Using a Pot-sized Demonstration to Teach the Effects of Season Extension Materials on the Early Growth of Winter Squash

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ADDITIONAL INDEX WORDS. calabaza, *Cucurbita moschata*, butternut, laboratory methods, polyethylene mulch, spun-bonded polyester

SUMMARY. In the northeastern United States, vegetable crop classes and growers' meetings are often held during winter months when field demonstrations are impossible. A pot-sized demonstration was set up in the greenhouse in May and Nov. 2002 as a student laboratory to show the effects of season extension materials on the early growth of winter squash. The treatments were black plastic mulch and rowcover, alone and in combination. The treatments were also placed on either a heated [18.3 °C (65 °F)] or unheated germination mat to simulate warmer and cooler spring soils. Butternut squash (*Cucurbita moschata*) was sown in 10.2 × 10.2 × 11.43-cm (4 × 4 × 4.5 inches) pots in soilless medium. The plants were grown and observed for 30 days, then harvested and weighed. The plants in the greenhouse grew as expected of plants grown under similar conditions in the field. Bottom heat, mulch, and rowcover had an increasingly greater effect on the growth of subsequent leaves as shown by comparisons of leaves 1, 2, and 3. Warmer soils tended to have the greatest effect on all measured parameters, but this was not as obvious in the May experiment as it was in the November experiment. Thus, this pot demonstration

can be used in a student laboratory. The pots and plants are small enough to transport to and set up at winter growers' meetings as well.

Winter squashes (*Cucurbita maxima* and *C. moschata*) are tropical or subtropical in origin and respond favorably to treatments that accelerate development and increase yields in cool conditions (Jenni et al., 1998; Rulevich, 2003; Waterer, 1993; Wells and Loy, 1985). The materials most commonly used to protect plants and warm the soil in the northeastern U.S. are black plastic mulch and rowcover. Black polyethylene mulch is used widely in U.S. production systems (Lamont, 1993) and has been the type most often studied with cucurbits (Hemphill and Mansour, 1986; Marr et al., 1991; Rulevich et al., 2003; Sanders et al., 1999; Soltani et al., 1995; Waterer, 1993). Spun-bonded polyester rowcover, used in combination with plastic mulch, has been shown to increase total yields and advance harvest of muskmelon (*Cucumis melo*), butternut, and calabaza (*Cucurbita moschata*) squash by ~1 week or more (Hemphill and Mansour, 1986; Loy and Wells, 1982; Rulevich et al., 2003; Wells and Loy, 1985).

Most grower meetings in the northeastern United States take place in November through March, when field trials cannot be demonstrated. Field days in late May or early June, when the growth advances of transplants on plastic or with rowcover are the most obvious, are poorly attended because growers are busy on their own farms. University vegetable crop courses are also taught when it is difficult to have field demonstrations of cultural practices in the field. Thus, it would be useful to find methods to demonstrate field techniques on a small scale that can be grown in a few weeks time and transported to the location of a winter meeting or grown in a teaching greenhouse. To this end, a small greenhouse experiment was set up to show that the field effects often seen with season extension materials can also be demonstrated on a small scale.

Materials and methods

'Waltham' butternut (Johnny's Selected Seed, Albion, Maine) was planted in a double-poly hoop house at the University of Massachusetts in

Amherst (lat. 42°28', long. 72°35') on 5 Nov. 2001 and 5 May 2002. Seeds were planted in sterile potting mix (Pro-Mix BX; Premier Horticultural Inc., Red Hill, Pa.) in the center of a 10.2 × 10.2 × 11.43-cm pot (Dillen Products, Middlefield, Ohio). Pots were either placed on heated (18.3 °C) or unheated germination mats. A 10.2 × 10.2 cm piece of 1.25 mil [0.00125 inch (0.032 mm)] black polyethylene (Griffin Greenhouse Supply, Tewksbury, Mass.) was laid on top of the growing media on the appropriate treatments. A cut was made in the plastic from one corner to the center to allow the stem to grow through. After planting, 5 mil [0.005 inch (0.127 mm) thick, 0.203 mg·cm⁻² (0.06 oz./yard²)] spun-bonded polyester (Reemay; Ken-Bar, Reading, Pa.) was laid over groups of six pots in the appropriate treatments. The rowcover was held down with stakes or tucked under the germination mats so that all air flow around the pots was through the rowcover.

Greenhouse night temperature was maintained at 18.3 °C in May and November. Daytime temperatures were only controlled through a ventilation system with the thermostat set to open the system if the temperature was above 23.9 °C (75 °F). In November, the daytime temperature in the greenhouse averaged 17.8 °C (64 °F) for all 3 weeks. In May, the daytime temperature averaged 22.2 °C (72 °F) the first 2 weeks and 25.6 °C (78 °F) for the third week. Soluble fertilizer, 20N-8.6P-16.6K (Peter's 20-20-20; J.R. Peter's Inc., Allentown, Pa.), was applied with each watering (as needed) at a rate of 0.6 g·L⁻¹ (0.08 oz./gal) the first 7 d and a rate of 1.2 g·L⁻¹ (0.16 oz./gal) the next 14 d. Light was ambient. This was a temperature × rowcover × mulch factorial design with six replications.

The plants were allowed to grow for 30 d after seeding or ~21 d after germination, which is the recommended age for a cucurbit transplant (NeSmith, 1993). On day 30, leaves one, two, and three from the cotyledon were removed at the petiole. Leaf area and fresh weight were measured on these three leaves separately. The fresh weight was measured on the remaining upper portion of the plant. The samples were dried for 3 d in drying oven at 60.0 °C (140 °F), then weighed. Data were processed by analysis of variance

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using SAS software (SAS Version 8.2 for Windows; SAS Institute, Cary, N.C.). Analysis compared the growing methods of temperature (heated, unheated), plastic (mulch, no mulch), and rowcover (rowcover, no rowcover).

Results and discussion

The desired objective of being able to see the differences caused by season extension materials was realized after 3 weeks growth in the greenhouse whether the experiment was conducted in May or November (a spring or fall semester). The immediate differences that students or growers would be able to see were the differences in the overall size of the plant and in the growth of the first three leaves. Table 1 shows the leaf area of leaves one, two, and three from the cotyledon for each comparison of temperature, plastic mulch, and rowcover and the statistical analysis of their interactions. All three factors had an effect on the overall growth of the leaves, although it varied between the May and the November experiments for each parameter. Heat, plastic, and

rowcover had a greater influence on leaf area in November than in May, but this may vary with the outside weather conditions in other years and in other greenhouses where daytime temperatures in the spring can be controlled.

The influence of the three parameters was different for leaves one, two, and three. The use of bottom heat (to represent colder and warmer soils) increased mean leaf area of leaf one by 13%, leaf two by 41%, and leaf three by 175%, respectively. This trend was also seen for the use of mulch (leaves one, two, and three increased mean leaf area by 12%, 55%, and 81%, respectively) and for rowcover (leaves one, two, and three increased mean leaf area by 1%, 31%, and 226%, respectively).

The total leaf area and the total fresh and dry weight of the entire plant are listed in Table 2. The differences among the three growing methods is not as variable as they were for the growth of the first three leaves. Generally, the use of the germination mat to warm the soil gave the largest

increase in the mean total leaf area (44%) compared to plastic (39%) and rowcover (39%). The treatments were affected similarly in November and May, although there was always greater leaf area in the May experiment. Total fresh and dry weight doubled when heat was used. There was between a 22% and a 36% increase in the mean total fresh or dry weight when plastic and rowcover were used.

The advances in growth using rowcover and plastic mulch were similar to those obtained in a field study in Massachusetts, although different measurements were taken to show the differences in growth found when plastic and rowcover were used (Rulevich et al., 2003). In the field study, mulch and rowcover treatments advanced early plant growth by 7 and 5 d, respectively, as measured by the number of days to 10% fruit set. The use of plastic mulch increased yield by 19% compared to bare soil, and the use of rowcover increased yield 16% compared to plants grown without rowcover.

Table 1. Statistical comparison of butternut leaf area for leaves (one, two, and three from the cotyledons) that had grown under various treatments for 30 d in May and November (Nov.). The plants were grown in 10.2 × 10.2 × 11.43-cm (4 × 4 × 4.5 inches) pots with or without bottom heat, with or without plastic mulch, and with or without rowcover in all possible treatment combinations as a laboratory demonstration of the effects of season-extension materials on the early growth of winter squash.

Growing method	Leaf 1 area (cm ²) ^a				Leaf 2 area (cm ²)				Leaf 3 area (cm ²)			
	May	Nov.	Mean	Change (%)	May	Nov.	Mean	Change (%)	May	Nov.	Mean	Change (%)
<u>Temp (H)</u>												
Unheated	118	73	96		110	47	79		42	6	24	
Heated	130 ^{NS}	87 ^{**}	109 [*]	13	126 [*]	95 [*]	111 ^{**}	41	75 ^{**}	57 ^{**}	66 ^{**}	175
<u>Plastic (P)</u>												
No mulch	128 ^{NS}	64	96		107	41	74		41	23	32	
Mulch	120	96 ^{**}	108 [*]	12	130 ^{NS}	101 ^{**}	115 ^{**}	55	76 [*]	41 [*]	58 ^{**}	81
<u>Cover (R)</u>												
No cover (R)	131 [*]	72	101		112	52	82		34	8	21	
Rowcover	118	88 ^{**}	103 ^{NS}	1	124 ^{NS}	90 ^{**}	107 ^{**}	31	83 ^{**}	55 ^{**}	69 ^{**}	226
<u>Interactions</u>												
H × P	NS	*	*		NS	**	NS		NS	NS	*	
H × R	NS	NS	NS		NS	**	NS		**	**	**	
P × R	NS	*	**		**	**	**		NS	NS	NS	
H × P × R	*	NS	NS		NS	NS	*		NS	NS	NS	
<u>H P R</u>												
0 0 0	119	30	74		75	2	39		8	0.1	4	
0 0 1	125	72	98		123	20	72		46	0.7	23	
0 1 0	131	101	116		129	82	106		42	10	26	
0 1 1	99	89	94		112	85	98		72	14	43	
1 0 0	137	54	96		94	15	55		14	1	8	
1 0 1	133	100	117		135	128	131		96	89	92	
1 1 0	136	103	120		150	108	129		72	22	47	
1 1 1	114	91	102		127	128	127		119	117	118	

^a1 cm² = 0.155 inch².

^{NS}, ^{*}, ^{**} Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

Table 2. Statistical comparison of butternut leaf area, fresh weight and dry weight for plants that had grown under various treatments for 21 d in May and Nov. The plants were grown in 10.2 × 10.2 × 11.43 cm (4 × 4 × 4.5 inches) pots with or without bottom heat, with or without plastic mulch, and with or without rowcover in all possible treatment combinations as a laboratory demonstration of the affects of season-extension materials on the early growth of winter squash.

Growing method	Total leaf area (cm ²)*				Total fresh wt (g)				Total dry wt (g)			
	May	Nov.	Mean	Change (%)	May	Nov.	Mean	Change (%)	May	Nov.	Mean	Change (%)
<u>Temp (H)</u>												
Unheated	270	126	198		13.7	7.2	10.4		1.1	0.6	0.8	
Heated	332* ^z	239**	285**	44	18.2*	12.8**	15.5**	49	1.5**	0.9**	1.2**	50
<u>Plastic (P)</u>												
No Mulch	276	128	202		14.4	7.8	11.1		1.2	0.5	0.9	
Mulch	326*	237*	282**	39	17.5**	12.1**	14.8**	33	1.4 ^{ns}	0.9**	1.1**	22
<u>Cover (R)</u>												
No rowcover (R)	277	139	205		13.3	7.5	11.1		1.2	0.6	204.7	
Rowcover	325*	233**	279**	39	18.6*	12.4**	14.8**	33	1.4**	0.9**	279.1**	36
<u>Interactions</u>												
HP	NS	**	NS		NS	NS	NS		NS	**	*	
HR	NS	**	**		NS	**	**		*	**	*	
PR	*	**	**		NS	**	*		*	NS	*	
HPR	NS	NS	NS		NS	*	NS		NS	NS	**	
<u>H P R</u>												
0 0 0	203	32	117		9.3	3.5	6.4		0.9	0.2	0.5	
0 0 1	294	92	193		15.7	6.0	10.9		1.1	0.3	0.7	
0 1 0	302	192	247		13.9	9.3	11.6		1.3	0.8	1.1	
0 1 1	283	188	236		15.9	9.8	12.9		1.1	0.9	1.0	
1 0 0	246	70	158		12.2	4.8	8.5		1.1	0.3	0.7	
1 0 1	363	317	340		20.5	16.8	18.6		1.8	1.1	1.5	
1 1 0	359	233	296		17.9	12.4	15.1		1.5	0.8	1.1	
1 1 1	360	336	348		22.1	17.1	19.6		1.6	1.1	1.4	

^z1 cm² = 0.155 inch².

^{ns}, *, **NONSIGNIFICANT OR SIGNIFICANT AT $P \leq 0.05$ or 0.001, respectively.

Thus, the goal of using a pot-based greenhouse study to show the effects of warm soils, mulch, and rowcover were realized. By both observing the plants and calculating differences between the means of the main effects and their interactions, students would be able to understand the influence of the interaction of two or more treatments on growth. The experiment took ~1 h to set up initially and could be done as part of a student laboratory. In a semester class setting, students could spend 15 min of a laboratory period observing growth under the various treatments for 2 weeks and spend the third week's laboratory (~2 h) harvesting and taking measurements to evaluate the differences among various season extension materials. Since the plants were grown in relatively small pots, the plants are easy to prepare and transport to a grower meeting or classroom.

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