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Vegetable Amaranth Trials 2008-2010

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ABSTRACT
In 2008-2010, eight cultivars of vegetable amaranth were grown on a loamy upland soil (Mt. Carmel, CT and on a sandy terrace soil (Windsor, CT) (2009-2010 only). Two to four harvests were conducted each year by cutting each plant about 8 inches from the soil surface. End-of-year plant survival was also determined. The average yield of all cultivars at Mt. Carmel for years 2008, 2009, 2010 was 2.8 lb/plant. Trials were only conducted at Windsor in 2009 and 2010 where the yields were 1.5 lb/plant compared to 2.7 lb/plant for the same two years at Mt. Carmel. At Windsor, decreased yields were due to lower fertility of the sandy soils especially in 2009. Yields at Windsor increased in 2010 when the fertilizer was split between pre-plant and side-dress applications. All Red had the highest yields and Bayam the lowest, but the yields were statistically equivalent to the other cultivars. When choosing which cultivar(s) to grow, color and taste should be considered as well as yield.

INTRODUCTION
Developing new crops provides new opportunities for farmers during a time of changing agriculture in Connecticut. Tobacco and dairy farming in Connecticut have declined dramatically in the last four decades. Acreage of tobacco declined from 8,700 acres in 1965 to 3,100 acres in 2007 (Anon. 2009). The number of Connecticut's dairy farms has also declined from 452 in 1986 to 269 in 2007 (Anon. 2009). Some tobacco and dairy farms have converted to vegetables, nursery stock, and Christmas trees and some diversified to provide supplemental income. New farming ventures on idle and rented land have increased the number of farms (annual income exceeding $1,000) from 3,900 in 2000 to 4,900 in 2007 (Anon. 2009). The number of vegetable farms increased from 582 in 2002 to 735 in 2007 (Anon. 2009). Today, about 11,000 acres in Connecticut are devoted to vegetable production. Seventy-seven percent of these farms are less than 100 acres in size. Historically, Connecticut has led New England in net farm income and has been among the leaders in sweet corn production. In 2007, the cash value of all vegetable crops grown in Connecticut was 30.2 million dollars or 5.5% of all crops grown (Anon. 2009). This compares to 19.1 million dollars in 2002 (Anon. 2004).

Small farm sizes in Connecticut have resulted in marketing shifts from wholesale contracts with local supermarkets to direct retail sales. Approximately 313 farms offer direct sales through roadside stands and sales rooms where a variety of fruit, vegetables, nursery stock, and Christmas trees are offered. About 36 of these are open all year. Nearly 20% of these farms offer pick-your-own fruit and vegetables to reduce the cost of harvest labor. These savings are passed on to the consumer.

The development of a network of farmers' markets in Connecticut's major urban centers and densely populated suburbs is an important segment of direct sales of vegetables to consumers. Most of the produce sold at farmers' markets is "Connecticut Grown". Farm fresh produce is offered to urbanites who cannot travel to the farms. Niche crops valued by diverse ethnic groups are often sold at these markets. According to the Connecticut Department of Agriculture, there were 126 farmers' markets in 2011, attended by over 400 farmers compared to 87 markets in 2007, a 45% increase.

As the popularity of farmers' markets in Connecticut have surged, so too has the need for growers to find a diversity of high value niche crops. Consumers used to a wide variety of fruits and vegetables in large supermarkets are seeking a greater diversity of ethnic and specialty crops at farmers' markets and roadside stands. Recent research in our New Crops Program has concentrated on vegetables of interest to ethnic populations, such as calabaza (Hispanic), pak choi (Asian), and jilo (Brazilian). According to the 2009 census, 11% of Connecticut's residents are of Hispanic heritage and 16% are of Italian ancestry (ranking it first in the United States). The Asian population grew 42% from 2000 to 2006. The greatest concentrations of these ethnic groups are in Hartford, New Haven, and Fairfield Counties where many of the farmers' markets are located. There is also a large Brazilian population in the Waterbury-Danbury, CT area. These ethnic groups wish to continue purchasing vegetables that are traditional in their diets, thereby giving farmers opportunities for production of crops with a ready market. Ethnic vegetables also appeal to high-end buyers for whom ethnic vegetables are not every day fare, but who enjoy gourmet produce and culinary variety. Many farmers wish to diversify their operations by growing specialty crops, but there has been little information on the culture of these vegetables in Connecticut. It is also important that cultural techniques for these vegetables be adapted to Connecticut's soils and climate.

The genus *Amaranthus* consists of 70 species which can be broadly categorized into grain, green leaf vegetable, and weed types. Native to the America's, over 400 varieties are now found throughout the world in both temperate and tropical climates. It is a monoecious annual with an upright growth habit that is moderately branched. Grain types form large loose panicles at the tips of the stems while vegetable types form flowers and seeds along the stem and smaller panicles (Huang 1980). In photosynthesis, vegetable amaranth follows the C4 pathway which occurs in only a few other crop plants such as corn, sorghum, and sugarcane. This enables it to use light and water more efficiently in converting CO2 to carbohydrate. This is particularly advantageous during hot dry spells when sunlight is abundant.

Not all amaranth plants are cultivated. Most Amaranthus species are summer annual weeds and are commonly referred to as pigweed. These species have an extended period of germination, rapid growth, high rates of seed production, and have caused problems for farmers since the mid-1990's (Bensch 2003). This is partially due to the reduction in tillage, reduction in herbicidal use, and evolution of herbicidal resistance in several species. Nine species of Amaranthus are considered invasive and noxious weeds in the United States: *A. albus, A. blitoides, A. hybridus, A. palmeri, A. powellii, A. retroflexus, A. spinosus, A. tuberculatus,* and *A. viridis.* Pigweed can also be a beneficial companion plant, serving as a trap for leaf miners and some other pests.

The leaves of both the grain and vegetable types may be eaten raw or cooked; however, the amaranths that are grown principally for vegetable use have more tasty leaves than the grain types (Huang 1980). Two species, *A. tricolor* and *A. dubius* have the desired characteristics for the vegetable type and are commonly grown in Asia, West Africa, and the Caribbean (Costea 2003). A third species, *A.cruentus*, is grown both for leaves and grain.

Cultivation of amaranth for their leaves (vegetable amaranth) dates back more than 2,000 years. Presently, vegetable amaranth is widely grown in the tropics and is one on the most important leafy vegetables in the lowlands of Africa and Asia. It is consumed as a vegetable in Africa, China, Greece, India, Italy, Nepal, the Caribbean, and the South Pacific Islands where it is commonly cultivated for use as a boiled leafy vegetable (Stallknecht and Schulz-Schaeffer 1993). In Asia and the West Indies, amaranth is widely used in soup. In Jamaica, it is routinely eaten at breakfast and dinner. Vegetable amaranth is also known as "calaloo" which is a Caribbean term for "leafy vegetable".

The awareness in the United States of the potentiality of vegetable amaranth was generated by the Rodale Research Center, in Kutztown, Pennsylvania during the mid-1970's (Singh and Whitehead 1996). Immigrants from countries where vegetable amaranth is widely consumed created a demand for this vegetable in the United States. Vegetable amaranth can also fill a void for fresh leafy vegetables during summer months. Amaranth leaves have a taste comparable to spinach (*Spinacia oleracea* L.) (Abbott and Campbell 1982). Unlike spinach, the ideal season for producing amaranth in the temperate climates is during hot months of the summer. Abbott and Campbell (1982) and Makus and Davis (1984) obtained high yields of amaranth greens during the summer in Maryland and Arkansas, respectively. Sealy et al. (1990) reported that a West African cultivar "Ibondwe" yielded 14 t/ha in central Texas and was comparable to spinach in taste.

Vegetable amaranth has three times as much iron as spinach. It is a good source of dietary fiber and contains high amounts of protein, vitamins, and minerals (Markus and Davis 1984). Both the leaves and the seeds contain protein of an unusually high quality. It may be a promising source of protein to those who are sensitive to gluten, because unlike the protein found in grains such as wheat and rye, its protein does not contain gluten. According to a 2007 report, amaranth compares well in nutrient content with gluten-free vegetarian options such as buckwheat, corn, millet, wild rice, oats, and quinoa (Gallagher et al 2003).

Vegetable amaranth leaves and stems, or entire plants, may be eaten raw or cooked. It is commonly cultivated for use as a boiled leafy green vegetable either alone or in combination with other vegetables and/or meat. Cook amaranth as you would spinach. The presence of rather high amounts of oxalic acid and nitrates places some limitation on the quantity of raw amaranth leaves that can be consumed daily. Boiling the leaves like spinach, then discarding the water reduces the levels of both oxalic acid and nitrates. The amount of oxalic acid is roughly the same as that found in spinach and chard.

METHODS AND MATERIALS

Sites and soils. Trials of vegetable amaranth were conducted over three years at the Valley Laboratory, Windsor, on Merrimac sandy loam (Entic Haplorthod), a sandy terrace soil with somewhat limited moisture holding capacity (Shearin and Hill, 1962); and at Lockwood Farm, Mt. Carmel, on Cheshire fine sandy loam (Typic Dystrochrept), a loamy upland soil with moderate moisture holding capacity (Reynolds, 1979).

Cultivars. Cultivars vary in size and color. The various leaf colors include light green, dark green, red, purple, and variegated (looking similar to the house plant coleus). Most attain a height of 3 feet, but some dwarf varieties grow only 1.5 feet high and are best suited for the small garden. The cultivars evaluated in this study were: Asia Red, Tender Leaf, White Leaf, Green Pointed Leaf, Green Round Leaf, Red Striped Leaf, Bayam, and All Red. Seeds were obtained from Evergreen Seeds, Anaheim, CA. All of the cultivars were the species *A. tricolor* which is prized for its leaves.

Culture. Each year 8 cultivars were seeded in a greenhouse on May 1-3. The seedlings were grown in Promix BX (Premier, Red Hill PA) in standard plastic pots (3601 insert) measuring 2 $^{5}/_{8}$ X 2 ¼ X 2 $^{5}/_{8}$ inches (volume 15.5 cubic inches). The seedlings were thinned to one plant/pot and then fertilized with water soluble 20-20-20 (N-P_2O_5-K_2O) (0.5 oz/gal) four weeks after germination. After hardening the plants in a cold frame, they were transplanted between May 17-25 at both sites. Plants were planted 1.5 feet apart in rows 3 feet apart. There were 5 replications with 5 plants per replication. Weeds were controlled by hand cultivation. Overhead irrigation was used as necessary. Plants were removed from all plots at the end of the growing season and the land fallowed over winter.

Fertilization. The soils were fertilized each year with commercial grade 10-10-10 (N-P2O5-K2O) at 1300 lb/A, a rate determined from analysis of soil from both sites before the experiment. Initially, the soil fertility at both sites was low. In Windsor, in 2010, 650 lb 10-10-10/A was applied preplant and 650 lb 10-10-10/A was sidedressed after the first picking.

Harvest. Vegetable amaranth was ready to harvest about a month after transplanting. The whole plant was severed at about 8 inches above the soil surface. The entire sample (leaves and stems) were weighed. Frequent harvesting of leaves and shoots delayed the onset of flowering, and prolonged the harvest period. In Connecticut, as many as four cuttings are possible. Eventually, the plants began to flower and develop fewer leaves. In 2008, plants were harvested on July 8, July 22, August 13, and September 12. In 2009, plants were harvested August 10 and September 16; while in 2010, plants were harvested July 7 and August 11. Plants may be harvested once or several times. With single harvests, whole plants are pulled from the soil with roots, washed, and tied in bundles. With multiple harvests, young leaves and tender shoots are picked at 2-3 week intervals or the entire plant severed as was done in these trials.

Insect and disease control. No insect or disease control was required.

Statistical Analysis. Tukey’s HSD test was used to test for significant differences between the yields of cultivars at $p < 0.05$.

RESULTS

Yield. At Mt. Carmel, the average yield of all cultivars for all three years was 2.8 lb/plant (Table 1). Yields averaged 2.9 lb/plant in 2008, 2.3 lb/plant in 2009, and 3.1 lb/plant in 2010. All Red had the greatest yields in 2008 and 2010 (4.2 lb/plant and 3.5 lb/plant, respectively) while Red Striped Leaf averaged the greatest yields in 2009 (2.8 lb/plant). However, in all cases, the yields were not statistically greater than other cultivars. In 2008, All Red was equal to Red Striped Leaf; in 2010, All Red was equal to all cultivars except Asia Red. In 2009, Red Striped Leaf was statistically equal to all cultivars except Bayam, and White Leaf. Bayam, White Leaf, and Asia Red had the lowest yields in 2008, 2009, and 2010, respectively, but, in all cases, the yields were not statistically different than other cultivars. When the yields of all three years were averaged at Mt. Carmel, All Red had the greatest yields (3.5 lb/plant) with while Bayam consistently had the lowest yields (2.1 lb/plant).

At Windsor, the average yield of all cultivars for two years was 1.5 lb/plant (Table 2). Yields averaged 0.7 lb/plant in 2009 and 2.2 lb/plant in 2010. All Red had the greatest yields in both years. However, in both years, All Red was statistically equal to all cultivars except Bayam and White Leaf. Bayam and White Leaf had the lowest yields in both years. In 2009, their yields were statistically equal to all cultivars except Asia Red and Red Striped Leaf whereas, in 2010, yields were statistically equal to all the other cultivars except Red Striped Leaf. When the yields of 2009 and 2010 were averaged at Windsor, All Red (1.9 lb/plant) was the highest yielding cultivar with Bayam and White Leaf (1.1 lb/plant) was the lowest.

End-of-year survival. At Mt. Carmel, the average end-of-year survival rate for all three years was 83% (Table 3). In 2008, the 8 cultivars averaged 74% end-of-year survival rate, in 2009, 78% survival rate, and in 2010, 98% survival rate. Red Striped Leaf had the greatest survival percentage in 2008 with 84% surviving to the end of the growing season. In 2009, Tender Leaf had 92% surviving while in 2010, all cultivars but Green Pointed Leaf (88%) and Green Round Leaf (96%) had 100% of the plants surviving until the end of the season.

At Windsor, the average end-of-year survival rate for two years was 89% (Table 4). In 2009, the 8 cultivars averaged 91% end-of-year survival rate and, in 2010, 86% survival rate. Bayam had the greatest survival percentage in 2009 with 100% surviving to the end of the growing season while in 2010, All Red, Asia Red, Green Pointed Leaf, and Tender Leaf had a 92% survival rate.

DISCUSSION

Average yields at both sites were greatest in 2010. There was an increase in yields of all cultivars in 2010 compared to 2009 in Windsor and an increase of 5 of the 8 cultivars at Mt. Carmel. When comparing the 3 years at Mt. Carmel, all 8 cultivars had their lowest yields in 2009. The weather data from the three years indicates 2010 was the hottest and the driest while 2009 was the coolest and rainiest (Table 5). Clearly, vegetable amaranth preferred hot and dry weather for optimum growth which is not surprising considering that it is normally grown in the tropics and the lowlands of Africa and Asia.

Average yields of Mt. Carmel were 2.8 lb/plant compared to 1.5 lb/plant at Windsor, a 87% difference. If just 2009 and 2010 are averaged at Mt. Carmel, the yields are 2.7 lb/plant compared to 1.5 lb/plant at Windsor, an 80% difference. The end-of year survival, however, was slightly better at Windsor, 89% compared to 83% (3-year average) or 87% (2-year average) at Mt. Carmel. Plants at Windsor were smaller compared to Mt. Carmel possibly due to a lack of nutrients. Although the two sites were fertilized at the same rate of 10-10-10 fertilizer (1300 lbs of N/acre), Windsor's soil is much sandier than Mt. Carmel's and thus nutrients tend to easily leach away. When extremely poor yields were observed in 2009, the fertilizer application was split the following year with half of the fertilizer applied preplant and the second half side-dressed mid-way through the season. Yields from 2010 improved 231% compared to 2009 while there was a 37% increase at Mt. Carmel over those two years. When comparing Windsor and Mt. Carmel yields in 2009, with one full fertilizer application at the start of the season at Windsor, average yields from Mt. Carmel were 234% greater than the average yields from Windsor; whereas in 2010, with the split fertilizer application, average yields from Mt. Carmel were only 37% greater than those from Windsor. Clearly, splitting the fertilizer application on sandier soils improved yields. A side-dressing of nitrogen (applied as calcium nitrate or ammonium nitrate) on sandy soils after the first cutting could be another alternative.

Comparing individual cultivars, All Red generally had the greatest yields, however, the yields were statistically equivalent to most of the other cultivars. Bayam had the lowest yields, but again, these yields were statistically equivalent to most of the other cultivars. When choosing which cultivar(s) to grow, other characteristics should be considered such as color and taste. Colors range from white (light green), dark green, red, purple, and variegated (looking similar to the house plant coleus). There are subtle variations in flavor among varieties. It is important to taste several cultivars to see which you, and your customers, prefer.

CONCLUSION

The demand for vegetable amaranth in the United States was initially created by immigrants from the countries where it is widely consumed. Vegetable amaranth can also fill a void for fresh leafy vegetables during the summer months. Most leafy greens grown in the United States prefer cool weather and perform poorly during hot summer months, while vegetable amaranth thrives in the heat of summer. For the commercial grower and backyard gardener alike, amaranth is easy to grow and provides a healthy vegetable in the hot summer months. In addition, the red-leafed and variegated forms are quite decorative, adding a splash of color to your garden or farm stand.

An early Greek fable counted among Aesop's Fables compares the rose to the amaranth to illustrate the difference in fleeting and everlasting beauty:

An amaranth planted in a garden near a Rose-Tree, thus addressed it: "What a lovely flower is the Rose, a favorite alike with Gods and with men. I envy you your beauty and your perfume." The Rose replied, "I indeed, dear Amaranth, flourish but for a brief season! If no cruel hand pluck me from my stem, yet I must perish by an early doom. But thou are immortal and dost never fade, but blooms for ever in renewed youth."

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Table 1. Yields (lb/plant) of vegetable amaranth at Mt. Carmel

Cultivar	2008	2009	2010	3-Year Average
All Red	4.2a	2.7ae	3.5a	3.5
Asia Red	2.6c	2.0ab	2.5b	2.4
Bayam	1.9d	1.7bd	2.8ab	2.1
Green Pointed Leaf	2.9bc	2.7ade	3.2a	2.9
Green Round Leaf	2.6c	1.8be	3.2ab	2.5
Red Striped Leaf	3.5ab	2.8 ace	3.4ab	3.2
Tender Leaf	2.9bc	2.7 a	3.0ab	2.9
White Leaf	2.6c	1.7bd	2.9ab	2.4
All cultivars	2.9	2.3	3.1	2.8

Values within the same year followed by the same letter are not significantly different by Tukey’s HSD test at the five percent level.

Table 2. Yields (lb/plant) of vegetable amaranth at Windsor

Cultivars	2009	2010	2-Year Average
All Red	1.1a	2.7a	1.9
Asia Red	0.8a	2.1ab	1.4
Bayam	0.4b	1.8b	1.1
Green Pointed Leaf	0.6ab	2.4ab	1.5
Green Round Leaf	0.5ab	2.3ab	1.4
Red Striped Leaf	1.0a	2.5a	1.8
Tender Leaf	0.6ab	2.4ab	1.5
White Leaf	0.4b	1.8b	1.1
All cultivars	0.7	2.2	1.5

Values within the same year followed by the same letter are not significantly different by Tukey's HSD test at the five percent level.

Table 3. End-of-year survival of vegetable amaranth at Mt. Carmel

Cultivars	2008	2009	2010	3-Year Average
All Red	80%	64%	100%	81%
Asia Red	64%	88%	100%	84%
Bayam	64%	88%	100%	84%
Green Pointed Leaf	80%	76%	88%	81%
Green Round Leaf	72%	68%	96%	79%
Red Striped Leaf	84%	64%	100%	83%
Tender Leaf	64%	92%	100%	85%
White Leaf	80%	80%	100%	87%
All cultivars	74%	78%	98%	83%

Table 4. End-of-year survival of vegetable amaranth at Windsor

Cultivar	2009	2010	2-Year Average
All Red	92%	92%	92%
Asia Red	96%	92%	94%
Bayam	100%	80%	90%
Green Pointed Leaf	88%	92%	90%
Green Round Leaf	76%	84%	80%
Red Striped Leaf	92%	76%	84%
Tender Leaf	88%	92%	90%
White Leaf	96%	84%	90%
All cultivars	91%	86%	89%

Table 5. Rainfall and temperature in 2008, 2009, 2010 (June 15-August 31)

Year	Mean Max. Temp. (^oF)	Mean Min. Temp. (^oF)	Days $\geq$ 85^oF	Rainfall (inches)	#rainy days
2008	82.0	62.2	19	13.09	27
2009	79.6	62.3	14	17.77	32
2010	84.5	64.6	44	11.76	20