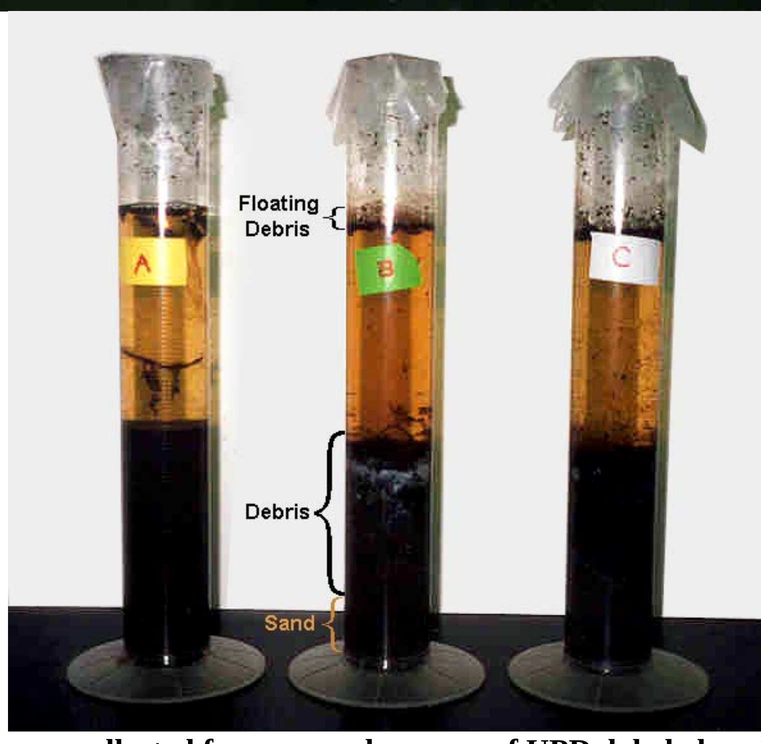


Fig. 11. Samples were collected from several sources of UPD, labeled, weighed, and placed in Ziplock plastic bags (upper photo). An 8 oz. sample was added with 450 ml of water to a 500 ml graduated cylinder, shaken and allowed to settle 24 hrs allowing for a visual determination of sediment volumes by type (lower photo).

Fig. 12. Plastic Ziplock bags were a handy way to label and store compost samples and also proved to be an easy means to check for viable weed seeds found in improperly composted UPD. Good compost must under sufficient heat (>160 degrees F.) during the composting process to kill pathogens and weed seeds.

Table 2. The results of compost evaluation by sedimentation for six sources of Urban Plant Debris (UPD) are shown here. Sedimentation was performed by placing 8 oz samples of compost in 450 ml water in 500 ml graduated cylinders. The mixtures were shaken 15 sec and allowed to settle 24 hrs before recording the sedimentation volumes.

				Sedimentation Volumes in 500 ml Graduated Cylinder				
UPD Sample	Wt/8 oz Cup	Color	Odor	Sand (ml)	Silt (ml)	Debris (ml)	Floating Debris (ml)	Bulk Density
A	89.52 gm	Brown/Black	Strong, Woody & Acrid Smoke					
B	90.50 gm	Black	Mild, Woody					
C	99.48 gm	Black	Faint, Earthy-Humus	~20	–	225	15	
D	59.44 gm	Brown	Medium, Woody Cypress					
H	97.01 gm	Black	Very Faint, Earthy-Humus					
E	103.75 gm	Black	Faint to Moderate, Earthy-Humus	~10	–	220	7.5	900 lb/yd
Composted	Broiler Litter							1000 lb/yd

The results from the laboratory analysis for the broiler litter and UPD are located at the end of this report in Appendices 3 & 4 . This report of analysis indicates the nutrient levels on both a "dry basis" and "as received". We used the "as received" basis to determine nutrient concentrations in standard fertilizer terms as: % N for nitrogen, % P_2O_5 for phosphorus, and % K_2O for potassium. The pounds of nutrients per ton for phosphorus as P_2O_5 and potassium as K_2O were converted to percent by dividing the pounds of nutrients per ton by 2000.

	Laboratory Analysis Results (expressed in fertilizer terms)			
Organic Matter	% N	% P_2O_5	% K_2O	% Mg
Composted Broiler Litter	2.23	2.38	1.88	0.34
Composted Urban Plant Debris	0.60	0.22	0.22	0.08

Chemical analyses are required for assurance that the concentration of heavy metals present was below the EPA approved levels (Table 3). It cannot be emphasized too strongly, the importance of obtaining a laboratory analysis and checking both the nutrient levels and heavy metals concentrations, before receiving any organic matter for agricultural application, which is required for Good Agricultural Practices (GAP). Appendix 2 lists a few compost vendors that growers can use to provide organic matter for application to citrus. For both safety and liability issues we highly recommend that shuffle-floor (a.k.a. walking floor) semi-trailers (Fig. 13) be used to deliver the compost.

Table 3. U.S. Environmental Protection Agency (US EPA CFR40, Part 503*) and State of Florida (Fla. Chapter 17-709) maximum heavy metals ceilings for unrestricted application of organic matter or bio-solids.

Heavy Metal	EPA Ceiling (ppm	Fla. Ceiling (ppm)
Arsenic	41	41
Cadmium	39	39
Copper	1500	1500
Chromium	1200	1200
Lead	300	300
Mercury	17	17
Molybdenum	75	75
Nickel	420	420
Selenium	36	36
Zinc	2800	2800

*US EPA CFR40, Part 503 is written for application of municipal solid waste or bio-solids.

Organic matter like all other bulk materials transported in semi-trailers is sold based on weight. However, weight is unlikely to be useable as a measurement for calibration by the grower. Since growers would use a front-end loader with a known bucket capacity in cubic yards to load the compost spreader, they could use volume to make their spreader calibrations as so many cubic yards per acre. To convert weight of organic matter to volume we first determined the bulk density or weight in pounds per cubic yard for both the broiler litter and UPD. The methods we used to do this and calibrate the spreader are indicated below:

Fig. 13 The composted broiler litter was delivered to the Merritt Island National Wildlife Refuge citrus groves using "walking floor" semi-trailers which are safer than dump type trailers because they are unlikely to tip over during unloading. The steam coming off the broiler litter is due to the heat produced from the bacterial decomposition inherent to the composting process.

Method to Calibrate Compost Application rates

1. Determine the bulk density or weight per cubic yard of the compost

   It is necessary to determine the bulk density of compost first before calibrating the compost spreader because volume of organic matter expressed as cubic yards is more practical for agricultural applications of low density materials like compost. Mike Litvany of Nutri-Source, Inc. in Orlando provided us with a simple method to determine the bulk density of compost. First, obtain a 5 gal plastic pail and a good hanging scale with a weight range of up to at least 50 lb. Next, weigh the empty pail and write down the weight of the empty pail. Then using a shovel, fill the pail with the compost that you will be using to make your applications. Make sure the compost at the top of the pail is level. Next, weigh the pail containing the compost and subtract the weight of the empty pail. This will be the weight of 0.79 cu ft of compost since a level, 5 gal pail has an internal volume of 0.79 cu ft. Next multiply the net weight of the compost by 34.2 and you will have the bulk density of your compost expressed in lb per cubic yard. To determine how many cubic yards of compost you have per truck load, you simply divide the net weight (in lb) of the compost (indicated on the weigh ticket as furnished by the trucker) by the bulk density. This gives the number of cubic yards per truck load.

Formula to determine bulk density:
Method to calculate bulk density of compost based on a 5 gal pail sample-
1. 5 gal pail contains 0.79 cu ft ($1 \div 0.79 = 1.266$ = correction factor to convert to 1 cu ft)
2. Weight empty 5 gal pail
3. Weigh material in a 5 gal pail
4. Subtract weight of empty 5 gal pail to yield the net weight of material
5. Multiply net weight of material in 5 gal pail times 1.266×27 = the number of lb/cu yd

These calculations were used to derive the following formula:
Net weight (lbs) of material in a 5 gal pail times 34.2 = no. of lb per cu yd

2. Determine the capacity of the loader bucket
Find out the full capacity of the bucket you will be using to load the spreader from the manufacturer of the front-end loader.

3. Calibrating the compost spreader
Load the compost spreader approximately half full with uniformly filled bucket-loads of compost. Keep track of the number of buckets dumped into the hopper of the spreader to calculate the number of cubic yards of organic material to be spread. Use Appendix 1 to determine the number of trees per acre based on the tree spacing and the distance between tree rows for the grove that will be receiving the compost. Multiply the number of trees per acre by the distance between the trees in the tree row. This distance multiplied by two (assuming you want to apply compost to both side of the trees) will be the distance the spreader must travel to spread 1 acre of trees with compost. By adjusting the ground speed of the tractor and the gate opening of the spreader, the operator can accurately apply the desired rate of compost to the citrus grove. Several trials may be necessary to find the right combination of ground speed and degree of gate opening. Use spacers placed on the hydraulic cylinder shaft to limit the extent of the gate opening so that when the gate is closed and reopened, it will only open to the preset dimension, thereby consistently delivering the desired amount of organic matter.

Load the compost spreader half full with uniformly full bucket-loads of compost keeping track of the number of buckets dumped into the hopper of the spreader. Based on the tree spacing and tree density chart found using Appendix 1, determine the number of trees per acre for the grove that will be receiving the compost and the desired amount of compost in cubic yards per acre.

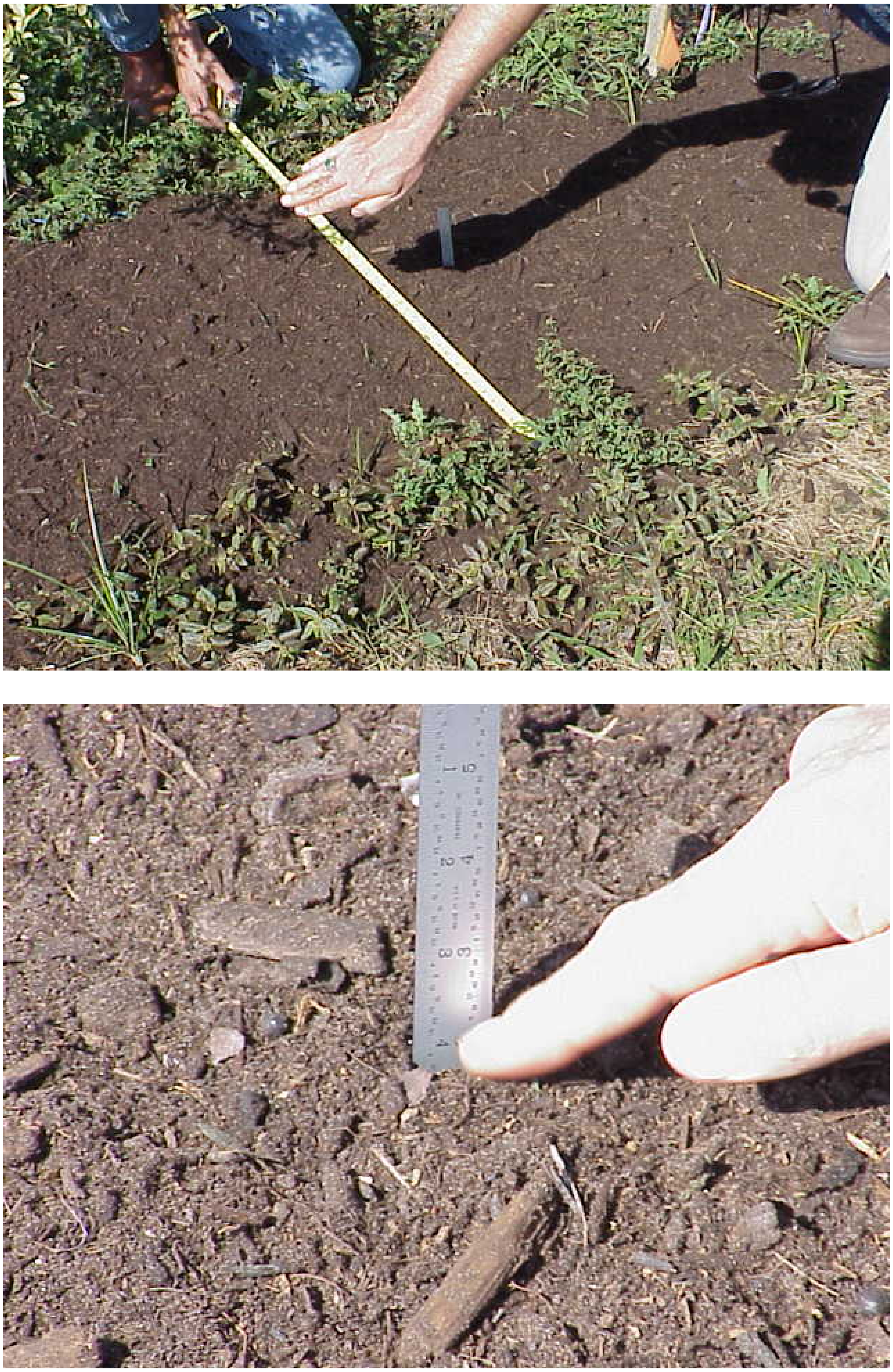


Fig. 14. The volume of the organic material discharged can be calculated by measuring the width of the band as shown in the upper photo and likewise for depth (lower photo). The width times depth times the length of the band applied (measured in yards) determines the cubic yards of organic matter applied.

Fig. 15. The material discharge rate is determined by two factors, the ground speed and the extent the side discharge gate is opened. The upper photo depicts a 12 cu yd/Ac (gate fully open) application rate versus a 2 cu yd/Ac rate (gate ¼ open) in the lower photo.

Fig. 16. The strategy for organic matter application used in this study was to apply an initial layer of 1.9 tons/Ac of chicken manure (upper photo) superimposed with an upper layer of Urban Plant Debris (UPD) at 2.4 tons/Ac as shown in the lower photo.

Multiply the number of trees per acre by the distance between the trees in the tree row. This distance multiplied by two will (assuming you want to apply compost to both side of the trees) will be the distance the spreader must travel to spread compost on one acre. By adjusting the ground speed of the tractor and the gate opening of the spreader the operator can achieve the desired rate of compost to the citrus grove. Several trials may be necessary to find the right combination of ground speed and amount gate opening. The video demonstrates the method we used to adjust the gate opening.

The compost spreader was hooked up to a 90 Hp tractor having a power take-off (PTO) to operate the compost spreader. Using a front-end loader, the spreader was loaded and made several practice applications using both the broiler litter and UPD from the sources noted in Appendix 2. During the calibration process described above, we attempted to deliver a 2 ft wide band of compost (Fig. 14). This was accomplished with the Knight Bedder Spreader Attachment in the fully down position (Fig. 15). As discussed earlier, our goal for the application of compost to citrus was to use economically affordable rates of organic matter optimally placed on the trees densest root zone for greatest agronomic impact to the tree and ultimately to increase crop production. To accomplish this, we were directed by Mike Ziegler of Agricultural Resource Management, Vero Beach, FL to use two superimposed bands of organic matter with broiler litter applied first for the lower layer and UPD for the second upper layer (Fig.16). The strategy was to use broiler litter as both a source of nutrients and soil amendment and utilize the UPD for the same but also as a mulch to trap and hold the volatile, ammoniacal nitrogen from the chicken manure as a nitrogen source for denitrifying bacteria. These bacteria in turn enhance the carbohydrate breakdown of the carbonaceous material in the organic material to produce soil building humus.

Outcome

Compost applications were made to the study site employing the modified compost spreader using the methodology described above. The modified compost spreader performed well and the overall application proceeded relatively well. There were a few difficulties encountered that bear mentioning for growers wanting to implement compost applications in their groves. They are:

1. A few shipments of wet broiler litter were delivered and caused considerable difficulty by clogging the spreader when the gate was partially closed to deliver the required 1.9 tons/acre. Two ways were found to deal with wet manure. One was to open the gate and the second was to mix the wet broiler litter with the dryer and coarser UPD. It is imperative that the grower's contract with the vender stipulates dry organic material coming from covered composting facilities.

2. Overloading the modified spreader with the increased capacity with materials having a higher bulk density (>1,200 lb/cu yd) may result in clutch slippage on the PTO shaft or breaking the drive chain for the twin augers. This happened during the early calibration process when the operator of the front-end loader added soil from the bottom of the

compost pile producing a denser material. When the PTO was placed in gear the clutch burned up and stretched the drive chain which eventually broke. Both the chain and the clutch were replaced. A Knight Manufacturing factory representative suggested replacement with a heavy duty clutch and their advice was correct. A word of caution concerning overfilling the modified spreader is that if the clutch slips or the chain breaks, the operator will need to shovel out the excess material by hand. We observed a very fast learning curve by operators not to fill the spreader more than two thirds full or about 9 cu yd. Simply stated, "Do not over fill the spreader"!

3. Do not make applications during the rainy season or when rainy periods are forecast. The delivery trucks will get stuck and the likelihood of receiving wet organic material is very high. Application during Florida's dryer winter and spring, after the crops are picked, are optimal.

4. Weld a treaded 1½ inch steel pipe to the wheel rims to protect the valve stems from breakage by tree limbs and debris in the grove. Repairing flats on the compost spreader were solely due to broken valve stems that proved to be costly to repair (Table 1, repairs).

The economics of the compost application are presented in Table 4. It should be pointed out that the applications were made in September, 2001 which was unseasonably wet and as a result increased the time for the two applications to be completed. Even still, the cost per acre of $36.13 was deemed to be acceptable to growers. With good weather and a little experience, this cost would likely approach $30 per acre.

Table 4. A detailed cost breakdown for two superimposed band (24") applications of broiler litter (at 1.9 T/Ac) and Urban Plant Debris (at 2.4 T/Ac) applied with the modified spreader to a 154.4 acre coastal citrus grove at the MINWR.

Equipment/Labor	Cost/hr	Total Cost	Cost/Acre
Compost Spreader ($134 hr)	$15.00[z]	$ 2,010.00	$ 6.51
85HP Tractor & Driver ($134 hr)	$29.00	$ 3,886.00	$12.58
John Deere 444H Loader, with 2.5 cu yd bucket		$ 2,850.00[y]	$ 9.23
Loader Operator	$18.00	$ 2,412.00	$ 7.81
TOTAL		$11,158.00	$ 36.13

[z] Estimated by using industry standard rates where the total spreader cost is multiplied by 0.1%.
[y] Monthly rental cost.

The implementation of both the conventional and candidate Foliar BMP fertility programs were comparatively uneventful with the exception of the prolonged dry period extending from November, 2000 to May, 2001 followed by a wetter than normal rainy season from July, 2001 to September, 2001. The actual costs and nutrient quantities for each fertility practice are compared in Table 5. The conventional program using two applications of chemical fertilizer was demonstrated to be the least expensive for both application and material costs. The Compost BMP was most costly due to greater application and material costs.

However, a more expensive chemical fertilizer ($27.61 more than the conventional fertilizer cost) was used at this site than was used at either of the other two sites. Even with similar chemical fertilizer costs, it was twice the cost of the conventional program. If both the application and material cost were each reduced by $30, then the combined cost per acre would be $210 which approaches the Foliar BMP program cost. The rates of applied nitrogen, phosphorus, and potassium for the conventional and Compost BMP programs are comparable, while the foliar BMP is below Univ. of Fla. recommended rates for citrus. This was because the grower managing the Foliar BMP site canceled his second application of chemical fertilizer. This reduced the total fertility cost by about $33. If this application had been performed as planned, the Foliar BMP fertility program cost would be $225 or virtually identical to the Compost BMP program, assuming the applications were made under the favorable conditions suggested above.

Table 5. Economic and fertility comparisons of a conventional fertility program with two candidate BMP fertility programs.

Conventional Program Fertilizer Type	Fertilizer Cost per Acre	Application Cost per Acre	Combined Cost per Acre	Nitrogen N lbs/Ac	Phosphorus P_2O_5 lbs/Ac	Potassium K_2O lbs/Ac
1st Ground Applied Chemical Fertilizer	$ 67.64	$ 7.30	$ 74.94	98	14	98
2nd Ground Applied Chemical Fertilizer	$ 38.65	$ 7.30	$ 45.95	56	8	56
Total	$ 106.29	$ 14.60	$ 120.89	154	22	154

Foliar BMP Fertilizer Type	Fertilizer Cost per Acre	Application Cost per Acre	Combined Cost per Acre	Nitrogen N lbs/Ac	Phosphorus P_2O_5 lbs/Ac	Potassium K_2O lbs/Ac
One Ground Applied Chemical Fertilizer	$ 58.50	$ 7.30	$ 65.80	98	0	98
Two Spray Applied Foliar Fertilizer	$ 74.99	$ 51.50	$ 126.49	27*	15	16
Total	$ 133.49	$ 58.80	$ 192.29	125	15	114

* Foliar applied nitrogen is three times more effectively taken up by the plant than ground applied nitrogen and this rate has been elevated accordingly.

Compost BMP Fertilizer Type	Fertilizer Cost per Acre	Application Cost per Acre	Combined Cost per Acre	Nitrogen N lbs/Ac	Phosphorus P_2O_5 lbs/Ac	Potassium K_2O lbs/Ac
One Ground Applied Chemical Fertilizer	$ 95.31	$ 7.30	$ 102.61	81	0	81
Composted Broiler Litter	$ 58.24	$ 31.93	$ 90.17	42†	72†	60†
Composted UPD	$ 36.48	$ 40.33	$ 76.81	11†	6†	7†
Total	$ 190.03	$ 79.56	$ 269.59	134	78	148

†Adjusted for the release rates for applied organic matter (N x 50%, P_2O_5 x 80%, K_2O x 85%). U.S. Department of Agriculture. Soil Conservation Service, 1992. Agricultural Waste Management Field Handbook.

According to the **Agricultural Waste Management Notebook**, 50% of the nitrogen is released the first yr, 25% the second yr, and 12% the third yr. Therefore, the true quantities of nutrients applied as organic matter would be 74% greater than indicated over a 3 yr period. This amounts to 39 lb more nitrogen that is actually applied to the trees that is slowly released the second and third yr by mineralization of the organic matter.

Table 6. Plant tissue nutrient status in percent dry weight of citrus leaves based on 4-6 month old spring flush leaves sampled from non-fruiting terminals [z].

Parameter	Deficient	Low	Optimum	High	Excess
N %	<2.2	2.2-2.4	2.5-2.7	2.8-3.0	>3.0
P %	<0.09	0.09-0.11	0.12-0.16	0.17-0.30	>0.30
K %	<0.7	0.7-1.1	1.2-1.7	1.8-2.4	>2.4

[z] D. P. H. Tucker, A. K. Alva, L. K. Jackson, and T. A. Wheaton (ed.). 1995. Nutrition of Florida Citrus Trees, IFAS, Fl. Coop. Ext. Serv. SP 169

Table 7 indicates that the soil fertility levels sampled from each of the study sites at the start of the study were all roughly comparable with the exception of the control site which indicated somewhat lower values due to the fact that it is an abandoned grove. The Foliar BMP site exhibited the best soil based on the four parameters featured. Similarly, the leaf analysis performed at the conclusion of the study, demonstrated a similar trend for primary nutrients expressed in leaf tissue. Leaf tissue analysis revealed nutrient levels for nitrogen, phosphorus, and potassium were all in the optimum category based on IFAS recommendations as shown in Table 6 except for the Control Site which displayed a low nitrogen concentration (Table 7). This indicates low resident soil fertility levels that would be expected from an abandoned citrus grove not receiving fertilizer. A low potassium level of 1.18 % occurred in the Foliar BMP site and can be explained by the large crop load that was observed at this site. In conclusion, all three fertility programs appeared to provide optimum nutrient levels to the trees based on leaf analysis. There were no clear nutritional differences observed visually between the three fertility programs.

Table 7. Fertility levels for each fertility program site based on soil and leaf analysis.

	Soil Analysis Parameters (onset of study)				Leaf Analysis Parameters (final)		
Fertility Program Site	% O.M.	pH	P ppm	K ppm	%N	%P	%K
Control	1.8	6.3	24	49	2.04 (Low)	0.12	1.64
Conventional	2.3	7.4	60	94	2.47	0.16	1.27
Foliar BMP	3.0	6.7	108	195	2.75	0.13	1.18
Compost BMP	2.3	7.1	28	74	2.58	0.14	1.50

Abbreviations used: O.M. = Organic Matter, P = Elemental Phosphorus, K = Elemental Potassium, and N = Elemental Nitrogen

The volume of surface water discharged by diesel powered pumps located at each of the study sites was calculated for the third quarter of 2001 and is displayed in Table 8. This time period was the most meaningful for this study since very little pumping activity occurred during the first two quarters of 2001 due to low rainfall. Using rainfall data obtained at two close proximity sites from NASA at the Kennedy Space Center, the volume of water received per acre at each study was determined and displayed for the third quater. Unfortunately, the data appears to be flawed since more surface water was pumped than received as rain water for all the study sites except the Compost BMP site. Several explanations are likely. Either the pump calibration rates were grossly overestimated or additional surface water originating from outside the study area entered the study area. The latter most likely happened at the Control Site since the grower managing that site observed water reentering the grove during periods of flooding. The other two sites may have experienced this same problem. The Compost BMP Site exhibited relatively credible amounts of discharged surface water. This site has an intact perimeter ditch and is located on higher ground. Locations of the two rainfall collection sites identified as TM 22 and TM 23 can be found on the aerial image GIS Image 1 (page 4). Rainfall site TM23 was closest to the Conventional Site while rainfall site TM 22 was closer to the other three study sites. This explains why the rainfall received per acre is identical for all the sites except the Conventional Site.

Table 8. Surface water volume received from rainfall and discharged by pumping for each fertility program site from July 1 to Sept. 30, 2001.

Fertility Program Site	Citrus Acreage	Total Surface Water Pumped/Acre (Units 10^6 gal)	Rainfall Volume Received/Acre (Units 10^6 gal)
Control	13.9	11.061	0.819
Conventional	45.7	3.354	0.770
Foliar BMP	262.2	1.006	0.819
Compost BMP	154.4	0.551	0.819

The results of the quarterly water analysis for nitrogen and phosphorus are graphically portrayed for each study site along with monthly rainfall (Appendix 5, Graphs 1-4). The third quarter provided the most meaningful data for nutrient levels discharged in the storm water since most of the rainfall and hence pumping activity occurred during this time period. All the chemical fertilizers were applied prior to that period of pumping activity either in February or May 2001. Graph 1 indicates very low total nitrogen levels, ranging from 1.6 mg/l to below Minimum Detection Limits (MDL), for all four collection periods. The phosphorus values were similarly low at the same site except for the dubious Oct, 2000 orthophosphate value of 0.41 mg/l which is greater than the total phosphorus level of 0.19mg/l. This indicates a laboratory error since total phosphorus must be greater than orthophosphate level since it is one of many phosphorus compounds making up the total phosphorus. Both these observations are consistent with the lack of fertilizer applied at the Control Site.

The highest phosphorus levels detected for all sites occurred at the Conventional Site in both June and September (Graph 2). Here, phosphorus containing fertilizer was applied in February 2001 prior to water sampling. Total nitrogen was also elevated at this site for the same collection periods. The Foliar BMP site exhibited low nitrogen and phosphorus values during this same time period (Graph 3). It is noteworthy to point out the elevated phosphorus levels indicated in September and October, 2000 at this site after a phosphorus containing fertilizer was applied prior to the inception of this study. The highest level of total nitrogen (5.7 mg/l) observed during the study occurred in June 2001 after a May application of nitrogenous fertilizer without phosphorus at the Compost BMP site (Graph 4). The data displayed an elevated total nitrogen in June, 2001 that diminishes in September while the total phosphorus remains consistently low throughout the study period. This observation is consistent with an application of nitrogen based fertilizer without phosphorus. It is important to point out that sites where no chemical phosphorus were applied, the total phosphorus was detected at 0.15mg/l or less. The source for this phosphorus is probably from naturally occurring phosphorus indigenous to the soil.

The application methodology was found to be efficient for the candidate BMP using foliar sprays of nitrogen and phosphorus using conventional citrus sprayers. The modified Knight compost spreader performed effectively and reliably under harsher conditions than are typically found in commercial citrus groves. Both the Foliar and Compost candidate BMP fertility programs were shown to be capable of providing adequate nitrogen and phosphorus levels to citrus trees without ground applications of chemical based phosphorus fertilizers. Both candidate BMP fertility programs, when applied at similar fertility levels were equivalent in cost assuming favorable application conditions, but were twice as expensive as the conventional fertility program using ground applied chemical fertilizer. No significant differences between the three fertility programs were observed based on the nutrient status of the trees.

While we were not able to quantify the amount of nutrients discharged in storm water for each fertility program, we were able to identify trends based on nutrient levels detected in the storm water. Unfortunately, we were not able to assess the impact of the applied organic matter on surface water due to the late application at the end of the study period. However, this data will be collected and archived for future study. Our data did demonstrate a reduction in phosphorus levels in storm water where fertilizers not containing phosphorus were applied. Storm water nitrogen levels were below the E.P.A. drinking water standard of 10 mg/l for all applications.

Further Recommendations

In light of the problems encountered with the pumping volumes, laboratory error(s), and the limited number of water samples taken per site, it was not possible to quantify the amount of the nutrients discharged in storm water. As a result, we were unable to make any conclusions regarding the degree of environmental impact by nitrogen or phosphorus arising from the different fertility programs. To make a recommendation as to the merit or fault of one fertility program based on the environmental impact based on our results presented here would be imprudent. Further research efforts are necessary to determine the precise environmental impact for different nutrient application methods as well as different nutrient sources for agricultural use that are economically viable for growers.

A second area regarding more research effort is finding new ways to reduce the materials and application costs for the use of foliar and organic matter fertilization on citrus. One possible approach to accomplish this would be to study nutrient release of citrus groves receiving successive organic matter applications. The values used in this study for the mineralization rates of organic matter are estimates and more reliable data tailored for Florida citrus needs to be determined. Continued work using foliar and organic matter applications to citrus is warranted to discover, develop, and improve the methodology and infrastructure for these important BMPs for coastal citrus to remain viable.

Lastly, it is strongly recommended that the momentum achieved as a result of this project, continue to receive support. This so-called momentum is expensive and has been paid for. It includes the equipment resources, experiential knowledge, and the tremendous resources of the four study sites at the MINWR citrus groves. The continuation of this study appeals for the opportunity to perform the above recommendations.

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Appendix 1. Tree spacing chart to determine number of trees per acre.

Tree Spacing	Row Spacing																						
Ft.	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
15	193.60																						
16	181.50	170.16																					
17	170.82	160.15	150.73																				
18	161.33	151.25	142.35	134.44																			
19	152.84	143.29	134.86	127.36	120.67																		
20	145.20	136.13	128.12	121.00	114.63	108.90																	
21	138.29	129.64	122.02	115.24	109.17	103.71	98.78																
22	132.00	123.75	116.47	110.00	104.21	99.00	94.29	90.00															
23	126.26	118.37	111.41	105.22	99.68	94.70	90.19	86.09	82.34														
24	121.00	113.44	106.77	100.83	95.53	90.75	86.43	82.50	78.91	75.63													
25	116.16	108.90	102.49	96.80	91.71	87.12	82.97	79.20	75.76	72.60	69.70												
26	111.69	104.71	98.55	93.08	88.18	83.77	79.78	76.15	72.84	69.81	67.02	64.44											
27	107.56	100.83	94.90	89.63	84.91	80.67	76.83	73.33	70.14	67.22	64.53	62.05	59.75										
28	103.71	97.23	91.51	86.43	81.89	77.79	74.08	70.71	67.65	64.82	62.23	59.84	57.62	55.56									
29	100.14	93.88	88.36	83.45	79.06	75.10	71.53	68.28	65.31	62.59	60.08	57.77	55.63	53.65	51.80								
30	96.80	90.75	85.41	80.67	76.42	72.60	69.14	66.00	63.13	60.50	58.08	55.85	53.78	51.86	50.07	48.40							
31	93.68	87.82	82.66	78.06	73.96	70.26	66.91	63.87	61.09	58.55	56.21	54.04	52.04	50.18	48.45	46.84	45.33						
32	90.75	85.08	80.07	75.63	71.65	68.06	64.82	61.88	59.19	56.72	54.45	52.36	50.42	48.62	46.95	45.38	43.91	42.54					
33	88.00	82.50	77.65	73.33	69.47	66.00	62.86	60.00	57.39	55.00	52.80	50.77	48.89	47.14	45.52	44.00	42.58	41.25	40.00				
34	85.41	80.07	75.36	71.18	67.43	64.06	61.01	58.24	55.70	53.88	51.25	49.28	47.45	45.76	44.18	42.71	41.33	40.04	38.82	37.68			
35	82.97	77.79	73.21	69.14	65.50	62.23	59.27	56.57	54.11	51.86	49.78	47.87	46.10	44.45	42.92	41.49	40.15	38.89	37.71	36.61	35.56		
36	80.67	75.73	71.18	67.22	63.68	60.50	57.62	55.00	52.61	50.42	48.40	46.54	44.81	43.21	41.72	40.33	39.03	37.81	36.67	35.59	34.57	33.61	
37	78.49	73.58	69.25	65.41	61.96	58.86	56.06	53.51	51.19	49.05	47.09	45.28	43.60	42.05	40.60	39.24	37.98	36.79	35.68	34.63	33.63	32.70	31.82

Appendix 2. Vendor List and Prices for Composted Chicken Manure

Source	Material Description	Price Delivered to Study Site
Boyd Brothers* Route 1, Box 212 Branford, FL 32008 ((904) 935-0120	Composted broiler chicken manure with pine sawdust	$33.00/Ton
Kiah Eubanks O'Brien, FL (386) 935-4216	Composted broiler chicken manure with pine sawdust	$35.00/Ton
Nutri-Source, Inc. 1212 Mt. Vernon Street Orlando, FL 32803-5418 (407) 876-1130	Layer chicken manure (not composted)	$26.00/Ton

Vendor List and Prices for Urban Plant Debris (UPD)

Source	Material Description	Price Delivered to Study Site
Overland Services, Inc.* P. O. Box 13869 Fort Pierce, FL 34979 (561) 467-1200	Composted UPD	$14.50/Ton, (23 Ton minimum charge per load)
Douglas H. Kutz Brevard Co. Extension Office 3965 Lake Drive Cocoa, FL 32926 (407) 633-1702	Partially composted UPD	$1.00/yard ***not*** inc. delivery
Nutri-Source, Inc. 1212 Mt. Vernon Street Orlando, FL 32803-5418 (407) 876-1130	Partially composted UPD with Sludge	$28.00/Ton

*Selected source of material used in this project.

Spreader Calibration and Application

Appendix 3. Broiler Litter Analysis Report

A&L Analytical Laboratories, Inc.
411 North Third St. Memphis, TN 38105 • Phone (901) 527-2780 • Fax (901) 526-1031
The One Source

Report Number
01-229-9105 Page : 1
Account Number
06790
Send To :
THE KERR CENTER
ATTN: ROBERT ADAIR
7055 33RD STREET
VERO BEACH, FL 32966

Client :

Land Application

REPORT OF ANALYSIS

Purchase Order :
Report Date : 08/30/2001
Date received : 8/17/01

Lab Number : 74944
Sample Id : 1 CHICKEN MANURE

	Nitrogen % N	Phosphorus % P	Potassium % K	Sulfur % S	Magnesium % Mg	Calcium % Ca	Sodium ppm Na	Iron ppm Fe	Aluminum ppm Al	Manganese ppm Mn	Copper ppm Cu	Zinc ppm Zn
dry basis	2.93	1.36	2.06	0.42	0.45	2.67	5830	1320	752	444	227	468
as rec'd	2.23	1.03	1.57	0.32	0.34	2.03	4437	1005	572	338	173	356

	Cadmium (Cd) ppm	Chromium (Cr) ppm	Lead (Pb) ppm	Nickel (Ni) ppm
dry basis	<0.01	10.8	0.71	7.56
as rec'd	0	8.22	0.54	5.75

POUNDS OF NUTRIENTS: PER TON

	Nitrogen N	Phosphate P205	Potash K20	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn
dry basis	58.6	62.6	49.4	8.4	9.0	53.4	11.66	2.64	1.50	0.89	0.45	0.94
as rec'd	44.6	47.6	37.6	6.4	6.8	40.6	8.87	2.01	1.14	0.68	0.34	0.72

Moisture 23.9 %
Solid 76.1 %

Scott McKee
M. Scott McKee, General Manager

Continued on Next Page

Appendix 4. UPD Analysis Report

A&L Analytical Laboratories, Inc.

411 North Third St. Memphis, TN 38105 • Phone (901) 527-2780 • Fax (901) 526-1031

The One Source.

Report Number
01-229-9105 Page : 3
Account Number
06790
Send To :
THE KERR CENTER
ATTN: ROBERT ADAIR
7055 33RD STREET
VERO BEACH, FL 32966

Client :

Land Application

REPORT OF ANALYSIS

Purchase Order :
Report Date : 08/30/2001
Date received : 8/17/01

Lab Number : 74945
Sample Id : 2 URBAN PLANT DEBRIS

	Nitrogen % N	Phosphorus % P	Potassium % K	Sulfur % S	Magnesium % Mg	Calcium % Ca	Sodium ppm Na	Iron ppm Fe	Aluminum ppm Al	Manganese ppm Mn	Copper ppm Cu	Zinc ppm Zn
dry basis	1.03	0.16	0.31	0.16	0.13	2.42	743	1250	898	104	36.5	132
as rec'd	0.60	0.09	0.18	0.09	0.08	1.40	429	723	519	60	21.1	76

	Cadmium (Cd) ppm	Chromium (Cr) ppm	Lead (Pb) ppm	Nickel (Ni) ppm
dry basis	<0.01	18.8	7.74	5.24
as rec'd	0	10.87	4.47	3.03

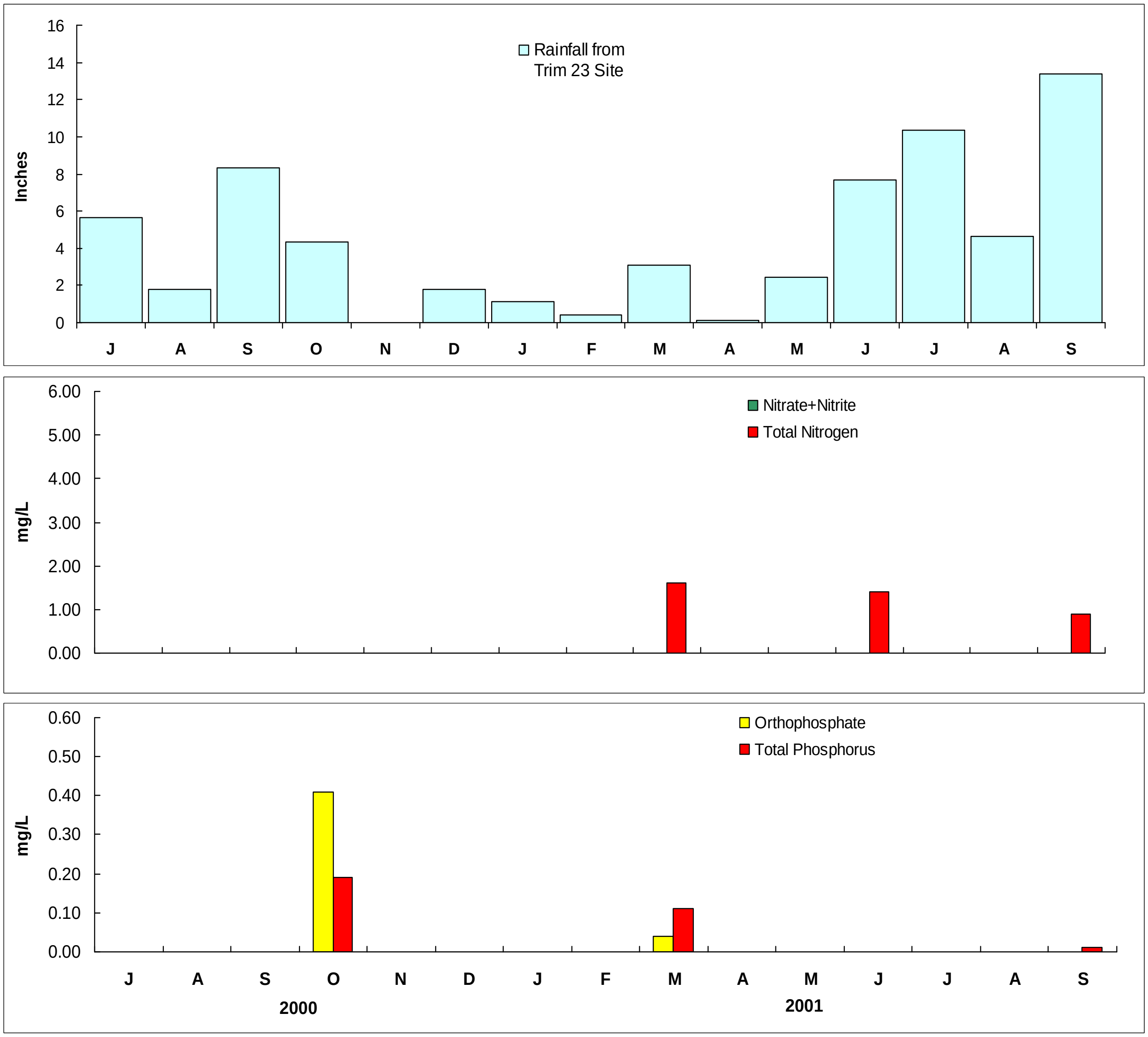
POUNDS OF NUTRIENTS: PER TON

	Nitrogen N	Phosphate P205	Potash K20	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn
dry basis	20.6	7.4	7.4	3.2	2.6	48.4	1.49	2.50	1.80	0.21	0.07	0.26
as rec'd	11.9	4.3	4.3	1.8	1.5	28.0	0.86	1.45	1.04	0.12	0.04	0.15

Moisture	42.2 %
Solid	57.8 %

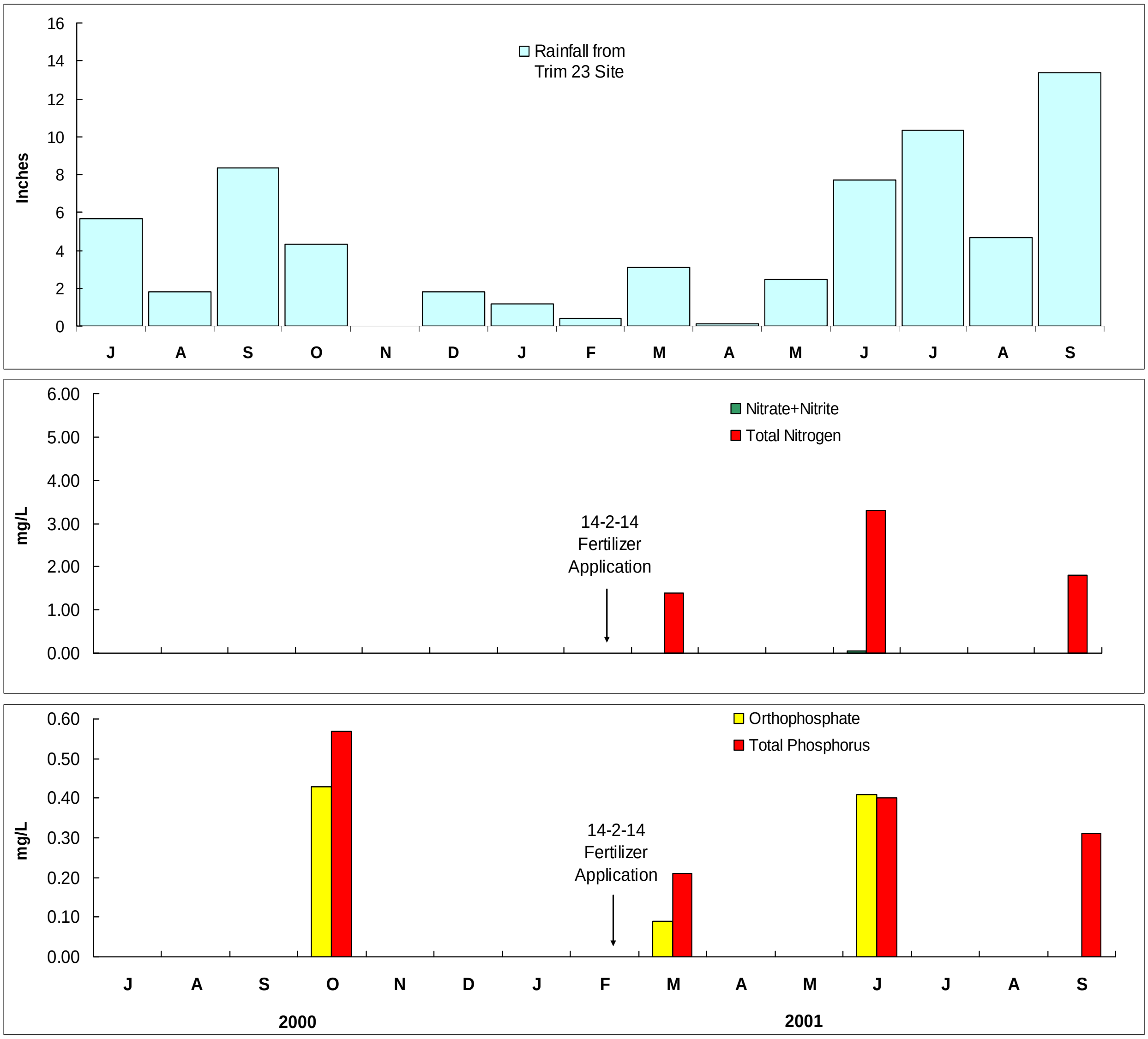
M. Scott McKee, General Manager

Appendix 5. Graph 1, Control Site, no fertilizers applied, pump N-7



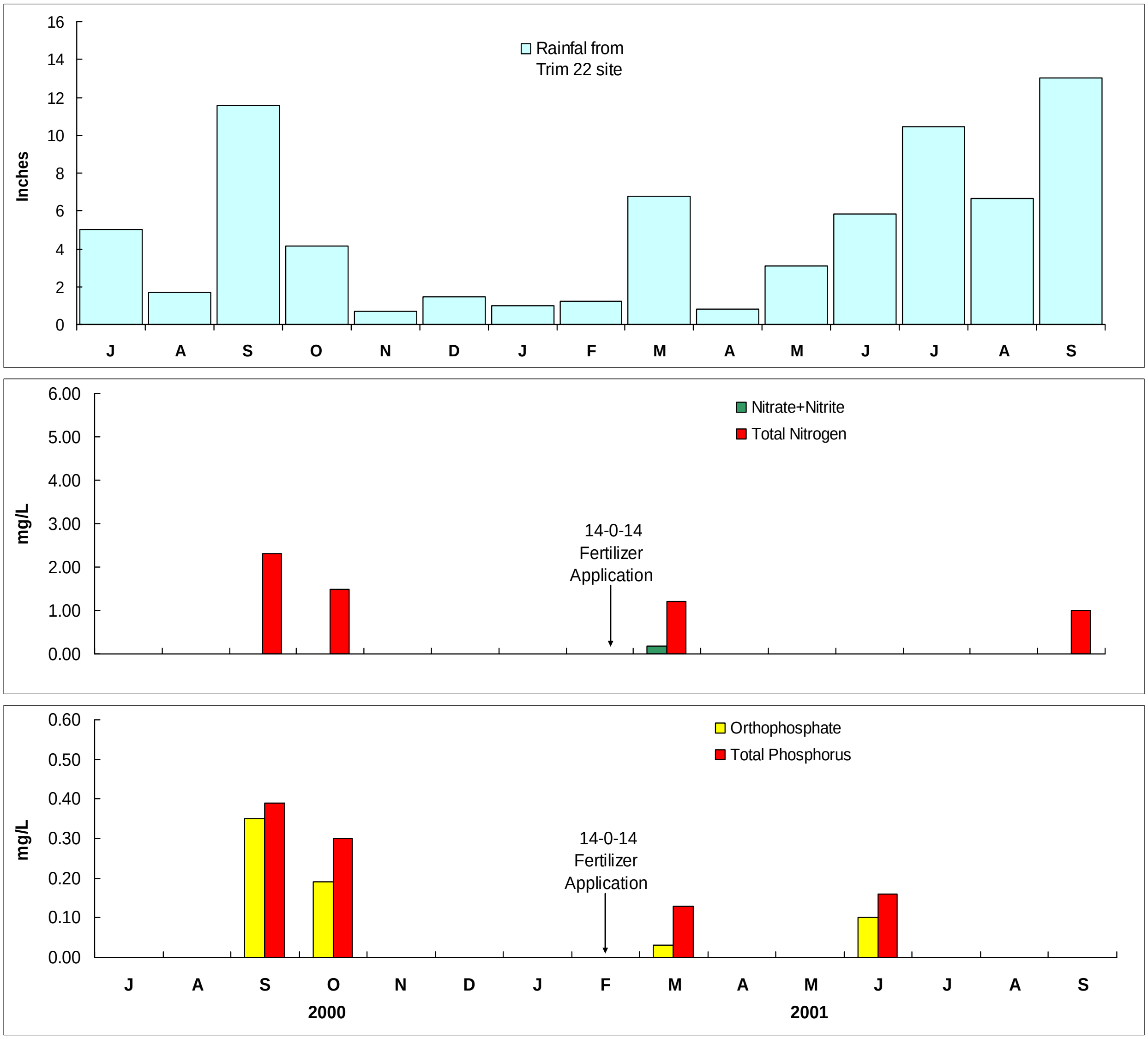
Note: Total Nitrogen was not sampled in 2000 at this site; however the nitrate-nitrite nitrogen was not detected at the Minimum Detection Limit (MDL) which is 0.01 mg/l. The MDL for orthophosphate and total phosphorus is 0.02 mg/l.

Appendix 5. Graph 2, Conventional ground applied fertility program site, Pump N-2



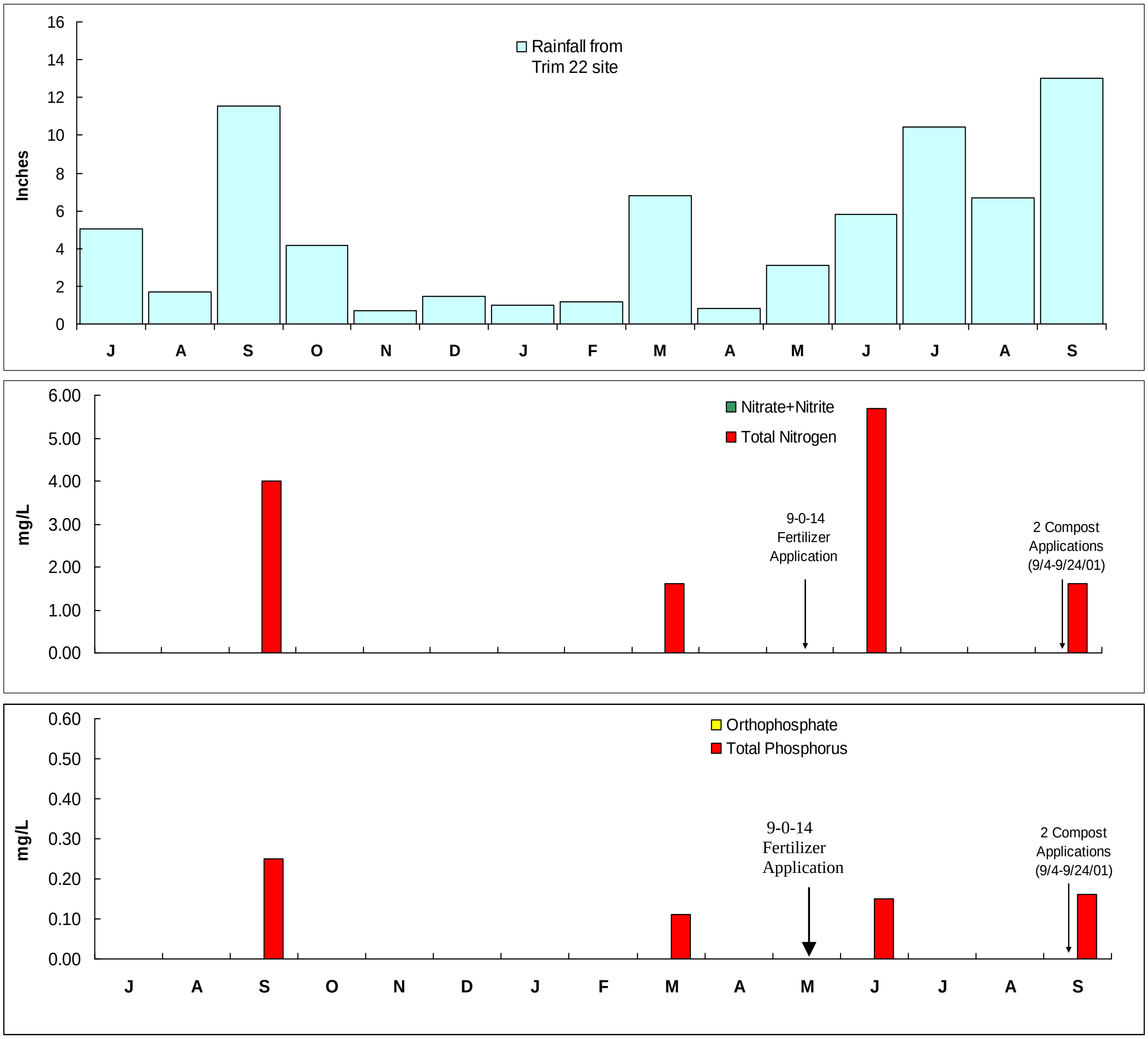
Note: Total Nitrogen was not sampled in 2000 at this site; however the nitrate-nitrite nitrogen was not detected at the Minimum Detection Limit (MDL) which is 0.01 mg/l. The MDL for orthophosphate and total phosphorus is 0.02 mg/l.

Appendix 5. Graph 3, Foliar Applied Phosphorus Site, no ground applied phosphorus fertilizers. Pump N-5



Note: The Minimum Detection Limit (MDL) for nitrate-nitrite nitrogen is 0.01 mg/l. The MDL for orthophosphate and total phosphorus is 0.02 mg/l.

Appendix 5. Graph 4, Compost and Chemical Fertilizer Site, Pump N-11



Note: The Minimum Detection Limit (MDL) for nitrate-nitrite nitrogen is 0.01 mg/l. The MDL for orthophosphate and total phosphorus is 0.02 mg/l.