deficient *Roystonea* spp. or *Cocos* palms would require the uptake of 6.5 kg of actual K by the plant. If a 0-0-38 formulation is used, but only 20% of the applied fertilizer is taken up by the palm, 87 kg of this fertilizer would have to be applied over a several year period to completely correct the deficiency.

One year after treatment with Osmocote 0-0-37 (Sierra Chemical Co.) began, K-deficient *Chrysalidocarpus lutescens* had replaced about two-thirds of their foliage with deep green leaves, while control plants remained orange to yellowish-green with extensive spotting and marginal necrosis. Based on the current growth rate, it is predicted that the treated K-deficient areca palms will be completely green and free from symptoms after about 1.5 years of treatment. One year after treatment began on severely deficient *Hyophorbe verschafeltii* H. Wendl. palms, the greatest difference between treated and control palms was in the vigor and in the number of leaves held by the palms. Treated palms appeared very vigorous and held an average of 6-7 leaves, although deficiency symptoms remained on the oldest leaves. Control palms retained only about an average of 1.5 leaves and all leaves showed severe symptoms. Since the deficient palms originally had greatly reduced canopies, a whole new canopy must be grown before complete recovery from the symptoms can be effected. This is predicted to require about 2 years for this species.

Literature Cited

1. Broeshart, H., J. D. Ferwerda, and W. G. Kovachich. 1957. Mineral deficiency symptoms of the oil palm. Plant Soil 8:289-300.
2. Broschat, T. K. 1984. Nutrient deficiency symptoms in five species of palms grown as foliage plants. Principes 28:6-14.
3. Broschat, T. K. 1990. Potassium deficiency of palms in south Florida. Principes 34:(in press).
4. Bull, R. A. 1961. Studies on the deficiency diseases of the oil palm. 2. Macronutrient deficiency symptoms in oil palm seedlings grown in sand culture. J. West African Inst. Oil Palm Res. 3:254-264.
5. Dickey, R. D. 1977. Nutritional deficiencies of woody ornamental plants used in Florida landscapes. Univ. Fla. Agr. Exp. Sta. Bull. 791.
6. Manciot, E., M. Ollagnier, and R. Ochs. 1979. Mineral nutrition and fertilization of the coconut around the world. Oleagineaux 34:576-580.
7. Marlatt, R. B. 1980. Noncontagious diseases of tropical foliage plants. Univ. Fla. Agr. Exp. Sta. Bull. 812.
8. Street, J. J. and N. Gamon. 1983. Plant nutrient deficiency symptoms. Univ. Fla. Coop. Ext. Serv. Circ. 435.

Proc. Fla. State Hort. Soc. 102:108-111. 1989.

MUSHROOM COMPOST AS A SOIL AMENDMENT FOR VEGETABLE GARDENS

J. M. STEPHENS
University of Florida, IFAS
Vegetable Crops Department
Gainesville, FL 32611

G. C. HENRY
University of Florida, IFAS
Leon County Extension Service
Tallahassee, FL

B. F. CASTRO
University of Florida, IFAS
Gadsden County Extension Service
Quincy, FL

D. L. BENNETT
University of Florida, IFAS
Wakulla County Extension Service
Crawfordville, FL

Additional index words. organic gardening, fertility, beans, collards, squash, tomatoes, *Agaricus bisporus.*

Abstract. **The relatively small industry in Florida that grows mushrooms [*Agaricus bisporus* (Lange) Sing.] produces tons of a by-product called spent mushroom compost. Quincy Farms, Inc., located in Gadsden County, discards around 14 tractor-trailer loads of the compost every 3 days. A study was conducted in 1989 at 3 locations—Crawfordville, Quincy, and Tallahassee, to evaluate the compost as a soil amendment and organic fertilizer for use in vegetable gardens. Effects were observed and evaluated on bush beans (*Phaseolus vulgaris* L.), collards (*Brassica oleracea* L. Acephala group), squash (*Cucurbita pepo* L.), and tomato (*Lycopersicon esculentum* Mill.). At Crawfordville, compost at 20 T/acre combined with 160-69.8-132.8 (N-P-K) fertilizer gave the highest yields. The trial at Quincy showed that a garden could be grown on compost alone, at the rate of 50 T/acre. Collard plants averaged 3 inches taller, squash yields 1 lb. more, and tomato yields about 1 lb. more than when fertilizer (108-62.8-119.5) was applied alone. The compost was evaluated both in 1988 and in 1989 at Tallahassee. In 1988, best plant response was observed in the all-fertilizer plot. However, in 1989 on plots which had received additional compost due to the residual from the previous year and the doubling of the rate from 20 to 40 T/acre, plant response was only slightly less than for plots receiving fertilizer only (224-97.7-185.9). Results of this trial indicated that the spent mushroom compost produced at Quincy Farms, Inc. is an effective organic fertilizer and soil amendment for growing vegetables in north Florida gardens.**

The production and preparation for market of most vegetable crops results in the accumulation of various kinds of by-products that must be discarded in some proper, non-polluting manner. In most instances the disposal problem involves an accumulation of plant trimmings and cull produce. In other cases the waste is composed of such residue as plastic mulch, pesticide-contaminated wash water, and used containers. But with mushrooms, the waste material of concern is the left-over production medium called spent mushroom compost.

The Florida mushroom industry is relatively small compared with that of such states as Pennsylvania, which is ranked No. 1 in the country (2, 3, 5). Sixty percent of the

U.S. production of mushrooms came from Pennsylvania in 1975 (10). Florida's industry centers around 2 large farms, one located near Zellwood and another near Quincy (4, 9). A smaller unit is situated near Eustis in Lake County. All of these production farms generate large quantities of the waste by-product referred to as compost, because new compost must by prepared and used with every new crop of mushrooms. Quincy Farms, Inc. produces about 14 tractor-trailer loads of spent compost every 3 days, amounting to 10,000 tons per year (1). Traditionally, the preparation of compost for mushrooms has resulted in a rich, homogenous, pasteurized mixture of organics and nutrients, a product well-suited as a soil amendment/organic fertilizer for higher plants such as vegetables. Early mixtures contained mostly horse manure and other natural ingredients (7, 10), thus rendering the product acceptable for organic farming and gardening. Later, the horse manure was often supplemented with inorganic fertilizer such as ammonium nitrate and muriate of potash (7, 10) which eliminated the compost from organic practice.

The utilization of the spent compost as a soil amendment for other crops has long been advocated (G. Stout and D. Buffington. 1973. Producing mushrooms in Florida. University of Florida Misc. Rpt. 73-1). However, current evironmental concerns about the use of chemicals in agriculture are providing a new incentive for finding acceptable and readily available forms of organic fertilizer.

Very few studies on the value of spent mushroom compost in vegetable production have been conducted. One such study in Illinois showed that mushroom compost provided balanced feeding for some vegetables, while a complete chemical fertilizer was more satisfactory for others (6). In 1980, agriculture students at Apopka Junior High School were applying compost from the nearby Ralston Purina plant in their vegetable garden. The students noted increased yields where the compost was used, and attributed this to improved water-holding capacity of the amended soil (J. Cloran, Apopka Jr. High School, personal communication). At the 1987 Sunbelt Agricultural Exposition, the use of compost acquired from Quincy Farms, Inc. was demonstrated on 6 kinds of vegetables (1, 8). Observers were impressed with the lush growth of the vegetables in the plots containing the compost.

Quincy Farms recognized the value of the compost and made it available to growers and gardeners direct from the plant and through retailers. It has been selling by the bag, cubic yard, and in truck-load lots (8).

Upon receiving numerous inquiries about the compost, extension agents in Gadsden, Leon, and Wakulla counties collaborated with the Extension Vegetable Crops Specialist at Gainesville in a study designed to evaluate the compost. This paper reports on the results of these observational trials.

Materials and Methods

During the spring of 1989, 3 observational vegetable gardens were planted concurrently at 3 locations—Quincy, Tallahassee, and Crawfordville, under the supervision of County Extension Agents, respectively, Ben Castro (Gadsden County), George Henry (Leon County), and Dale Bennett (Wakulla County). To all 3 gardens, spent mushroom compost was incorporated alone and in combination with commercial fertilizer, and was compared with commercial fertilizer applied according to standard gardening recommendations (11). The test crops were similar at all three locations, and consisted of collards, bush beans, summer crookneck squash, and tomatoes.

Compost. The raw materials for making the Quincy Farms (QF) compost are listed in Table 1. The exact process for making QF compost understandably was not divulged. However, most mushroom growers use some form of the following procedure outlined by San Antonio (10). In the first step the raw materials are assembled and wetted in long heaps. Gypsum is added as a conditioner. As the heap is turned, watered, and aerated, the supplements such as chicken manure are added. About 5-20 days after step 1 begins, a partially composted product is placed in trays where the composting continues under controlled conditions. Pasteurization at 104°-126°F is then used to control pests, The cooled finished product containing about 2% nitrogen is ready for inoculation with spawn approximately 30 days from start to finish.

Usually 4-8 tons of compost are required to produce 1 ton of mushrooms. After 150 days of yielding mushrooms, the spent compost is discarded. At this time, it may still contain 2% N (10). The composition of the QF compost is shown in Table 1. As the compost ages, it dries out, becomes more acidic and less salty, but retains most of its nutritive value (Table 2).

Quincy trial garden. A trial was conducted in the spring of 1989 at the Gadsden Country Agricultural Center at Quincy on sandy soil, non-tilled and which had been planted in Bahia-Bermuda-red clover for 25 years. Main plots (12 x 14 ft) were the compost treatments, and sub-plots (3 x 4 ft) were the 4 vegetables—'Better Boy' tomatoes, 'Blue Lake' bush beans, 'Georgia' collards, and yellow crookneck (YCN) squash. The main plots were not replicated but were repeated at Crawfordville and Tallahassee.

On 24 March 1989 the compost (2 months aged) and the fertilizer treatments were applied (Table 3). The subplots, planted the same day, were replicated 3 times and contained the following: 3-4 tomato plants, 5 collard plants, 6 squash plants, and a 4-6 ft row of beans. Plots were irrigated with a single trickle tube placed 3 inches from row center and operated 3 times each day. Normal garden care was provided, except that no fertilizer sidedressings were made.

Yields were recorded for collards and tomatoes from a once-over harvest. Squash was picked 3 times. Bean growth was observed, but not recorded.

Crawfordville trial garden. The Wakulla County trial was conducted in the spring of 1989 on the Buck Miller Farm in Hilliardville, near Crawfordville, on recently cultivated sandy soil. Again, main plots (9 x 12 ft) were the compost treatments, and sub-plots (3 x 3 ft) were the vegetables.

Table 1. Initial composition of Quincy Farms mushroom compost.[z]

Ingredient	Proportion (%)
Wheatstraw	51
Chicken litter	20
Peat moss	20
Limestone	5
Gypsum	3
Feather meal	1

[z]Data provided by Al Willis, distributor for Quincy Farms, Inc.

Table 2. Analysis of Quincy Farms spent compost at various stages of storage.[z]

Age[y] month	Moisture (%)	Salts (mmhos/cm	Acidity (pH)	Chemical composition[x] NO$_3$ (ppm)	P (%)	K (%)	CA (%)	Mg (%)
0	64.9	12.0	7.3	7	.69	1.46	6.10	.38
18	58.7	17.3	6.2	902	.87	1.23	6.70	.45
48	50.3	6.1	6.4	655	.74	.53	6.70	.35

[z]Data is from A & L Agriculturan Laboratories of Memphis, TN, 5/26/89.
[y]Samples taken for analysis 0. 18, and 48 months after stockpiling outdoors.
[x]Dry weight basis.

On 29 March 1989 the compost and fertilizer treatments were applied (Table 4), and the vegetables planted. The vegetable sub-plots were replicated 3 times and contained the following: 3 'Monte Carlo' tomato plants, 3 'Georgia' collard plants, 3 'YCN' squash plants, and a 3-ft row of bush snap beans.

Plots were irrigated by overhead sprinkler. No further fertilizer was applied, and the plants received no pesticides. Otherwise, reasonable care was provided through the efforts of a local Master Gardener. The vegetables were harvested and a limited amount of yield data was taken prior to 30 June 1989.

Spring 1988, Tallahassee. A preliminary observation of the compost was made by George Henry on sandy soil in Leon County during the spring of 1988. Main plots (9 x 12 ft) were the compost treatments and sub-plots were the 4 vegetables.

On 1 April 1988, the compost and fertilizer treatments were applied (Table 5) and the vegetables planted. The sub-plots were replicated 3 times and contained the following vegetbles: 3 'Better Boy' tomato plants, 3 'Vates' collard plants, 3 'YCN' squash plants, and 1 row of 'Blue Lake' bush beans. After the initial broadcast/banded application of fertilizer (128-55.8-106.2), 3 side-dressing (32-14-26,6) were made at 2-week intervals in the plots containing fertilizer alone. When applied in combination with compost, the fertilizer rate was reduced to 63-27.9-53.1, with no side-dressing.

Care of the garden was normal for the area. Overhead irrigation was used. The vegetables were harvested at precise intervals and yield data were taken, except for beans (crop loss).

Spring 1989, Tallahassee. The same plots in Tallahassee that were evaluated in 1988 were treated and planted again in 1989 in a similar manner except for the rate of compost which was doubled, from 20 T/acre in 1988 to 40 T/acre in 1989. The garden received normal care as in the previous year, and yield/growth rates were recorded again.

Table 3. Compost treatments applied at Quincy.[z]

Treatment	Amount	Application
Compost, QF	50 T/acre (2.38 lb./ft^2)	Broadcast/incorporated
Fertilizer, 6-8-8[y]	1800 lb./A (108-62.8-119.5)	Banded
Compost QF + fertilizer, 6-8-8	50 T/acre (2.38 lb./ft^2) 1800 lb./A 108-62.8-119.5)	Broadcast/incorporated Banded

[z]Compost and fertilizer treatments were applied day of planting. 24 March 1989.
[y]Fertilizer was a 6-8-8 tomato special which included micronutrients.

Table 4. Compost treatments at Crawfordville.[z]

Treatment	Amount	Application
Compost, QF	20 T/acre (1 lb./ft^2)	Broadcast/incorporated
Fertilizer, 10-10-10	1600 lb./A (160-69.8-132.8)	½ broadcast/½ banded
Compost, QF + fertilizer, 10-10-10	20 T/acre (1 lb./ft^2) 1600 lb./A (160-69.8-132.8)	Broadcast/incorporated ½ broadcast/½ banded

[z]Treatments were applied day of planting, 28 March 1989.

Results and Discussion

Crops differed in response to treatments at the various locations (Table 7). Since this trial was designed for observational purposes, the data were not statistically valid. However, there were trends in the effects on collard plant height, squash yield, and tomato yield. Bean production was poor at all locations, so no data are reported for this vegetable.

Spring 1988, Tallahassee. Observational data gathered from the preliminary test in Tallahassee indicated that while the compost was beneficial in the garden, the amount tested (20 T/acre) did not produce yields comparable to the commercial fertilizer. With compost alone, collard height was 6.5 inches, squash yield was 3.0 lb./plant, and tomato yield was 1.3 lb./plant, compared with a collard plant height of 7.8 inches, squash yield of 5.8 lb./plant, and a tomato yield of 2.1 lb./plant, respectively, for the fertilizer (224-97.7-185.9). Even when fertilizer (64-27.9-53.1) was added with the compost, the fertility level was still too low for yields comparable to the higher rate of fertilizer alone. In fact, yields were the same as for the compost alone. Therefore, it was decided to apply the compost more liberally in the 1989 trial.

Spring 1989, Tallahassee. On plots which had received additional compost over 1988 due to the residual from that previous year and the doubling of the rate from 20 to 40 T/acre, plant growth and yields were closer to that from the all-fertilizer plot. Growth and yields from compost

Table 5. Compost and fertilizer treatments at Tallahassee, Spring 1988.[z]

Treatment	Amount	Application
Compost, QF	20 T/acre (1 lb./ft^2)	Broadcast/incorporated
Fertilizer, 8-8-8	2800 lb./A (224-97.7-185.9)	Broadcast/banded/ sidedressed
Compost, QF + fertilizer, 8-8-8	20 T/acre (1 lb./ft^2) 800 lb./A (64-27.9-53.1)	Broadcast/incorporated Broadcast/incorporated

[z]Treatments were applied at planting time, 1 April 1988.

Table 6. Compost and fertilizer treatments at Tallahassee, Spring 1989.[z]

Treatment	Amount	Application
Compost, QF	40 T/acre (2 lb./ft²)	Broadcast/incorporated
Fertilizer, 8-8-8	2800 lb./A (224-97.7-185.9)	Broadcast/banded/ sidedressed
Compost, QF + fertilizer, 8-8-8	40 T/acre (2 lb./ft²) 800 lb./A (64-27.9-53.1)	Broadcast/incorporated Broadcast/incorporated

[z]Treatments were applied at planting time, 21 March 1989.

alone were just slightly less than that from fertilizer alone, with collard plants averaging 8.6 inches in height compared with 9.2 inches for the fertilizer-alone plot, squash yields averaging 2.5 lb. vs. 2.8 lb. for the fertilizer, and tomato yielding 2.3 lb. on compost compared with 2.8 lb. for fertilizer.

Adding fertilizer to the compost apparently made no difference, as growth and yields were similar in the compost-only plot and the compost plus fertilizer plot. These results would indicate that gardens could be grown quite satisfactorily where spent mushroom compost is the sole source of fertility.

Spring 1989, Crawfordville. As was the case at Tallahassee the previous year, compost applied at the rate of 20 T/acre (.92 lb./sq ft) appeared to be insufficient to produce comparable yields to commercial fertilizer. However, the only evidence for this observation was with squash where only 2.0 lb. of fruit/plant were produced with compost compared with 3.7 lb./plant for fertilizer (Table 7). The addition of a little fertilizer to the compost apparently enhanced growth to some degree. Tomato yield increased from 1.7 lb./plant with compost to 2.7 lb./plant where fertilizer had been added to the composted plot. While collard plants were a little shorter in the combination plot, the leaves were observed to be longer and wider than for the other treatments. In an overall assessment of the plots, observers rated the combination of fertilizer and compost as the best treatment in the trial at Crawfordville.

Spring 1989, Quincy. Results of the trial at Quincy during the spring of 1989 provided more evidence for the usefulness of spent mushroom compost as both a soil amendment and as a fertilizer source. Collards, squash, and tomatoes grown on the plot treated only with compost produced as well or better than plots receiving commercial fertilizer. On the compost-only plot, collard plants averaged 3 inches taller, squash yielded 1 lb. more, and tomato about 1 lb. more than fertilizer alone (Table 7). Part of the reason that compost applied alone may have performed better at Quincy than at Tallahassee or Crawfordville may have been due to the use of trickle irrigation and the larger amount of compost used at Quincy.

For unexplained reasons, plants in the plot receiving a combination of compost and commercial fertilizer did not perform as well as those in the compost-alone plot. While tomatoes produced about the same amount of fruit-weight (Table 7), measurements taken on plant height showed tomato plants averaged 29 inches on compost alone compared with 27 inches with the addition of fertilizer to the compost. Without any compost, tomato plants averaged only 24 inches in height. With squash, the differences were even more striking. With compost alone, squash plants averaged 32.5 inches high and produced an average of 4.2 lb./plant, compared with a height of 24.5 inches and yield of 3.2 lb./plant in the combined fertilizer-compost plot.

Table 7. Crop response to compost and fertilizer treatments at three locations, 1988 and 1989.[z]

	Collard	Squash	Tomato
Location and treatment	Plant height (inches)	Yield/plant (pounds)	Yield/plant (pounds)
Crawfordville, Spring 1989			
Compost	20	2.0	1.7
Fertilizer	20	3.7	.6
Compost/fertilizer	17	3.6	2.7
Quincy, Spring 1989			
Compost	22	4.2	2.4
Fertilizer	19	2.7	1.3
Compost/fertilizer	19	3.2	2.7
Tallahassee, Spring 1988			
Compost	6.5	3.0	1.3
Fertilizer	7.8	5.8	2.1
Compost/fertilizer	5.2	2.6	.8
Tallahassee, Spring 1989			
Compost	8.6	2.5	2.3
Fertilizer	9.2	2.8	2.8
Compost/fertilizer	8.0	2.6	2.3

[z]Data not statistically analyzed due to observational design.

Results of this trial provide strong indication that the spent mushroom compost produced as a by-product of Quincy Farms, Inc. is an effective soil amendment and organic fertilizer for vegetables grown in north Florida gardens. While it is not clear from this study the exact amounts to suggest for best results in various locations and with different cultural schemes, most evidence shows a rate in the range of 40 to 50 T/acre (1.84-2.3 lb./sq ft) might be recommended for a compost treatment without additional fertilizer. Some supplemental application of commercial fertilizer might be beneficial with lower rates of the compost, but these rates were not well-defined by this study. More work is needed to establish precise guidelines for the use of this compost on a wider range of vegetable crops. In the meantime, the utilization of the spent mushroom compost on home gardens and organic farms appears to be a most viable way to help solve the current problem of waste accumulation and disposal from this particular agricultural industry.

Literature Cited

1. Adams, V. 1987. Mushroom compost—wonderful, rich soil amendment and conditioner. The Atlanta Journal and Constitution. Nov. 8.
2. Anonymous. 1973. U.S. faces mushrooming challenge. American Vegetable Grower. May 1973. p. 21-22.
3. Anonymous. 1985. The farm beneath the hills. National County Agent. XLVI, No. 3.
4. Clayton, D. 1976. Business "mushrooms" for Zellwood industry. Florida Market Bulletin. Vol. 18, No. 10.
5. Coale, C. W. 1970. Physical specifications of mushroom processing plants. Penn State University Progress Rpt. 309.
6. Hashim, I. B., W. E. Splittstoesser, and J. S. Vandemark. 1978. Response of vegetable crops to three kinds of fertilizer. Illinois Research. Spring 1978. p. 12-13.
7. Lambert, E. B. 1955. Mushroom growing in the United States. U.S. Dept. Agr. Farmers' Bul. No. 1875.
8. Marshall, D. W. 1987. Tallahassee fortunate to have mushroom compost. Tallahassee Democrat. Dec. 4.
9. Peck, D. 1987. Mushrooms bring quiet prosperity. Florida Market Bulletin Vol. 30, No. 9.
10. San Antonio, J. P. 1975. Commercial and small scale cultivation of the mushroom, *Agaricus bisporus* (Lange) Sing. HortScience 10(5):451-458.
11. Stephens, J. M. 1987. Vegetable gardening guide. University of Florida Ext. Cir. 104p.