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Shading Reduces Yields of Edible Ginger Rhizomes Grown in Sub-Irrigated Pots

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Introduction

The purpose of this study was to determine the effects of 4 shading levels on the yield of edible ginger rhizomes which were grown in sub-irrigated pots under plastic-covered rainshelters. Temporary wilting of edible ginger foliage (*Zingiber officinale* Roscoe) has been observed at mid-day during hot, sunny weather conditions (Figure 1). Wilted plants generally have lower photosynthetic rates than normally turgid plants, and this usually reduces crop yields. Shading of crops typically alleviates foliage wilting, because shading reduces leaf temperatures as well as maximum air and soil temperatures, which in turn causes a decrease in transpiration rate, and this lowers the water requirement for normal leaf turgor pressure.

Figure 1. Temporary wilting of edible ginger foliage at mid-day during hot, sunny weather conditions.

Semi-head lettuce yield increases were observed on O‘ahu under moderate shading levels of 30 to 47%, but heavy shading levels (60 and 73%) reduced both yield and quality (Wolff and Coltman 1990a and b). In addition, head lettuce, Chinese cabbage, and head cabbage yields were also increased by moderate shading. However, yields of eggplant, soybean, peanut, and sweetpotato decreased linearly with increasing shading (Wolff and Coltman 1990a). In other Hawai‘i studies, shading reduced tip burn of a sunlight-sensitive watercress strain (Kratky et al. 2002), and shading anthuriums is a recommended practice to prevent fading and burning (Higaki et al. 1995). Edible ginger has previously been grown in pots (Kratky and Bernabe 2009) and trays (Kratky 1998; Kratky et al. 2009) that were sub-irrigated with nutrient solution.

Materials and Methods

Trials were conducted during the 2010–2011 growing seasons at the University of Hawai‘i's Waiakea Experiment Station located at 165 m elevation near Hilo, Hawai‘i. Edible ginger was grown in sub-irrigated pots that were protected by small rainshelters.

Three-liter plastic pots (16 x 20 cm x 13 cm high) were placed upside down in 26-liter plastic pots (30 x 36 cm x 30 cm high) in an effort to reduce growing medium and provide more air space to the roots (Kratky and Bernabe 2009). The 26-liter pots in this pot-in-pot method were filled with growing medium (3 Sunshine #1 mix: 2 medium perlite, by volume). Two and three ginger seed pieces (50 ± 10 g) were planted per pot in 2010 and 2011 respectively. Pots rested on the floor of polyethylene-lined wooden tanks (0.6 x 2.4 m x 14 cm high) (Figure 2). Tanks were sup-

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ported by leveled cinderblocks at a height of 48 to 64 cm from ground level, depending upon the slope of the land.

Tanks were sheltered by 3 m long x 1.8 m wide x 1.9 m high rainshelters covered with Griffolyn TX 1200 (Reef Industries) clear plastic rated at 80% light transmission. The ends and lower 0.5 m of the rainshelter sides remained uncovered. Rainshelter construction consisted of 3 arches connected together by a bamboo purlin on

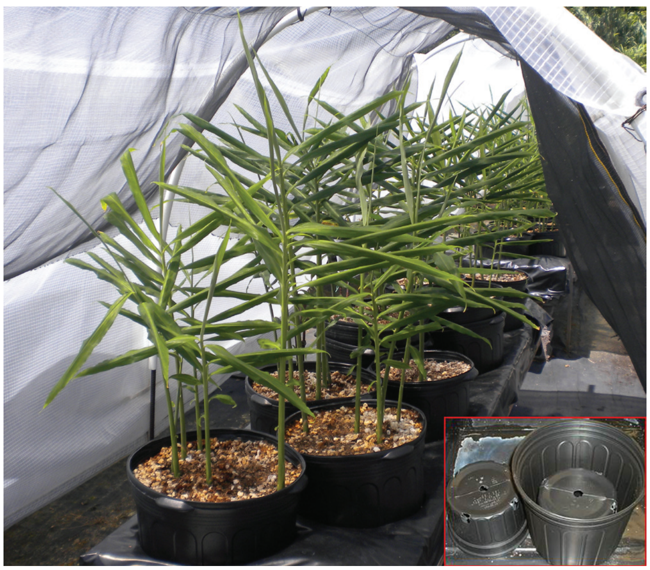

Figure 2. Ginger growing with a pot-in-pot method where 26-liter pots rest on the bottom of a tank which is sub-irrigated with 5 cm of nutrient solution.

top of the arches. A wire purlin was placed on each side to attach the bottom edges of the plastic cover. Arches were assembled by driving two 1.5 m lengths of 1.2 cm steel reinforcing bars into the rocky "soil" at a 1.8 m distance, and either 1.9 or 2.5 cm Schedule 40 PVC pipe was slipped over the upper 15 cm of the bars.

Nutrient solution flowed by gravity from a storage tank (1,135 liters) to a plastic sump container with a float valve adjusted to maintain a 5-cm depth of nutrient solution in each growing tank. Nutrient solution (EC = 2.0 mS) was prepared from 2 stock solutions, which were added in equal volumes to water in the storage tank. One stock solution consisted of 120 g/liter of a commercial (Hydro-Gardens, Colorado) hydroponic fertilizer (8% N, 6.6% P, 29.9% K, 0.20% B, 0.05% Cu, 0.4% Fe, 0.2% Mn, 0.01% Mo, and 0.05% Zn) plus 72 g/liter of magnesium sulfate; the second stock solution consisted of 120 g/liter of soluble grade calcium nitrate.

Treatments consisted of 4 shading levels generated by placing 0, 30, 47, and 80% shade screen material (2.1 m width) under the plastic film cover of the rainshelters (Figure 3). However, the lower 1.1 m of the rainshelter sides was not covered by the shade screen. The experiment was arranged as a randomized complete block with 3 replications. Yield data were analyzed by Analysis of Variance (ANOVA), with differences between means tested using Duncan's Multiple Range Test ($P \leq 0.05$).

Ginger was planted on 12 April 2010 and 31 March 2011; foliage (green plus drying) was removed and pots

Figure 3. Rainshelters covered with 0, 47, 80, and 30% shade screens (l–r) resting under Griffolyn TX 1200 plastic sheeting rated at 80% light transmission.

were placed in a drying shed on 16 December 2010 and 7 December 2011, respectively. Rhizomes were removed from the pots and washed during February 2011 and 2012, respectively. After drying for 1 week, fresh weight data were collected. Photosynthetic photon flux light readings were collected 15 cm below the top center of the rainshelter cover with a digital Quantum Meter by Apogee Instruments (Figure 4) during sunny to partly cloudy conditions between 10 a.m. and noon on 10 August 2010 and 15 February 2012.

Results and Discussion

Shaded ginger foliage was darker green in color and exhibited less wilting than non-shaded plants. However, ginger rhizome yield production (Figures 5 and 6) was reduced by all 3 shading treatments during the 2010 and 2011 growing seasons (Table 1). The 30, 47, and 80% shade screen treatments reduced rhizome yields by 34, 52, and 67% in the 2010 season and 25, 44, and 61% in the 2011 season.

Lower yields in 2011 may have been caused by lower light transmission through the plastic rainshelter cover in 2011 (Table 2) and/or planting only 2 seed pieces per pot in 2011 instead of 3 seed pieces as planted in 2010.

The discovery that shading caused reduced yields of edible ginger was similar to findings for other non-leafy crops (eggplant, soybean, peanut, and sweetpotato), whereas leafy vegetables (Chinese cabbage, head cabbage, and head and semi-head lettuce) had increased yields under moderate shading as reported by Wolff and Coltman (1990a and b).

Light intensity values measured 15 cm below the top center of the rainshelters were 86, 58, 39, and 18% of the outside ambient light for the 0, 30, 47, and 80% shade screens, respectively, on 10 August 2010 (Table 2). Similarly, the light intensity values were 74, 52, 39, and 16% of the outside ambient light, respectively, for the 0, 30, 47, and 80% shade screens on 15 February 2012. Both sets of readings underestimated the total light intensity reaching the plants in the shaded treatments, however, because

Table 1. Effects of 4 shading levels on the fresh weight of edible ginger rhizomes grown by sub-irrigation culture at Waiakea Experiment Station.

Shade treatment	Yield in kg per 26-liter pot	
	2010[1]	*2011*[2]
None[3]	4.99 d[4]	3.66 c
30% shade screen[5]	3.31 c	2.76 b
47% shade screen[5]	2.42 ab	2.05 b
80% shade screen[5]	1.63 a	1.42 a

[1]Three seed pieces were planted per pot on 12 April 2010. Foliage was removed on 16 December 2010, and yield determination of washed and air-dried rhizomes was made during February 2011.
[2]Two seed pieces were planted per pot on 31 March 2011. Foliage was removed on 7 December 2011, and yield determination of washed and air-dried rhizomes was made during February 2012.
[3]Rainshelter was covered with a Griffolyn TX 1200 clear plastic cover.
[4]Means followed by the same letter within individual columns are not significantly different ($P \leq .05$) by Duncan's Multiple Range Test.
[5]Rainshelter was covered with a Griffolyn TX 1200 clear plastic cover plus shade screen.

Table 2. The effects of 4 shading levels on light transmission into a plastic-covered rainshelter[1] at Waiakea Experiment Station during 2010 and 2012.

Shade treatment	Percentage outside light transmitted into rainshelter			
	Aug. 10, 2010		*Feb. 15, 2012*	
	Actual	*Predicted*[2]	*Actual*	*Predicted*
None[3]	86	86	74	74
30% shade screen[4]	58	60	52	52
47% shade screen[4]	39	46	39	39
80% shade screen[4]	18	17	16	15

[1]Light intensity data were collected 15 cm below the top center of the rainshelter cover with a Digital Quantum Meter by Apogee Instruments during sunny to partly cloudy conditions between 10 a.m. and noon.
[2]Transmitted light from the "None" shade treatment x (100% - shade screen rating) x 0.01.
[3]Rainshelter was covered with a Griffolyn TX 1200 clear plastic cover.
[4]Rainshelter was covered with a Griffolyn TX 1200 clear plastic cover plus shade screen.

Figure 4. Light-intensity data were collected with a hand-held light meter.

the ends and lower 1.1 m of the rainshelters were not covered with the shade screen. Light intensity data were not collected from these locations, because light readings varied greatly with the size of the plants. The greatest differences occurred at the ends of the tanks. Therefore, yield data from the outermost pots were not included in Table 1.

Incident sunlight passed through the clear plastic rainshelter cover before it was additionally reduced by the shade screen treatments. New Griffolyn TX 1200 clear plastic was rated at 80% light transmission; however, light reading data indicated 86% light transmission on 10 August 2010, which decreased to only 74% transmission on 15 February 2012, due to accumulated dirt and, perhaps, aging of the film.

The predicted light transmission under the combined plastic cover and shade screen equals the light transmission percentage of the plastic cover x (100 – shade screen rating) x 0.01 (Table 2). Thus, the predicted light transmission in the plastic-covered rainshelter under the 30% shade screen was 52% on 15 February 2012 (74% light transmission of the plastic cover x 70% light transmission of the 30% shade screen treatment). The actual vs. predicted comparisons were quite similar except for the 47% shade screen readings on 10 August 2010. The Quantum Light Meter is a hand-held device, and readings are affected by the angle at which the meter is held. Exact duplication of the meter angle was somewhat thwarted by the height at which data were collected, because the readings under the cover were taken near the top of the rainshelter and the outside readings were taken above the rainshelter. In addition, the changing cloud cover challenged reproducibility of data collection.

Figure 5. Ginger growth on 16 November 2010.

Shading of ginger reduces wilting during the hottest part of the day, and this would be expected to positively influence yields. However, shading caused reduced rhizome yields in this experiment. Covering the crop with a permanent shade screen reduces light throughout the day, including those periods (early to mid-morning and later afternoon) when light intensity is less than optimal for the maximum photosynthetic rate, and this negative effect appears to predominate over any positive effects of shading.

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Figure 6. Ginger rhizomes were cleaned and are suitable for edible purposes or as seed for next season's crop.

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