into raised beds prevented the tree growth and yield advantages reported for raised beds on fine particle soils (Funt et al., 1997). Soil type among these three studies reveal a basic finding, heavier soils benefit from mounding (aeration) and not from irrigation while the lighter soils benefit from irrigation and not mounding. Optimizing growth requires an understanding of what limits growth and production. Mounding increased tree growth and yield only where soils were heavy and trees on heavy soils did not respond to supplemental irrigation. Mounding soils on lighter soils without irrigation will not improve tree growth and yield. Only irrigation had that effect. Determining what soil type will benefit from mounding must then be based on soil gas exchange capacity caused by the lack of adequate drainage.

The well-drained Aura soil did not respond to the moisture conservation benefits of mulching with killed sod. In defense of the mulch, the amount used was designed to be thin and temporary to avoid providing winter habitat for voles that damage tree bark. With that concern limiting mulch deposition, the benefits to available soil moisture were lost (Glenn and Welker, 1989; Tanaka and Anderson, 1997).

This study showed that mounding and/or the use of mulching under conditions of flat terrain and an Aura sandy loam soil was not effective for enhancing early peach performance. Mounding and/or mulching, without irrigation, did not result in significant improvements in tree growth or yield compared to the standard commercial practice in New Jersey of planting on flat terrain and using chemical weed control. The results of this study would likely be different on finer textured soils.

The major benefit of mounding fine textured soil has been to increase soil air space to prevent root stress from anaerobic conditions. Since increased soil moisture has been positively correlated with the distribution of *Phytphthora cactorum* spores (Horner and Wilcox, 1996), mounding poorly drained soils would be expected to decrease tree death from phytophthora root rot. Since studies of soil mounding in peach orchards have contradictory results where soil type and orchard floor management vary, future studies should be extended over a range of soils to determine when mounding, mulching, and/or irrigation should be considered.

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A Foam Mulching System to Control Weeds in Tomatoes and Sweet Basil

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ADDITIONAL INDEX WORDS. ***Lycopersicon esculentum*, *Ocimum basilicum*, mulch color, natural mulch, weed control**

SUMMARY. A foam mulch system was developed that can be applied as an aqueous mixture of cotton and cellulose fibers, gums, starches, surfactants and saponins and dries to an one inch thick mat. This mulch may overcome the difficulty in applying and lack of persistence with natural mulches. Foam mulch also has the advantage of being able to be incorporated into the soil without requiring disposal like some plastic mulches. The objective of our study was to determine the effect of foam mulch and its color on weed control within the crop row and on yields of basil (*Ocimum basilicum*) and tomatoes (*Lycopersicon esculentum*). The foam mulch maintained its integrity for the entire growing season and provided weed control within the crop row comparable to black plastic mulch. The only weeds that emerged in the crop row were through holes in either the black or foam mulch. Foam mulch color did not affect weed control because regardless of color it did not allow light penetration and

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served as a physical barrier impeding weed emergence. Basil shoot biomass was not affected by mulch treatment. Mulch color affected early, ripe fruit, and total yield of tomato. Tomato yields in the blue foam were greater than other treatments. Yields in the black foam mulch were similar to those in black plastic mulch. Further research is needed to characterize the effects of foam mulch on crop microenvironment. Currently foam mulch is being commercialized for use in the home landscape and other high-value situations.

The use of plastic mulches is common in herb and vegetable production. Plastic mulches control weeds within the crop row and modify the crop microenvironment. They form a physical barrier for weed seedlings, prevent sunlight from reaching the soil surface, and modify the microenvironment effecting weed seed germination and subsequent weed populations (Anderson et al., 1995; Brown et al., 1992; Hanna, 2000). Plastic mulches also can increase vegetable crop growth, improve earliness and yield compared to bare ground production systems. The effect of plastic mulch on weed and crop microenvironment (e.g., soil temperatures, mulch surface temperatures, and radiation balance) is determined primarily by optical properties of the material, extent of mulch–soil contact, and prevention of evaporation from the soil surface (Brown et al., 1992; Decoteau et al., 1989; Ham et al., 1993; Kasperbauer and Hunt, 1998; Tarara, 2000).

Black plastic is preferred for early season production of warm season crops such as tomato and basil because of its warming effect on the soil (Hanna, 2000; Ricotta and Masiunas, 1991; Schmidt and Worthington, 1998). But later in the season black plastic mulch can reduce yields because of excessive surface and soil temperatures (Roberts and Anderson, 1994; Schmidt and Worthington, 1998). The apparent surface temperatures of black plastic mulches can approach 158.0 to 176.0 °F (70 to 80 °C) during midday (Ham et al., 1993; Tarara, 2000).

Mulches with lighter surface colors, such as red and blue, have been developed to slow the accumulation of heat units and improve later season crop growth compared to black plastic mulch (Schmidt and Worthington, 1998). Tomatoes in red mulches set fruit earlier, produced more ripe fruit, and had a greater number of fruit than plants grown in black plastic (Brown et al., 1992; Decoteau et al., 1989; Gough, 2001; Kasperbauer and Hunt, 1998). The effectiveness of the red mulch is attributed primarily to the far-red to red photon ratio reflected to the developing fruit and nearby leaves from the mulch surface (Kasperbauer and Hunt, 1998).

Problems still exist with plastic mulches. The petroleum used to synthesize agricultural mulches is a nonrenewable resource. Removing plastics from fields for disposal is a labor intensive and unpleasant job (Anderson et al., 1995). Anderson et al. (1995) reported that 242 million lb (109.8×10^6 kg) of agricultural plastic mulch are generated annually, representing a serious disposal problem. Natural or organic mulches may solve these problems associated with plastic mulches while still providing weed control and increasing vegetable crop yield compared to bare ground.

Natural mulches include straw and bark, paper products such as black paper, and hydromulches. Natural mulches do not require disposal, add organic matter when tilled into the soil, and can suppress weeds (Anderson et al., 1995; Summers et al., 1995). Bark and straw are bulky, require an application to a depth of at least 2 inches (5.1 cm) to suppress weeds, and can immobilize nitrogen and lower soil temperatures affecting vegetable crop yield (Anderson et al., 1995; Ashworth and Harrison, 1983; Roberts and Anderson, 1994). Paper mulches have been used in vegetable production since the 1920s but they are difficult to lay and edges covered with soil decay rapidly, causing loss of weed control (Anderson et al., 1995). Hydromulches are easy to apply but rainfall and high humidity results in a mulch that is easily penetrated by insects such as the cabbage maggot (*Delia radicum*) and weeds (Liburd et al., 1998).

We evaluated a new natural mulch, called a foam mulch, which has the ease of application of hydromulch but does not degrade or soften on the soil surface like paper mulches and hydromulches. Foam mulch can be incorporated into the soil at the end of the growing season and will biodegradable similar to other natural mulches, thus alleviating the disposal problem associated with plastic mulches. The objective of our study was to determine the effect of foam mulch color on weed populations and yields of basil and tomatoes.

Materials and methods

The research was conducted on the Cruse Tract Irrigated Vegetable Research Farm, Champaign, Ill. The soil type was a Drummer silty clay loam (fine montimorrillontic, mesic, Aquic Arguidoll) with a pH of 6.2 to 6.4 and 3% organic matter. The experiment was a factorial with crop (basil or tomatoes) and mulch treatments as the factors in a split-block design with four replications. The mulch treatments were bare ground, black plastic mulch, black foam mulch, red foam mulch, and blue foam mulch.

The previous crop both years was soybeans (*Glycine max*). The experimental area was chisel plowed in and disced in the fall. In the spring the area was disced twice and a fine seedbed prepared with a roterra. Raised beds, 8 inches (20.3 cm) high and 2 ft (61.0 cm) wide, were made and black plastic mulch was laid on 7 June 1999 and 30 May 2000. The foam mulch was placed on the soil surface between 20 and 27 June 1999 and 10 and 11 June 2000. 'Mountain Supreme' tomato was transplanted on 9 June 1999 and replanted on 22 June due to fermented foam mulch killing the plants. In 2000, the tomato was transplanted on 2 June. 'Sweet' basil was transplanted on 9 June 1999 and 3 June 2000. The transplants were started in a greenhouse as previously described (McGiffen et al., 1992; Ricotta and Masiunas, 1991).

In 1999, the plots were 12 by 20 ft (3.7 by 6.1 m) and in 2000 because of space limitations the plots were 12 by 15 ft (3.7 by 4.6 m). In both years there were four rows per plot. The two outside guard rows were tomatoes and the inner rows, used for data, were one tomato row and one basil row. The spacing was 36 inches (91.4 cm) between rows and 18 inches (45.7 cm) between plants within the row.

The foam mulch was prepared as an aqueous slurry with 7.8% solids. The aqueous mix included recycled cotton and cellulose fibers (5.9% by weight), natural gums and starches

(0.6% by weight), natural surfactants and saponins (0.6% by weight), and natural pigments, fertilizer, and buffers (0.4% to 0.7% by weight) (Morgan, 2000). The foam mulch was generated on site and was applied at about 0.068 oz/inch^2 (0.3 g·cm^{-2}) solids with an average wet foam density of 0.47 oz/fl oz (0.45 g·mL^{-1}) and an average wet foam thickness of 1.7 inches (4.32 cm). Dry foam mulch had an average thickness of 1 inch (2.5 cm) initially and 0.5 inch (1.3 cm) after 3 months. The mulch maintained its strength and coherence throughout the study. Blue, black, and red colored foam mulch were created using ferric and ferrous ions and natural pigments. Basil and tomato plants were transplanted prior to foaming and the foam directly contacted the stems of the transplants.

The equipment for applying the foam mulch was trailer mounted and used a conventional gasoline powered 5 horsepower impeller pump which circulated the mixture between a 200-gal (757.1-L) mix tank and a 500-gal (1892.7-L) spray tank. A conventional 2-inch water hose and ball valves were used to apply the foam mulch to the plots.

Standard cultural practices for fresh-market tomatoes including staking were used. Urea was broadcast applied at 100 lb/acre (112.0 kg·ha^{-1}) N before planting. No pesticides were applied to the experiment. The plots were irrigated to ensure that 1 inch of water in the form of rain or overhead irrigation were applied each week.

Weeds were counted on 13 July 1999 and on 5 July and 2 Aug. 2000. Each weed species was identified and plants were counted by species in 3 ft^2 (2787.1 cm^2) within the crop row. After counting weeds, the plots were hoed and hand-weeded to remove weeds within the crop row and cultivated to remove any emerged weeds between crop rows. No herbicides were used in the experiment.

Basil was harvested on 12 and 2 Aug. 1999 and 2000, respectively. The number of plants were counted, the shoots cut at the soil surface, and fresh weight determined. Early maturing tomato fruit were harvested on 11 and 1 Sept. 1999 and 2000, respectively and weighed. The remainder of the fruit (both green and ripe) were harvested on 19 and 13 Sept. 1999 and 2000, respectively. At the final harvest the number of tomato plants were counted and in 1999, a subsample of 25 fruit was selected to determine percent green fruit and fruit quality. In 2000, because there were so few green fruit and culls the actual numbers were counted.

Data were tested for homogeneity of variance and weed counts transformed using a square root transformation. The data were then analyzed using the analysis of variance (ANOVA) procedure from SAS (SAS Institute, Cary, N.C.). Means were separated using Fisher's least significant differences test with an alpha of 0.05. Because it did not affect the mean separation or the conclusions the untransformed weed data are shown in Table 1.

Results and discussion

There were more weeds in 2000 than 1999 due to a change in location of the experiment but the weed spectrum was similar in both years. The dominant weeds were foxtail species (*Setaria* spp.) and large crabgrass (*Digitaria sanguinalis*) along with the broadleaf weeds, pigweed [redroot pigweed (*Amaranthus retroflexus*), smooth pigweed (*A. hybridus*), tumble pigweed (*A. albus*), and prostate pigweed (*A. blitoides*)], common purslane (*Portulaca oleracea*), and prickly sida (*Sida spinosa*).

Most weeds within the crop row were in the bare ground treatment (Table 1). For example, at the midseason count the bare ground treatment had 30 pigweed/10 ft^2 (27.9 pigweed/m^2) and 53 common purslane/10 ft^2 (49.2 purslane/m^2) while the foam or plastic mulch treatments had 1.5 or less pigweed and common purslane/10 ft^2 (1.39 plants/m^2). These weeds at 5 weeks after basil transplanting were at the two-true leaf stage. Throughout the growing season, the foam mulch provided weed control within the crop row comparable to plastic mulch.

Foam mulch maintains its integrity through tomato harvest and served as a physical barrier preventing weed emergence, unlike other natural mulches such as planters paper or hydromulch (Anderson et al., 1995; Liburd et al., 1998). Bark or straw mulch must be applied to a depth of 2 inches for weed suppression (Ashworth and Harrison, 1983), whereas foam mulch was initially 1 inch thick and only 0.5 inch after 3 months, yet it still controlled weeds for the entire growing season.

The only weeds that emerged in the foam or plastic mulch treatments were through holes in either the black plastic or foam mulch. Walking on the

Table 1. The effect of mulches on weed control within the crop row. Results are averaged over weed counts in the tomato and basil crop rows. Midseason weed control is 5 weeks after basil transplanting (WABT) (13 July 1999 and 17 July 2000) and is averaged over year. Late- season weed control is 9 WABT (14 Aug. 2000).

	Midseason weed control				Late-season weed control			
Treatment	Grass[z]	Pigweed[y]	Purslane	Prickly sida	Grass	Pigweed	Purslane	Prickly sida
	(no./10 ft^2)[x]							
Bare ground	6.5 a[w]	30 a	53 a	6.3 a	2.1	9.2 a	36.3 a	6.3 a
Black plastic	1.7 b	0 b	0 b	0 b	0	0.4 b	0.8 b	0 b
Black foam mulch	0.4 b	0.4 b	0.4 b	0 b	1.3	0 b	0.8 b	0 b
Red foam mulch	0.6 b	0.8 b	0.4 b	0 b	0	0 b	0 b	0 b
Blue foam mulch	3.1 ab	0.4 b	1.5 b	0.4 b	0.4	0 b	1.3 b	0 b

[z]The grasses were mainly foxtail species (*Setaria* spp.) and large crabgrass (*Digitaria sanguinalis*).
[y]The broadleaf weeds were mainly pigweed species (*Amaranthus* spp.), common purslane (*Portulaca oleracea*), and prickly sida (*Sida spinosa*).
[x]10 ft^2 = 0.93 m^2.
[w]Means within a column followed by the same letter do not differ significantly according to Fisher's protected least significant difference, 0.05 level. Means in columns without letters are not significantly different.

Table 2. The effect of mulches on tomato yields and basil shoot biomass. Results are averaged over year.

Treatment	Tomato yield				Basil shoot biomass
	Early harvest[z]	Late harvest	Ripe fruit	Total fruit	
	(ton/acre[z])				
Bare ground	12.4 c[y]	26.2	36.2 c	38.7 c	4.4
Black plastic	19.4 b	26.8	44.2 b	46.1 b	5.9
Black foam mulch	13.9 bc	30.6	40.9 bc	44.5 bc	5.1
Red foam mulch	11.2 c	34.3	41.6 bc	45.5 b	5.0
Blue foam mulch	34.4 a	50.3	80.2 a	84.7 a	4.7

[z]1 ton/acre = 2.24 $t \cdot ha^{-1}$.
[y]Means within a column followed by the same letter do not differ significantly according to Fisher's protected least significant difference, 0.05 level. Means in columns without letters are not significantly different.

foam mulch did not damage it, although cultivation between crop rows did damage the edges of some foam mulch treatments. Holes in the foam mulch can easily be repaired by adding fresh foam mulch to the damaged area. Some of the weeds in the black plastic mulch emerged in the crop hole and would have to be removed by hand-weeding. Because the foam mulch was applied after transplanting and surrounded the crop stem, there were no holes near the crop that weeds could emerge through.

The color of the foam mulch did not affect weed control (Table 1). All three foam mulch colors did not allow light to penetrate to the soil surface and maintained their integrity throughout the growing season. Plastic mulches whose colors do not allow photosynthetically active radiation to reach the soil surface also will prevent weed growth under the mulch (Anderson et al., 1995). Also similar to plastic mulch, foam mulch will not control weeds in unmulched areas between crop rows. Cultivation or herbicides will be required to control weeds between rows of foam mulch.

Mulches did not affect yield of basil (Table 2). Ricotta and Masiunas (1991) found that black plastic mulch increased basil biomass over the bare ground treatment. The difference between the two studies might be related to differences in planting date or environmental conditions. In 1999 and 2000 conditions were optimum for basil growth and the soil warming provided by black plastic mulch was not necessary to increase early-season basil growth.

In 1999, rainfall occurred before the foam mulch could be applied and the mulch sat in the mix tank for 2 d, causing it to ferment. The fermented mulch killed the tomatoes with green succulent stems but did not injure the larger basil plants with woody stems. In 2000, application technology was improved and the foam mulch was not allowed to sit in the mix tank overnight. No tomato or basil injury or stand reduction occurred during 2000.

The percent green and the percent cull tomato fruit were not affected by year or treatment. At final harvest, the percent green fruit ranged from 9 to 16% and cull fruit were less than 5% (data not shown). This differs from Brown and Brown (1992) who found less catfaced fruit due to more stable soil moisture conditions in plastic mulch than bare ground treatments. We had regular rainfall and irrigation, so moisture conditions probably were not as great between the bare ground and mulch treatments in our study compared to in the study of Brown and Brown (1992).

Mulch treatments affected early, ripe, and total tomato yield (Table 2). Fruit yields in blue foam mulch were 1.5 to 3 times greater than in the other treatments. For example, early yields were 34.4 tons/acre (77.11 $t \cdot ha^{-1}$) in blue foam mulch compared to 11.2 to 19.4 tons/acre (25.11 to 43.48 $t \cdot ha^{-1}$) in the other treatments. Average fresh-market tomato yields are 14 tons/acre (31.38 $t \cdot ha^{-1}$) (Maynard and Hochmuth, 1997). The early yields and total yields in the blue foam mulch were above even the reported good yields of 20.5 tons/acre (45.95 $t \cdot ha^{-1}$) for fresh-market tomatoes (Maynard and Hochmuth, 1997). The high total yields in our study were likely due to the close plant spacings that we used compared to normal spacings of 5 ft (1.5 m) between rows and 1.5 to 2 ft (0.46 to 0.61 m) between plants within the row.

The yield in the other foam mulch treatments did not consistently differ from the bare ground treatment. Early and ripe fruit yields in the red and black foam mulch were similar to those in the bare ground treatment. Thus, foam mulch by itself did not increase yields compared to the bare ground treatment; it was the color of the foam mulch that was important. Also yields in the black plastic and black foam mulches were similar, again indicating that mulch color and not the material (plastic versus recycled cotton and cellulose fibers) was affecting tomato yield.

Other studies reported that tomato yields were greater in red or black plastic mulches compared to bare ground treatments (Decoteau et al., 1989; Gough, 2001; Kasperbauer and Hunt, 1998) whereas some studies have found variable results (Brown et al., 1992; Lehrlein, 2001). But the studies did not include a blue colored mulch. Tomato response to red mulches also depends on the particular pigments used to color the mulch (Kasperbauer and Hunt, 1998) which may explain the lack of increased early, late, and ripe fruit yield in the red foam mulch compared to the bare ground treatment.

There were no differences between in late yields between treatments. The lack of differences in percent green or in late yield means that none of the treatments delayed tomato maturity, even though tomato plants in the foam mulch had to be replanted in 1999. Unlike other natural mulches, the foam mulch probably did not reduce soil temperatures. Lower temperatures have been associated with delayed tomato maturity in other natural mulch systems (Ashworth and Harrison, 1983). The lack of an affect of mulch treatment on the late harvest also could be due to the large tomato plants shading much of the soil or mulch surface causing similar light and temperature conditions between the treatments (Brown and Brown, 1992).

In conclusion, foam mulch maintained its integrity for the entire growing season and provided similar weed suppression to the black plastic mulch. Mulch color did not affect weed suppression. This is probably because regardless of color the foam mulch did not allow light penetration and likely served as a physical barrier impeding weed emergence.

Mulch color but not mulch type affected early, ripe fruit, and total yield. Yields in blue foam mulch were greater than in the other treatments. Tomato fruit yields in black foam and black plastic mulches were similar. Further research is needed to confirm the effect of blue color on tomato yield and to compare blue foam mulch with blue plastic mulch. Microenvironment monitoring is also needed under foam mulch to determine its effects on the crop environment and to understand how foam mulch impacts tomato growth and yield.

Foam mulch is currently being commercialized for use in high-value situations. Foam mulch may also have potential for use in organic vegetable production. At this stage, foam mulch is more costly than plastic mulch and is uneconomical to use on larger conventionally-produced, commercial plantings of tomato or basil. We expect that as application technology is improved and the use of foam mulch becomes more common, the price of foam mulch will decrease and its use in larger vegetable plantings will increase.

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Genotypic Variation in Chilling Sensitivity of Mature-green Bananas and Plantains

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ADDITIONAL INDEX WORDS. ***Musa paradisiaca*, chilling injury**

SUMMARY. The variation in chilling sensitivity of mature-green specialty bananas (*Musa paradisiaca* var. *sapientum*) and plantains (*Musa paradisiaca* var. *paradisiaca*) was examined using four cultivars of bananas and one plantain cultivar stored under various time and temperature combinations. Cold storage for 1 day at 5.0, 7.2, or 10.0 °C (41, 45, or 50 °F) resulted in acceptable fruit quality for up to 8 days at 20.0 °C (68 °F) for 'Petite' and 'Red Macabu' bananas and 'Dominico Harton' plantains. 'Grand Nain' and 'Yangambi' bananas were considered unmarketable due to moderate to severe graying after 8 days at 20.0 °C when fruit were previously stored for 1 day at 5.0 or 7.2 °C. Storage for 3 days at 10.0 °C was acceptable for all cultivars tested, however 5 days at 10.0 °C resulted in moderate to severe browning and graying of the 'Grand Nain' fruit. The traditional Cavendish-type, 'Grand Nain', as well as 'Petite' and 'Yangambi', required temperatures greater than 10.0 °C for a 7-day storage duration while 'Red Macabu' bananas could be safely stored for 7 days at 10.0 °C. Plantains could be stored at 7.2 °C for 7 days without visible chilling injury symptoms. The storage of specialty bananas and plantains at or above their minimum safe temperatures resulted in improved uniformity of ripening and overall quality of the fruit due to a decrease in chilling injury symptoms.

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