ORGANIC FARMING RESEARCH FOUNDATION

Organic farming research project report submitted to the Organic Farming Research Foundation:

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Improving the quality of organic herb production and marketing

FINAL REPORT

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Project locations: Iowa State University Heenah Mahyah Student Farm, Ames Iowa; Iowa State University Horticulture Research Center, Gilbert, IA; Organic Herb Producers Cooperative Herb Demonstration Site, Soberg Farm, Lakeville, Minnesota

Project period: 4 years

Project budget: $16,500 (2001, 1 year) **Funding provided by OFRF:** $5,500 (2001)

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Summary

Farmers interested in transitioning some or all of their land into organic production need information regarding the best management practices for these systems. Soil fertility and weed management strategies are imperative for optimum plant growth and yields. Current research in organic herb production at Iowa State University has included investigations into certified organic methods of fertilization and use of organic mulches for weed suppression. Organic medicinal herbs research plots were established in 1999 in Ames, Iowa, to investigate the effect of organic fertilizer and compost on *Echinacea purpurea, E. angustifolia* and lemon balm plant growth and yields. Although increased yields were obtained with vegetables (broccoli and green peppers) fertilized with composted turkey manure (UltraGro®, Ellsworth, IA), results with herb crops were not consistent. Soil amendments increased herb leaf growth only in the case of *Echinacea angustifolia.* With lemon balm (*Melissa officinalis*), which is harvested for leaf matter, fertilization effects were more pronounced, but not to the level of significantly improving yields. *Echinacea* root production, the most important factor for commercial sales, was not significantly affected by soil amendments. Because *Echinacea* is a native plant, and Iowa soils are rated as sufficiently fertile, additional fertilization does not appear necessary to increase yields. The long-term benefits of compost to the soil-plant system in terms of improving soil structure through the addition of organic matter, soil moisture retention, and soil microbial activity may exceed benefits derived from the supply of plant nutrients alone. This information was transferred through on-farm Field Days and workshops at Iowa State University. Additional organic medicinal herbs (catnip and St. John's Wort) research plots were established in 2001 in a 2-3 year project to identify, through replicated trials, which organic mulches provide the optimum level of weed suppression, yields, and herbal quality. Weed suppression and yield increase were obtained from natural mulches (flax mat, wool mat and oat straw). Comparisons of biochemical constituents and essential oil yields for both projects are underway at Iowa State University, Rutgers University and Frontier Natural Products Cooperative, Norway, IA. Funding from the Organic Farming Research Foundation helped support a graduate student (Lisa Duppong) for her analysis of the soil amendment component of this project, and establishment of the weed management component. Funding was also used to support the establishment of an herb demonstration site with the Organic Herb Producers Cooperative in Lakeville, Minnesota.

Introduction to Topic

As a consequence of surplus crops of commodity corn and soybeans in the Midwest, and the resulting low prices, an excellent opportunity exists for organic farmers to plant crops for high-value niche markets. Iowa farmers reported 150,000 acres of organic production to the Iowa Department of Agriculture and Land Stewardship (IDALS) survey in 1999 (IDALS, 2000). This figure reflects only acreage reported by those farmers who returned their survey; thus, many more acres are believed to go unreported. In addition to comparable yields with conventional systems, organic systems have been reported to produce more flavorful products and garner a 20-400% premium price in the marketplace. While a number of specialty crops have been explored, the potential for growing crops that provide health benefits, such as the medicinal herbs, *Hypericum*, *Echinacea* and catnip, has been little exploited (Simon et al.,

1984). The European Union currently controls the majority share of essential oil products exported throughout the world, despite the fact that similar yields for these products can be obtained in the U.S. With prices reaching $50 per ounce, the essential oil market offers a lucrative option for small- and mid-size growers. Many herbs, including *Echinacea purpurea*, can be sold at a 100% premium if grown organically. Although herbs have been used medicinally for thousands of years, worldwide use of herbs as a source of "natural" medicine is increasing. Recently we have seen a dramatic increase in American consumer interest in these alternatives to synthetic drugs. Because of this interest, there is also a large demand for production information under U.S. growing conditions, particularly for organic systems.

Because synthetic fertilizers and herbicides are not permitted in organic production, organic growers must use alternative nutrient and weed management practices for their crops. Some of these alternatives include compost from various feedstocks and fertilizers made from feathermeal, bone meal, and seaweed. Natural fertilizers are reported to help preserve soil structure and quality, and protect groundwater from toxic runoff/infiltration. In addition, soil amendments consisting of green and livestock waste products have been shown to mitigate vegetable disease and insect problems. In order to obtain premium prices for certified organic crops, farmers need scientifically validated information to help develop successful organic farming systems. In addition to production information, the majority of organic farmers surveyed expressed a need for improved marketing structures to strengthen their profitability. The overall market for organically grown herbs can be characterized as diverse in product and fragmented in distribution. The demand for products derived from organic herbs is expected to continue to grow. It is the challenge of the industry to assure a consistent stream of product that will satisfy the quality standards of the processors and the end-users.

These organic herb projects were established to integrate resources from two research institutions (Iowa State University and the University of Minnesota) and a farmer group (Organic Herb Producers Cooperative) working in organic herb production, processing, quality analysis, marketing and education, to address the problems of consistent herbal quality and distribution. The long-range goal of this project is to develop systems for organic medicinal herbs as profitable alternative crops, and to improve our understanding of the beneficial effects of herbs. The objectives of each particular project, which are the first steps toward the attainment of the long-range goal, are to critically assess the effects of field management systems on the herbal quality of organic medicinal herbs. A concomitant objective is technology transfer through Field Days and grower guidebooks to increase marketability of herb crops and improve growers' profitability.

Three medicinal herbs—purple coneflower (*Echinacea purpurea),* narrow-leaved purple coneflower (*E. angustifolia*), and lemon balm *(Melissa officinalis)*—were selected for soil amendment research and two others, catnip (*Nepeta cataria*) and St. John's Wort (*Hypericum perforatum* 'Helos'), were selected for weed management research, based on discussions with the Organic Herb Producers Cooperative of Lakeville, Minnesota, and Community Development Services of Minneapolis, Minnesota. Information on these herbs is presented below. Valerian (originally proposed) was eliminated form the project after problems with root diseases at Renne Soberg's farm. "Time of harvest" treatments were also eliminated after

slow plant growth in 2001 dictated one harvest only. I report here the *Soil Amendments* component of the research.

SELECTED HERBS

Echinacea purpurea (L.) Moench

Purple coneflower is a hardy herbaceous perennial with a branched or fibrous root and longer, dark purple ray petals (Bremness, 1994; Hobbs, 1995; Powell, 1995; Stuart, 1979). The tops and roots are used medicinally as an immune system stimulant (Hobbs, 1995). *E. purpurea* growth is greatest in well-drained soils with a pH of 5.5 - 7.0. Problems include powdery mildew and aster yellows, a mycoplasma-like organism (Powell, 1995).

Echinacea angustifolia De Candole

Narrow-leaved purple coneflower is an herbaceous perennial with a vertical taproot and shorter, purple ray petals (Bremness, 1994; Hobbs, 1995). *E. angustifolia* is native to central and southwestern United States and appears from mid-summer to early autumn (Stuart, 1979). The dried rootstock is used medicinally as an antiseptic (Stuart, 1979) and immune system stimulant (Bremness, 1994).

Melissa officinalis L.

Lemon balm is a bushy herbaceous perennial with lemon-scented foliage (Bremness, 1994; Powell, 1995; Stuart, 1979). A native to central and southern Europe, lemon balm became widespread in northern temperate zones. Sandy, dry soil with a pH level of 6.5 - 7.5 is preferred for maximum growth, with more aromatic leaves produced in dry soil (Powell, 1995). Fresh or dried leaves are used medicinally as a carminative, a diaphoretic, an anti-spasmodic, or an anti-depressant agent (Bremness, 1994; Stuart, 1979).

Objectives

- Address the key questions of management and processing of organic medicinal herbs through research and demonstration trials on-farm and at University stations.

- Identify, through biochemical analysis, the key medicinal constituents of target herbs for the purpose of standardization as a marketing tool.

- Develop production and processing guides to promote market development of organic herbs

- Promulgate technology transfer of organic herb production and marketing strategies through the establishment of on-farm and institutional demonstration sites, annual Field Days, and new crop training programs for extension staff, growers, and buyers.

Materials and Methods

Effect of Soil Amendments on Organic Medicinal Herbs

The organic herb research project was established at Iowa State University in 1999 in consultation with Renne Soberg and the Organic Herb Producers Cooperative of Lakeville, Minnesota**,** and Todd Thompson of Organic Alliance/Community Development Services, Minneapolis, Minneapolis. Erica Renaud, Organic Research Farm Manager, Frontier Natural Products Cooperative, Norway, Iowa, served as a consultant on many issues of this project.

Experimental Design

Plots previously planted to a cover crop of sorghum-sudangrass at the Heenah Mahyah Student Farm (HMSF) at Iowa State University, Ames, Iowa, were selected for the soil amendment component of this project. This site qualified for the first year of transition to certified organic in 1999 [the land was not certified in subsequent years due to the small amount of produce/sales from the farm (less than $2,000/year)]. Soils were sampled at pre-planting on October 15, 1998, and on 19 May 2000. Plots were cultivated for bed preparation on 15 May 1999. *E. purpurea*, *E. angustifolia* and *M.officinalis* seeds were planted in the Iowa State University Horticulture Department greenhouses on 20 January 1999. Transplants were set at 3 in. (7.6 cm) depth on 1 June 1999. Treatments were applied at the beginning of plant growth on 24 June 1999 and on 5 June 2000. Treatments were applied annually: Treatment 1 = Midwestern Bio-Ag® (Blue Mounds, WI), an organic feathermeal-based, pellet fertilizer (approved by the State of Iowa Organic Certification Program) applied at a rate equivalent to 50 lb N/acre (56 kg N ha^{-1}); Treatment 2 = Midwestern Bio-Ag® at 100 lb N/acre (112 kg N ha^{-1}); Treatment 3 = Midwestern Bio-Ag® at 150 lb N/acre (168 kg N ha^{-1}); Treatment 4 = composted turkey litter (Ultra-Gro®, Ellsworth, IA–approved by the State of Iowa Organic Certification Program) applied at a rate equivalent to 50 lb N/acre (56 kg N ha^{-1}); Treatment 5 = composted turkey litter at 100 lb N/acre (112 kg N ha^{-1}); and Treatment 6 = control (no amendments). There were 4 replications of 16 plants (in each plot) per 6 treatments for the 3 herb species for a total of 1,152 plants in the experiment.

No insecticides, fungicides, or herbicides were applied in keeping with certified organic standards. Weeds were managed through mechanical cultivation between rows until canopy closure, followed by an application of 6 in. (15.2 cm) organic oat straw mulch on each plot (10 June 1999 and 12 June 2000) and hand-weeding when needed. Parameters measured for all plants per plot included: plant height, leaf number, flower number and insect number. In 1999, plants were sampled on June 12, 25 and 30, July 6, 13 and 22, August 11, September 11, October 23, and November 13. In 2000, plants were sampled on June 9, 23 and 26, July 7,and 21 and August 4. In the first year, leaves from 3 *M. officinalis* plants per plot (72 plants total) were harvested on November 13, 1999, before frost. Second-year harvest of ***M.*** *officinalis* occurred before flowering on June 27–28 and September 21, 2000. *Echinacea* leaves and roots were harvested from all viable plants in each plot on 21 September 2000 (maximum of 16 plants per plot; minimum of 2 plants per plot). Measurements were subjected to analysis of variance and Fisher's PLSD test (SAS Institute, 1988).

Organic Herb Producers Cooperative /Minnesota Work

Because of the reduction in our funding (a 45% decrease from requested funds), the University of Minnesota was unable to collect data from their herb project. The future of the herb project at UM is in question with the departure of Dr. Elizabeth Dyck. Work in Minnesota with the Organic Herb Producers Cooperative (OHPC), however, continued as a result of this project. Funding was used to support the establishment of an irrigation system to conduct research at the OHPC Herb Demonstration Site at the Soberg Farm in Lakeville, Minnesota. After several seasons of conducting field research, and dealing with the frustrations of seeding and transplanting without adequate natural rainfall, compounded with the need to rebuild the farm's domestic well after using it to water crops during last summer's dry-spell, it was apparent that, if field research was to continue, there was a need to supplement rainfall by pumping water from an existing pond. This irrigation project is now underway to support data collection from herbs planted in 2001. Dr. Delate and Lisa Duppong met with this group of producers, practitioners, and marketers at three meetings to develop research plans targeting key problems in the industry and view OHPC herb plots in Minnesota. On-going discussions with OHPC and Cooperative Development Services include issues of improving markets for organic herb producers in the Midwest.

Results and Discussion

Pre-plant soil analysis revealed a high level of P and K in the experimental fields (Table 1), which may be related to the lack of significant differences in plant growth in amended soils. In the first year of growth, plant height in *Echinacea purpurea* increased with the addition of the biological fertilizer at rates ≥ 50 lb N/acre or with compost at rates ≥ 100 lb N/acre, but plant height was not significantly greater than the control plants where no amendments were applied (Figure 1). The 100 lb N/acre (112 kg N ha^{-1}) fertilizer treatment resulted in the tallest *M. officinalis* plants (Figure 2); however, the differences among treatments were not significant.

In 2000 (the year of commercial harvest), organic fertilizer or compost inputs did not significantly increase *E. purpurea* leaf dry matter at harvest (Figure 3). This result does not correlate with the soil data (Table 2) which indicated a significantly higher level of soil nitrate and ammonium in the 150 lb N/acre (168 kg N ha^{-1}) plots. It may suggest that fertilization with 50 lb N/acre (56 kg N ha^{-1}) may be optimal for plant growth, and greater N addition does not result in an increase in yield. Neither the application of the biological fertilizer nor the compost significantly increased harvested root weight in *Echinacea purpurea* (Figure 4).

In the slower growing *E. angustifolia,* significant treatment effects were found for leaf dry weight at harvest (Figures 5). Leaf dry matter in the 100 lb N/acre (112 kg N ha^{-1}) fertilizer treatment was significantly greater than all other treatments (Figure 5). This does not correlate with the soil data (Table 3), where soil nitrate and ammonium were not significantly greater in the 100 lb N/acre (112 kg N ha^{-1}) fertilizer treatment. No other soil parameters, which could account for the additional growth, were significantly greater in the 100 lb N/acre (112 kg N ha^{-1}) plots. *E. angustifolia* root dry weight at harvest did not differ among treatments despite the variability in yield (Figure 6). Differences were more readily apparent in above-ground

plant parts, perhaps a reflection of differential growth between above and below ground. After a third or fourth year of root growth, differences may have become more apparent below ground.

Lemon balm (*M. officinalis)* plants in the compost and organic fertilizer treatments of 50 lb N/acre (56 kg N ha^{-1}), 100 lb N/acre (112 kg N ha^{-1}) and 150 lb N/acre (168 kg N ha^{-1}) produced numerically higher dry weight at harvest compared to the control, but differences were not statistically significant. This has important ramifications for farmers when yield benefits are not obtained with additional fertilization.

Production and processing guides to promote market development of organic herbs
Development of an Organic Herb Production and Marketing Guide is on-going, due to the need to complete Lisa Duppong's medicinal herb research. Once the organic weed management research is completed in December 2002, the Guide will be completed.

Conclusions

Because *Echinacea* is a native plant, and Iowa soils are rated as sufficiently fertile, additional fertilization does not appear necessary to increase yields. Because lemon balm (*M. officinalis*) is harvested for leaf matter, fertilization effects were more pronounced, but not to the level of significantly improving yields. The addition of compost or biological fertilizer as soil amendments should not be confused with a synthetic fertilizer addition, however. While compost applications did not increase the yield of the most commercially important plant part (roots) in *Echinacea*, the long-term benefits of compost to the soil-plant system in terms of improving soil structure through the addition of organic matter, soil moisture retention, and soil microbial activity may exceed benefits derived from the supply of plant nutrients alone. A study of the long term effects of compost addition and varying rates and types of compost would prove beneficial to organic farmers and gardeners in choosing the optimum conditions for organic vegetable and herb production. In addition, the interaction between cultivar and response to compost appears to be significant and warrants further investigation.

Impact of the Results–Education and Outreach

Lisa Duppong (2000-2002) has been supported through this grant, and continues research on mulches for herbs for her M.S. in Agronomy. Specific impacts of this project include that approximately 7,000 people were made aware at Field Days and presentations about the benefits of compost and other organic agricultural practices in the three years of this work. The farmers involved in these trials have adopted sustainable practices of soil testing and applying compost when needed.

Other aspects of this project include the following:

- Training 35 key agricultural professionals in compost and mulch benefits in organic agriculture
- 268 educational meetings, field days, workshops, one-on-one contacts, phone contacts related to organic agriculture;
- 7 mass media articles for dissemination of project results
- An Organic Agriculture Gateway webpage was created with assistance from the Brenton Center. Completion of the webpage in March 2002.

Publications with Information from this Project:
(* represents availability on the Web)

*Delate, K. 2001. Weed Management for Organic Farmers. PM 1883. Iowa State University Extension Communications, Ames, IA.

*Delate, K. 2001. Soil Quality in Organic Agricultural Systems. PM 1882. Iowa State University Extension Communications, Ames, IA.

* Delate, K. 2001. Organic Agriculture. PM 1880. Iowa State University Extension Communications, Ames, IA.

Delate, K. 2002. Using an agroecological approach to farming systems research. HortTechnology July 2002.

Delate, K.M. 2000. Organic Agriculture. Encyclopedia of Pest Management , Professor David Pimentel (ed.), Cornell University, Marcel Dekker Press, New York.

* Delate, K. and V. Lawson. 2000. Evaluation of Soil Amendments and Cover Crops for Certified Organic Pepper Production. Horticulture Research Report, Dept. of Horticulture, ISU, Ames, IA.

*Delate, K., V. Lawson and C. Cambardella. 2000. Evaluation of Organic Soil Amendments for Certified Organic Vegetable and Herb Production. Annual Report for the Leopold Center for Sustainable Agriculture, LCSA, ISU, Ames, IA.

* Delate, K. 1999. Targeting the Premium Market: Organic Crops for Iowa. Integrated Crop Management Conference Proceedings, November 17, 1999, Iowa State University, Ames, IA.

*Delate, K. and V. Lawson. 1999. Evaluation of Organic Soil Amendments for Certified Organic Vegetable and Herb Production. Annual Report for the Leopold Center for Sustainable Agriculture, LCSA, ISU, Ames, IA.

Delate, K. and V. Lawson. 1999. Evaluation of Organic Soil Amendments for Certified Organic Pepper Production. Horticulture Research Report, Dept. of Horticulture, ISU, Ames, IA.

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Producer/Extension Workshops

Composting for Organic Producers Workshop

At the invitation of the Planning Committee of the Upper Midwest Organic Farming Conference, a 6-hour composting workshop was organized on March 18, 2000, that consisted of faculty from the University of Wisconsin and Iowa State University and growers engaged in compost operations. Over 400 people attended these sessions and gained valuable information on compost composition and utilization.

Toolbox Training for Organic Agriculture

On August 22-23, 2000, a tri-state training on organic agriculture was held in Greenfield and Orient, Iowa. This training focussed on organic principles and practices for 35 Extension specialists in Iowa, Missouri, and Wisconsin. Efforts in this activity included contacting appropriate administrators in other states, securing arrangements for speakers (including seven Iowa State University professors and seven farmers), arranging hotel and meeting rooms, meal orders/ delivery, and conducting a pre- and post-test to measure course effectiveness.

Organic Crop Production Iowa Communication Network (ICN) Course

In the fall of 1999, the first Organic Crop Production ICN course for Extension and ISU university credit (AGRON/HORT 494X) for Spring semester 2000 was developed. The total attendance for the course was 168 participants, including 24 ISU students.

Upper Midwest Organic Farming Intensive Workshop

Based on request from organic farmers and agricultural professionals in the Midwest, a six-hour workshop was organized for March 23, 2001, in La Crosse, Wisconsin. I was responsible for a course on "Resources for Organic Farmers" that included publications, video tapes, farmer contacts, and organizations supporting organic producers in terms of funding and research initiatives. My course involved Extension personnel from the Universities of Minnesota and Wisconsin, along with agricultural professionals from lending agencies. Regional attendance was estimated at 400 participants.

Iowa Fruit and Vegetable Growers Association Organic Workshop

On February 11, 1999, over 100 people attended the first Organic Fruit and Vegetable Workshop I organized for the IFGVA annual conference in Cedar Rapids. In addition to arranging for seven professor- and producer-speakers, an all-organic meal was organized for the event, which allowed involvement of farmers with the conference participants. An Organic Session was also held at the 2000 and 2001 meetings.

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Simon, J.E., A.F. Chadwick, and L.E. Craker. 1984. Herbs, An Indexed bibliography, 1971-1980. The Scientific Literature on Selected Herbs, and Aromatic and Medicinal Plants of the Temperate Zone. Archon Books, Hamden, CT.
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Budget Report-2001

Category	OFRF Funds	Matching Funds	Explanation
Salary	$2,000	$11,500*	Annual salary for Graduate Student, L. Duppong
Supplies	$3,500	$5,000	Irrigation supplies, data collection supplies
TOTAL DIRECT COSTS	$5,500	$16,500	

*Matching funds from the Agronomy Department, Iowa State University, and the Leopold Center for Sustainable Agriculture, Ames, IA. Irrigation system matching funds from Renne Soberg, Lakeville, Minnesota.

Figure 1. *E. purpurea* plant height, 1999.

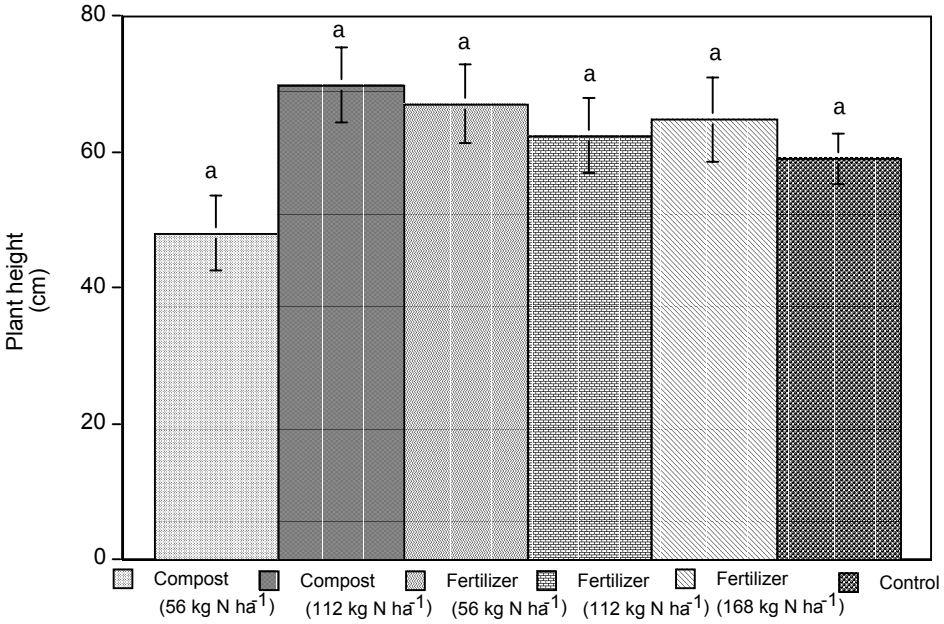

Figure 2. *M. officinalis* plant height, 1999.

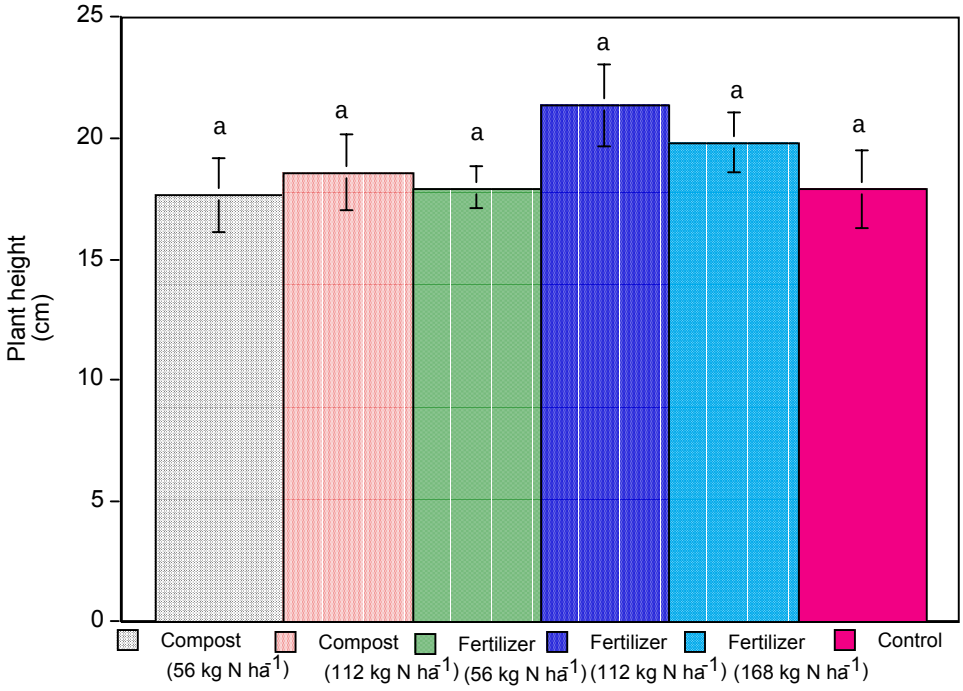

Figure 3. *Echinacea purpurea* leaf harvest dry weight, 2000.

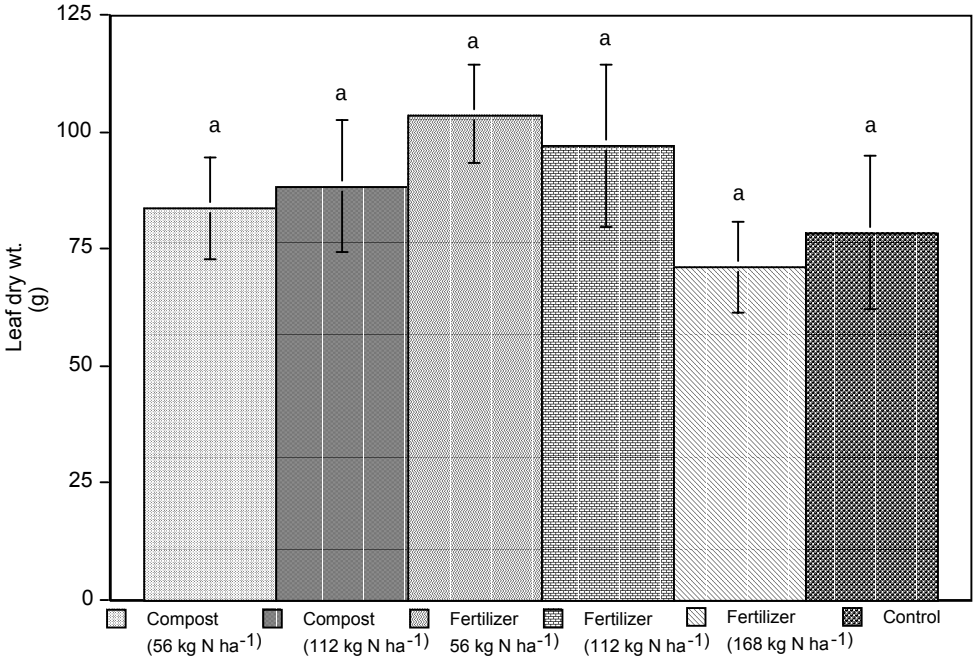

Figure 4. *Echinacea purpurea* root harvest dry weight, 2000.

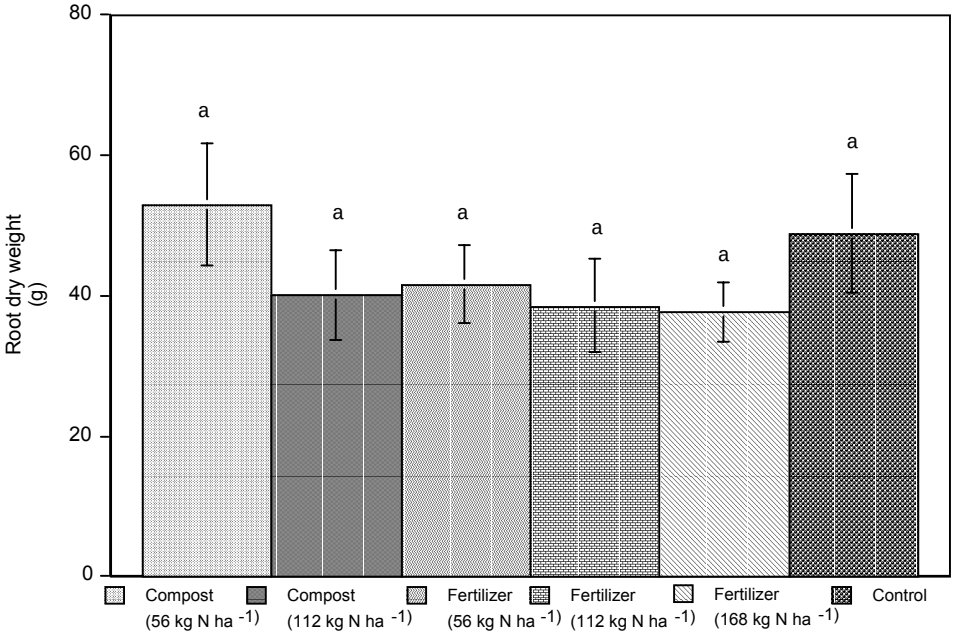

Figure 5.*E. angustifolia*leaf harvest dry weight, 2000.

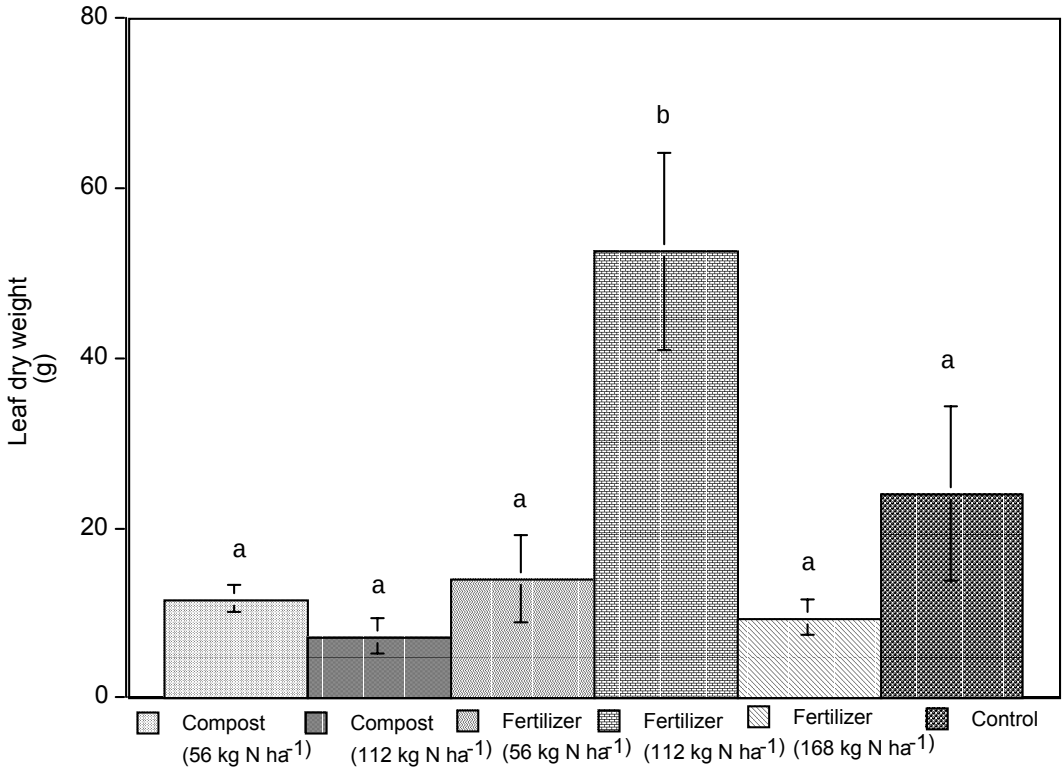

Figure 6. *Echinacea angustifolia* root harvest dry weight, 2000.

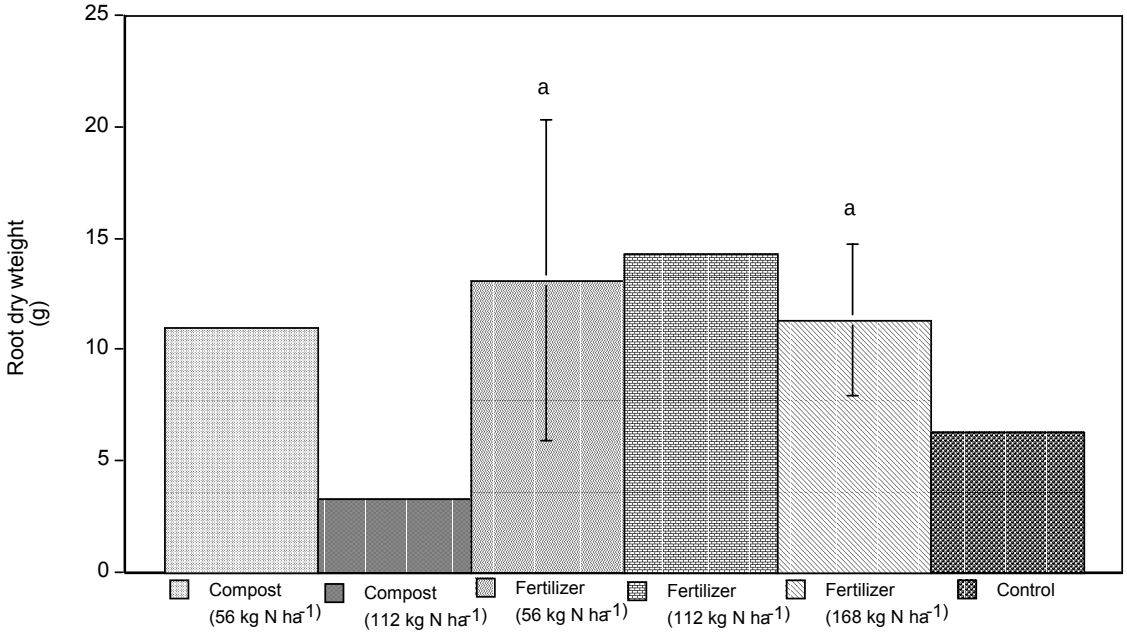

Figure 7. *M. officinalis* leaf harvest dry weight, 2000.

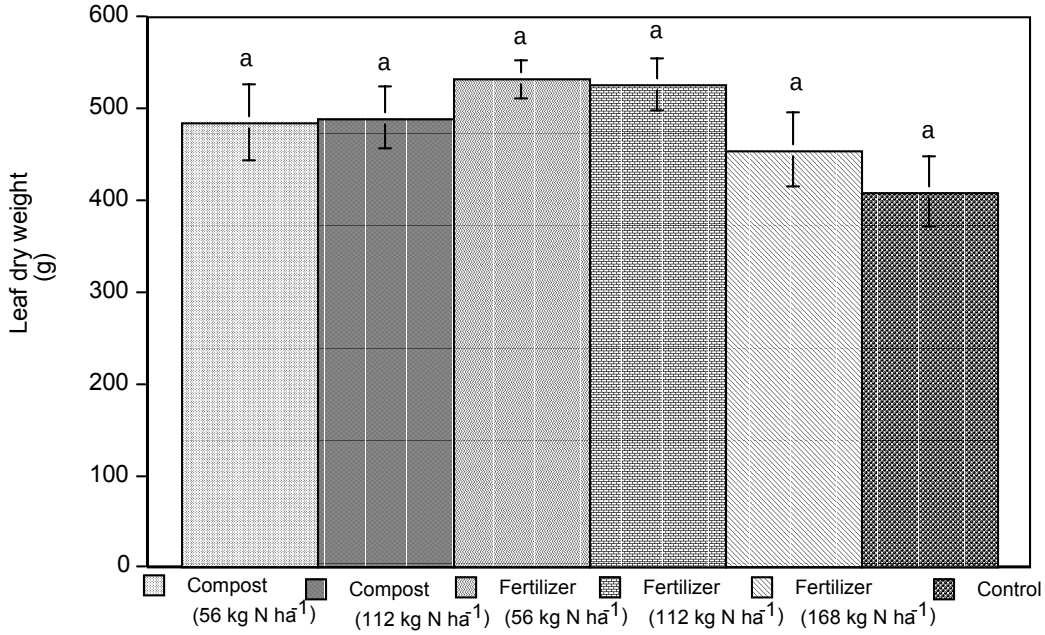

Table 1. Pre-plant soil characteristics at the HMSF Organic Herb Trial, 1998.

Soil Characteristic	Amount
Organic Matter	3.7%
pH	6.6
Buffer pH	6.9
P	424 ppm
K	619 ppm

Table 2. Soil characteristics of *Echinacea purpurea* plots with organic fertilizer and compost treatments at the HMSF Organic Herb Trial, 2000.

Treatment	Moisture (%)	pH	Total C ppm	NH_4-N ppm	NO_3-N ppm
Control	19.0a†	6.5a	26791a	4.0b	7.0a
Compost (56 kg N ha^{-1})	18.2a	6.8a	26056a	2.0a	8.0a
Compost (112 kg N ha^{-1})	18.9a	6.6a	24219a	2.6ab	6.3a
Fertilizer (56 kg N ha^{-1})	19.1a	6.5a	27341a	2.1a	5.0a
Fertilizer (112 kg N ha^{-1})	17.6a	6.2a	28358a	2.0a	8.6a
Fertilizer (168 kg N ha^{-1})	18.1a	6.6a	28512a	4.3b	12.7b
LSD	NS	NS	NS	1.81	5.78

† Within a column, means with the same letter are not significantly different.

Table 3. Soil characteristics of *Echinacea angustifolia* plots with organic fertilizer and compost treatments at the HMSF Organic Herb Trial, 2000.

Treatment	Moisture (%)	pH	Total C (ppm)	NH_4-N (ppm)	NO_3-N (ppm)
Control	17.0a	6.5a	25151a	3.7a	8.8a
Compost (56 kg N ha^{-1})	16.9a	6.5a	28031a	2.4a	6.6a
Compost (112 kg N ha^{-1})	18.4a	6.7a	28103a	3.3a	4.7a
Fertilizer (56kg N ha^{-1})	15.5a	6.5a	28544a	3.9a	5.4a
Fertilizer (112 kg N ha^{-1})	17.9a	6.6a	27844a	3.2a	3.9a
Fertilizer (168 kg N ha^{-1})	19.4a	6.6a	28585a	3.1a	11.3a
LSD	NS	NS	NS	NS	NS

† Within a column, means with the same letter are not significantly different.

Table 4. Soil characteristics of *Melissa officinalis* plots with organic fertilizer and compost treatments at the HMSF Organic Herb Trial, 2000.

Treatment	Moisture (%)	pH	Total C (ppm)	NH_4-N (ppm)	NO_3-N (ppm)	Fe (ppm)	S (ppm)
Control	18.7a	6.4a	30071a	3.7a	9.1a	274a	12.9a
Compost (56 kg N ha^{-1})	19.2a	6.5a	30314a	2.4a	4.4a	235a	11.0a
Compost (112 kg N ha^{-1})	19.6a	6.6a	28512a	2.2a	6.8a	218a	9.7a
Fertilizer (56kg N ha^{-1})	16.2a	6.7a	26065a	4.4a	9.3a	219a	11.4a
Fertilizer (112 kg N ha^{-1})	15.7a	6.8a	30190a	3.1a	6.9a	252a	14.8a
Fertilizer (168 kg N ha^{-1})	16.8a	6.6a	27586a	3.5a	13.1a	330a	16.8a
LSD	NS	NS	NS	NS	NS	NS	NS

† Within a column, means with the same letter are not significantly different.