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Eat your Veggies!!!!!

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Selecting and Monitoring Fertility Regimes in Organic Greenhouse Basil

By: D.D. Treadwell, R.C. Hochmuth, G.J. Hochmuth, E.H. Simonne, T. Olczyk, K.W. Migliaccio, Y.C. Li, R.K. Sprenkel, L.S. Osborne[1]

Demand for organic fresh produce, including culinary herbs, is increasing at a steady rate. Organic greenhouse herb production in soilless culture offers several benefits to the grower including increased protection from crop pests, increased control of temperature and efficient irrigation management. In organic systems, fertilizer is generally the most expensive input, and nitrogen management is often cited as one of the more challenging aspects of this type of crop production. Synthetic fertilizers are largely prohibited. Instead, plant nutrients are supplied by plant and animal-based (natural) fertilizers. Nutrients from natural fertilizers must be converted to forms that plants can use. This is accomplished by microbes through several biological processes. The efficiency of these biological processes depends on several environmental conditions including temperature and moisture and as such is highly variable. This variability can result in nutrient release patterns that are out of synchrony with crop nutrient demand.

At the time of this study, few fertility products that could be delivered through a drip line without clogging emitters or conversely filtering out valuable nitrogen were available. Since the season for fresh cut greenhouse herbs can extend to several months, maintaining a balanced fertility program can be a challenge (Treadwell et al., 2007). Few research reports have been published on organic greenhouse production of culinary herbs. A previous study of organic greenhouse basil examined the effect of various growing mediums and fertilizers on total basil yield. The researchers observed 22% -100% higher total basil yields from plants grown with perlite bags and organic fertilizer than total basil yields from perlite bags and conventional fertilizer. However, conventional fertilizer performed best in a rockwool slab, and total basil yields were higher than those grown in organic fertilizer and rockwool slab (Succop and Newman, 2004). However, in that trial, only one organic fertilizer, a proprietary blend of poultry compost, hydrolyzed fish emulsion, kelp extracts and soft rock phosphate was used.

New greenhouse technologies and nutrient sources are now available to producers. To identify fertilization sources, rates and timing of application that optimize yields of organic fresh cut basil, research trials were conducted in Live Oak, FL in 2005 and 2006. This publication discusses the results of that research, and provides suggestions for producers who desire to grow organic greenhouse basil.

Materials and Methods

Figure 1. Soilless media with four different organic fertilizers prior to incorporation.

Open troughs were constructed with semi-rigid plastic (Crop King, Seville OH) approximately 20-inches wide by 8-inches deep (Hochmuth et al., 2008). The troughs were tilted slightly to allow leachate to drain. Troughs were filled to a depth of 6 inches with a commercially available soilless medium approved for organic systems (Fafard # 30, Conrad Fafard, Inc., Anderson, SC). The medium was composed of peat, pine bark, perlite and dolomitic limestone. Each trough contained approximately 21.5 gals (1.7 cu ft) of media.

Four organic fertilizer treatments were compared to a standard hydroponic nutrient solution (Fig. 1). The treatments were arranged in a randomized complete block design, replicated six times, and repeated two years. Fertilizer was applied and incorporated prior to transplanting and at least once during the season with the same material except for the 5-2-2 fish emulsion. The four organic fertilizer treatments (N-P_2O_5-K_2O) were:

1. 4-2-3 (Perdue AgriRecycle, Seaford, DE)
2. 4-2-4 (Fertrell Company, Bainbridge, PA)
3. 8-5-5 (Nature Safe, Griffin Industries, Coldspring , KY)
4. 8-5-5 (Nature Safe) plus 5-2-2 fish emulsion (Hytech Foliar, Agro-K Corp., Minneapolis, MN)

Fertilizer materials were selected because they are approved for use in organic production, have similar ratios of nutrients and are commercially available. The two 'base' fertilizers have a 1.6:1:1 (8-5-5) and a 2:1:2 (4-2-4) ratio of N, P_2O_5 and K_2O, respectively. Fertilization practices were based on available production recommendations for basil (Davis, 1997). The application rates of fertilizer materials (both preplant and sidedress) were based on nitrogen analysis and each treatment received the same amount of nitrogen at each application (Table 1). To compare the growth response of crops from sidedressed fertilizers, the 8-5-5 fertilizer treatment was repeated so that one 8-5-5 treatment received the same material at sidedress, and the second 8-5-5 material received fish emulsion fertilizer in a liquid formulation. The liquid fish fertilizer was expected to solubilize more rapidly than the dry granular, and therefore we expected higher yields in those treatments following sidedressing due to an increase of available nitrogen. The hydroponic solution treatment was supplied at the concentration summarized in Table 2. All troughs were irrigated with drip tape with 4-inch emitter spacing (Roberts Irrigation, San Marcos, CA). Each trough had two lines of tape: one line for water only that was delivered to the organic treatments, and one line that delivered water plus nutrients to the hydroponic control treatment.

Table 1. Organic fertilizer sources and amounts used to grow basil in open troughs. The amount of nutrient added is reported as grams (g) of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O).

Fertilizer Source	Analysis (%N-P_2O_5-K_2O) and Amount of Product Added	Per Trough (21.5 gals medium)								
		Preplant			Sidedress			Season Total		
		0 DAT			58 DAT			106 DAT		
		Amount of Nutrient Added (g)								
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Perdue	4-2-3 + 4-2-3 (1720g) + (430g)	69	34	52	17	9	13	86	43	65
Fertrell	4-2-4 + 4-2-4 (1720g) + (430g)	69	34	69	17	9	17	86	43	86
Nature Safe	8-5-5 + 8-5-5 (860g) + (215g)	69	43	43	17	11	11	86	54	54
Nature Safe +Hytec	8-5-5 + 5-2-2 (860g) + (316 ml)	69	43	43	16	6	6	85	49	49

Table 2. Nutrient solution concentrations used in the conventional hydroponic nutrient solution treatment.

Nutrient	Concentration (mg/L)
Nitrogen (N)	150
Phosphorus (P)	50
Potassium (K)	200
Calcium (Ca)	150
Magnesium (Mg)	80
Sulfur (S)	60
Iron (Fe) - chelated	2.8
Copper (Cu)	0.2
Manganese (Mn)	0.8
Zinc (Zn)	0.3
Boron (B)	0.7
Molybdenum (Mo)	0.05

In accordance with the National Organic Standards, organically grown transplants of basil cultivar ‘Nufar’ was used for this experiment. Seven transplants per trough were established in each trough in December 23 in 2005 and October 10 in 2006. All plots were thoroughly irrigated by hand following transplanting to ensure the medium was uniformly wet. All subsequent irrigation was supplied via the drip tape designated for water only (Roberts RoDrip, 4 inch emitter spacing, Roberts Irrigation, San Marcos, CA) (Fig. 2). Troughs were irrigated daily, three times daily, approximately 5 minutes each time.

Figure 2. Basil transplants in troughs with irrigation system.

Fertilizer solubilization was assessed by measuring the electrical conductivity (EC) of media to a depth of three inches with a hand held EC probe (Spectrum Technologies, Plainfield, IL). In addition, growing medium was analyzed 4 weeks after transplanting and immediately prior to sidedressing for pH, nitrate (NO_3), P, K, Ca and Mg concentration. Shoot nutrient uptake was assessed by collecting and analyzing dried whole leaves of basil for complete nutrient concentrations.

Basil was harvested by cutting plant tips six to eight inches and weighed immediately after harvest. In 2005, Basil was harvested seven times each in 2005 and 2006. Herbs were harvested approximately every 14 days. The final harvest was 110 DAT In 2005 and 128 DAT in 2006. There are no official USDA market grades for culinary herbs; therefore, cut herbs were graded using market standards of a local commercial grower selling herbs in clamshells. Herbs were considered marketable if the stems and leaves were turgid, uniform in color and vigor and free from damage. All data were analyzed using SAS (V 8.2) analysis of variance general linear model. When significant differences among treatments were detected, means were distinguished with Duncan's Protected Least Significant Differences (LSD).

Results and Discussion

Basil differently to fertilizer sources and those responses were different each year. Therefore, data were analyzed and are presented by year. The sum of marketable basil yields are presented in Table 3. Overall, basil yields were greater in 2006 than in 2005 possibly due to an earlier transplanting date and the subsequent increase in the number of days with favorable temperatures during the course of the season. In 2005, the harvest occurred from January to April (16 wks) and in 2006, the first harvest occurred in November 2005, and the final harvest was in February 2006 (18 wks). Basil fertilized with the 4-2-3 had similar yields to the hydroponic nutrient solution control in 2005, but yielded less only to the control in 2006.

Reduced basil yields with the 8-5-5 formulation were also observed for a similar south Florida trial that examined organic basil production in 4 inch containers (Migliaccio et al., 2007). In that trial, highest yields were obtained with the 4-2-3 and the 4-2-4 formulations compared to the remaining treatments. Interestingly, the EC levels reported for that trial were not different among fertilizer treatments, but varied widely. At the end of the trial (4 weeks after planting), the 4-2-3 EC measured 450 uS/cm while the 4-2-4 EC measured 1772 NS/cm. Thus, for that trial, EC seemed to have little influence on yield. High EC levels in growing medium can be an indication that excess fertilizer was applied or that the irrigation water contains a high amount of dissolved salts. Generally, high EC levels are associated with poor crop development.

In this experiment, trough produced basil yielded highest in 4-2-3 in 2005. In 2005, EC levels in basil growing medium were higher than all other treatments through 56 DAT with the exception of the 8-5-5+ at 35 DAT (Table 4). In 2006, EC levels in basil growing medium were highest in 4-2-3 throughout the season (Table 5). High salt concentration present mostly as potassium in the 4-2-4 and 8-5-5 formulations may have slowed crop development. The potassium was evident in the high petiole sap at 50 and 76 DAT (Table 6).

Previous petiole sap N and K concentrations have been reported for basil (Hochmuth et al., 2007). Sampling the most recently matured basil leaf petiole resulted in both nitrate (NO_3-N) and K concentrations that ranged from 1000 – 2000 mg/L (ppm) when basil was fertilized with conventional hydroponic nutrient solution. Basil fertilized with 4-2-3 organic fertilizer had the highest K sap concentration (2683 mg/L) of all treatments in 2005 (Table 6), and the highest K at 72 DAT (2881) in 2006 (Table 7). Basil petiole sap K was higher than organic 8-5-5 and 8-5-5+ and similar to remaining treatments at 91 DAT (2933 mg/L) and equal to HNS but higher than remaining organic treatments at 128 DAT (3183 mg/L). These results are 34% to 59% higher than basil petiole sap K reported for conventionally produced basil by Hochmuth et al. (2007).

The results for basil petiole N concentration are generally opposite those of K. Basil petiole N was lower than all treatments at 76 DAT (1248 mg/L) in 2005 (Table 6), 72 DAT (914 mg/L) and 91 DAT (1083 mg/L) in 2006 (Table 7). By 128 DAT, basil petiole N was reduced to 555 mg/L and was similar to HNS and lower than remaining organic treatments (Table 7). These trends indicate that high K and low N in petiole sap are not necessarily an indication of low yields and that perhaps for organic fertility sources, the ranges previously reported by Hochmuth et al. (2007) are not directly applicable and should be increased for organic greenhouse basil. These data indicate that lower concentrations of N and higher concentrations of K can be associated with high yields without reducing crop quality.

Table 3. Basil cumulative yield reported as marketable fresh weight (g/plant) in 2005 and 2006.

Fertilizer Sources and Analysis (N-P_2O_5-K_2O)	2005 110 DAT		2006 128 DAT	
	g/plant			
Perdue 4-2-3	325	a[z]	339	b
Fertrell 4-2-4	237	b	223	c
Nature Safe 8-5-5	250	b	180	cd
Nature Safe 8-5-5 + Hytech Foliar 5-2-2	222	b	147	d
Hydroponic Nutrient Solution	321	a	417	a
Significance	*P* < 0.01		*P* < 0.01	

[z]Values within a column followed by different letters are significantly different according to Duncan's LSD.

Table 4. Electrical Conductivity (EC) in basil growing medium at seven sample dates in Live Oak, FL in 2005 under five different fertilizer programs.

	Fertilizer Source	Days after transplanting (DAT)						
		35	42	52	63[z]	71	85	106
		EC (mS/cm)						
Basil	4-2-3[y]	1.51a[x]	1.23a	0.71a	0.96a	1.01b	1.27a	0.54b
	4-2-4	0.82b	0.54b	0.19c	0.40b	0.50c	0.59b	0.39bc
	8-5-5	0.86b	0.65b	0.31bc	0.48b	0.54c	0.66b	0.21c
	8-5-5+	1.40a	0.81b	0.32bc	0.82a	1.50a	1.52a	0.38bc
	HNS	0.67b	0.71b	0.40b	0.99a	1.20ab	1.22a	1.15a
	Significance	**	**	**	**	**	**	**

[z] Side dress occurred at 58 DAT.

[y] Fertilizer sources are reported as percent of nitrogen – potassium oxide (K_2O) – phosphorus oxide (P_2O_5) and are as follows: 4-2-3 = Perdue 4-2-3 preplant and sidedress; 4-2-4 = Fertrell preplant plus sidedress; 8-5-5 = Nature Safe preplant sidedress; 8-5-5 = Nature Safe preplant plus 5-2-2 Hytech Foliar fish emulsion sidedress; and HNS = hydroponic nutrient solution.

[x] Values within a crop and column followed by different letters are significantly different according to Duncan's Multiple Range Test. NS = not significantly different.

Table 5. Electrical Conductivity (EC) in basil growing medium at seven sample dates in Live Oak, FL in 2006 under five different fertilizer programs.

Fertilizer Source		Days after transplanting (DAT)					
		37	43	84[z]	94	99	107
		EC (mS/cm)					
Basil	4-2-3[y]	1.75a[x]	1.71a	1.60a	1.51a	1.25a	0.81a
	4-2-4	0.54b	0.41b	0.85b	0.81b	0.54b	0.26b
	8-5-5	0.56b	0.45b	0.59b	0.48b	0.54b	0.25b
	8-5-5+	0.66b	0.68b	0.60b	0.43b	0.41b	0.34b
	HNS	0.69b	0.84b	0.66b	0.41b	0.38b	0.20b
	Significance	**	**	**	**	**	**

[z] Side dress 58 DAT
[y] Fertilizer sources are reported as percent of nitrogen – potassium oxide (K_2O) – phosphorus oxide (P_2O_5) and are as follows: 4-2-3 = Perdue 4-2-3 preplant and sidedress; 4-2-4 = Fertrell preplant plus sidedress; 8-5-5 = Nature Safe preplant sidedress; 8-5-5 = Nature Safe preplant plus 5-2-2 Hytech Foliar fish emulsion sidedress; and HNS = hydroponic nutrient solution.
[x] Mean separation within crop/ column (DAT) Duncan's Multiple Range Test $P \leq 0.05$.

Table 6. Nitrogen (N) and potassium (K) content in basil petiole sap in 2005. Samples were collected at 50 and 76 days after transplanting (DAT).

Fertilizer Source	50 DAT[Z]		76 DAT	
	NO_3^{-N}	K	NO_3^{-N}	K
	Parts per million			
4-2-3[y]	1308	2683a	1248b	2933a
4-2-4	1408	1742b	1633a	1307c
8-5-5	1433	1449b	1683a	1333c
8-5-5 +	1392	1353b	1650a	1400c
HNS	1350	1526b	1617a	2000b
Significance	NS	**	**	**

[Z] At 50 DAT, n=2 k=2; at 76 DAT, n=1 k=1
[y] Fertilizer sources are reported as percent of nitrogen – potassium oxide (K_2O) – phosphorus oxide (P_2O_5) and are as follows: 4-2-3 = Perdue 4-2-3 preplant and sidedress; 4-2-4 = Fertrell preplant plus sidedress; 8-5-5 = Nature Safe preplant sidedress; 8-5-5 = Nature Safe preplant plus 5-2-2 Hytech Foliar fish emulsion sidedress; and HNS = hydroponic nutrient solution.
[x] Mean separation within crop/ column (DAT) by Duncan's $P \leq 0.05$.

Table 7. Nitrate (NO_3^{-N}) and potassium (K) content in basil petiole sap in 2006. Samples were collected at 72, 91 and 128 days after transplanting (DAT).

Fertilizer Source	DAT 72[Z]		DAT 91		DAT 128	
	NO_3^{-N}	**K**	**NO_3^{-N}**	**K**	**NO_3^{-N}**	**K**
	Parts per million					
4-2-3[y]	914c	2881a	1083c	2933a	555c	3183a
4-2-4	1617a	1586b	1833a	1853a	1400a	1155b
8-5-5	1483ab	971c	1467b	887b	1165ab	822b
8-5-5 +	1648a	1110c	1683ab	817b	1310a	1023b
HNS	1273b	2068b	1448b	1472ab	855bc	2367a
Significance	**	**	**	*	**	**

[Z] At 72 DAT, n=3 k=3; at 91 and 128 DAT, n=1 k=1

[y] Fertilizer sources are reported as percent of nitrogen – potassium oxide (K_2O) – phosphorus oxide (P_2O_5) and are as follows: 4-2-3 = Perdue 4-2-3 preplant and sidedress; 4-2-4 = Fertrell preplant plus sidedress; 8-5-5 = Nature Safe preplant sidedress; 8-5-5 = Nature Safe preplant plus 5-2-2 Hytech Foliar fish emulsion sidedress; and HNS = hydroponic nutrient solution.

[x] Mean separation within crop/ column (DAT) Duncan's Multiple Range Test $P \leq 0.05$.

Summary

Four organic fertilizer programs were compared for basil greenhouse production. Relative to the hydroponic control, basil yields responded similarly to the 4-2-3 (Perdue) overall when herbs are planted in a peat-pine bark-perlite medium. Since organic fertilizer response can be influenced by the composition of potting medium, growers are encouraged to try several fertilizers if employing a growing medium other than a peat-pine bark-perlite blend.

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1. Danielle Treadwell, Extension Specialist, Horticultural Sciences Department, Gainesville, FL; Robert Hochmuth, Extension Agent, Vegetables, Multi-County, North Florida Research and Education Center (NFREC), Live Oak, FL; George Hochmuth Associate Dean and Professor, Gainesville, FL; Eric H. Simonne, Horticultural Sciences Department, Extension Specialist, Gainesville, FL; Teresa Olczyk, Extension Agent, Commercial Ag./Vegetables, Miami-Dade Cooperative Extension, FL; Kati Migliaccio, Extension Specialist, Department of Agricultural and Biological Engineering, Tropical Research and Education Center (TREC), Homestead, FL; Yuncong Li, Extension Specialist, Soil and Water Science Department, TREC, Homestead, FL.; Richard Sprenkel, Extension Specialist, Department of Entomology and Nematology, NFREC, Quincy, FL.; and Lance Osborne, Professor, Department of Entomology and Nematology, Mid-Florida Research and Education Center, Apopka, FL.