Variety Trials

Yield and Quality of Spinach Cultivars for Greenhouse Production in Oklahoma

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SUMMARY. Greenhouse spinach production is an alternative to fruiting vegetables produced in the greenhouse because it allows for multiple short-duration production cycles and a much faster economic return. Ten spinach (*Spinacia oleracea*) cultivars were evaluated for yield and quality using greenhouse float bed production techniques in Fall 2005 and Spring 2006. Time required for production was 52 days in Fall 2005 and 37 days in Spring 2006. Highest yields in Fall 2005 were 2093, 1996, 1956, 1920, and 1884 g·m⁻² for ‘Olympia’, ‘Samish’, ‘Padre’, ‘Bolero’, and ‘F91-415’, respectively. ‘F91-415’ and ‘Bolero’ were the highest yielding cultivars in Spring 2006 with yields of 1649 and 1560 g·m⁻², respectively. Bolting ratings were recorded in both tests and only ‘Samish’ had any bolting in Spring 2006 and none in Fall 2005. Quality ratings for leaf color and foliage mass were recorded in Spring 2006 with ‘Samish’, ‘Padre’, and ‘Cypress’ having the highest quality ratings. Color factors, including lightness, hue, and vividness, varied in Fall 2005 but not in Spring 2006. Based on yield and quality factors, the authors recommend further commercial trials of ‘Olympia’, ‘Samish’, ‘Padre’, and ‘F91-415’ for fall greenhouse production and ‘F91-415’ and ‘Padre’ for spring production.

Increases in fresh spinach consumption during the past decade have been attributed to spinach salad products and a growing public awareness of the health benefits of the crop (Silva, 2002; U.S. Dept. of Agriculture, 2006). Spinach provides

dietary fiber and supplies high levels of vitamins, minerals, and antioxidants (Leskovar et al., 2000; McCord and McVeigh, 2000).

Numerous aspects of spinach production have been evaluated in field cultivar trials, including yield,

color intensity, and bolting resistance. Yield has been included in a majority of studies and is considered to be a key component of cultivar selection (Dainello et al., 1987; Djurovka et al., 1988). The presence of dark green color in spinach is an important aspect of evaluation (Brandenberger et al., 2004; Dainello et al., 1984). Murphy and Morelock (1999, 2000) indicated that dark green vegetables contain high levels of carotenoids such as lutein, which may be visually selected because of a strong correlation between carotenoids and chlorophyll-a. Flower stalk formation (bolting) in spinach is controlled by daylength (Chun et al., 2001) and renders the crop unsalable when it occurs (Knott, 1939).

Fruiting vegetables, leafy greens, and herbs have been produced in the greenhouse (Hood, 2000). Tomatoes (*Lycopersicon esculentum*) are perhaps the most popular, but Snyder (2001) noted that greenhouse tomatoes are difficult because of the processes and time (2 to 5 months) needed to produce the crop. Greenhouse spinach production is an alternative to traditional tomato production because it allows for multiple short-duration production cycles during the same time period as one tomato crop.

Production cycles of 30 to 48 d for spinach are possible year round in a soilless culture with appropriate cultivars and manipulation of the nutrient solution temperature (Ikeda et al., 1995). Frantz and Welbaum (1998) used hydroponic float beds for growing several horticultural crops in the greenhouse, including basil (*Ocimum basilicum*) and water spinach (*Ipomoea aquatica*). Other investigators (Thompson et al., 1998) demonstrated the use of float beds for greenhouse lettuce (*Lactuca sativa*) production. There are few reports of spinach cultivar trials in the greenhouse; Joshi et al. (1992)

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.5400	inch(es)	cm	0.3937
25.4000	inch(es)	mm	0.0394
6.4516	inch ²	cm ²	0.1550
16.3871	inch ³	cm ³	0.0610
305.1517	oz/ft ²	g·m ⁻²	0.0033
1	ppm	mg·L ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

evaluated six cultivars and found differences in yield and leaf area.

The objective of this work was to determine the suitability of spinach cultivars for greenhouse production in Oklahoma. Production attributes included in the studies were fresh leaf yield, quality including color intensity and foliage mass, and bolting resistance.

Materials and methods

Ten spinach cultivars (Table 1) were evaluated for spring and fall greenhouse production. Seeds were soaked in distilled water for 48 h at 8 °C and then drained and rinsed with distilled water. Rinsed seeds were placed in petri dishes containing filter paper to absorb excess water and incubated at 8 °C for 48 to 72 h until radicles reached 3 to 5 mm. Seeds with visible radicles were planted into 18-cell (100 cm², 400 cm³ per cell) polystyrene trays (Speedling, Sun City, Fla.) using BM1 commercial root substrate (Berger, St. Modeste, Que., Canada) on 18 Oct. 2005 and 9 Mar. 2006. Seedlings were hand-irrigated with tap water as needed until roots were visible in 50% of the drainage holes of tray cells. Trays were then floated in a solution of fertilizer and water contained in a 5 × 6-ft watertight bench top (Midwest Gro-master, St. Charles, Ill.). Fertilizer concentration in the solution was based on 100 mg·L⁻¹ of nitrogen from

a liquid fertilizer containing 20N–8.7P–16.6K (The Scotts Co., Marysville, Ohio). The nutrient solution was replenished as needed to maintain a 4-inch depth in the watertight bench as a result of evaporation or plant uptake. Plants were grown for 53 and 37 d in a polycarbonate-covered greenhouse with average daily maximum and minimum temperatures of 25 (±2), 17 (±2), 28 (±3), and 20 (±1) °C for fall and spring, respectively, and then harvested. Plants were harvested once their height reached 4 to 6 inches by cutting at the substrate surface, and then counted, weighed, and evaluated for bolting. Color was analyzed using a chromometer (CR-200; Minolta Corp., Ramsey, N.J.) by randomly selecting three leaves from each tray. The color analysis with the chromometer included lightness, hue, and vividness. Three representative plants from each cultivar were evaluated by three panelists for consumer preference based on appearance using a 1 to 5 rating scale with “1” having pale sparse foliage with little plant mass and “5” having dark, densely packed foliage with large foliage mass.

STATISTICAL DESIGN AND ANALYSIS. All tests were arranged in a randomized complete-block design with four replications. Experimental units consisted of one 18-cell polystyrene tray per replication. Data sets from each of the two tests were analyzed

using analysis of variance (PROC MIXED) and means were separated using protected pairwise *t* tests at a 0.05 level of significance with SAS (version 9; SAS Institute, Cary, N.C.).

Results and discussion

The highest producing cultivars in Fall 2005 were ‘Olympia’, ‘Samish’, ‘Padre’, ‘Bolero’, and ‘F91-415’ with yields of 2093, 1996, 1956, 1920, and 1884 g·m⁻², respectively (Table 1). The six cultivars that produced highest in Spring 2006 were ‘F91-415’, ‘Bolero’, ‘Baker’, ‘Space’, ‘Padre’, and ‘F-380’, which had yields of 1649, 1560, 1471, 1453, 1444, and 1396 g·m⁻², respectively. Of these six cultivars, ‘F91-415’, ‘Bolero’, and ‘Padre’ also did well in Fall 2005. Three cultivars, ‘Baker’, ‘Catalina’, and ‘F91-415’, were consistent in yield for both Fall 2005 and Spring 2006 exhibiting no differences within a cultivar between seasons. Production was generally higher in these studies compared with that reported by Joshi et al. (1992) and although their yields were recorded from studies in Antarctica, similar greenhouse growing conditions were maintained in both studies.

‘Samish’, ‘Padre’, and ‘Cypress’ had the highest consumer preference ratings in Spring 2006 (Table 1) indicating a darker foliage color and more plant mass than other cultivars in the study. Ratings for these three cultivars were 5.0 for ‘Samish’, 4.3

Table 1. Yield and quality of spinach cultivars for greenhouse production in Oklahoma: marketable yields, visual ratings, and leaf color analysis.

Cultivar information		Marketable yield		Visual rating (1–5 scale) ^x	Leaf color analysis ^w					
		(g·m ⁻²) ^y			Lightness		Hue		Vividness	
Name	Source ^z	2005	2006	2006	2005	2006	2005	2006	2005	2006
Baker	AC	1476 c ^v	1471 a–c	2.7 de	103.3 ab	40.0	1.7 b	–11.1	–3.9 e	15.6
Bolero	RS	1920 ab	1560 ab*	1.3 f	108.5 a	41.0	–2.7 de	–12.6	5.8 bc	17.3
Catalina	AS	1107 d	822 d	2.7 de	103.9 ab	37.6	0.2 bc	–9.8	–0.2 de	13.7
Cypress	AS	1693 bc	1244 bc*	4.0 b	94.3 c	40.6	–1.4 cd	–11.7	2.6 cd	17.4
F-380	AC	1782 a–c	1396 a–c*	2.2 e	103.0 ab	39.8	4.7 a	–10.6	–7.8 f	14.8
F91–415	AC	1884 ab	1649 a	2.8 de	36.1 d	38.2	–8.9 f	–9.8	10.6 a	14.1
Olympia	AC	2093 a	1196 c*	3.8 bc	102.0 b	37.4	0.7 bc	–10.9	–1.0 de	15.5
Padre	AS	1956 ab	1444 a–c*	4.3 ab	101.0 b	38.5	0.8 b	–11.2	–0.8 de	15.2
Samish	AC	1996 ab	1289 bc*	5.0 a	105.2 ab	36.5	–3.7 e	–10.5	8.3 ab	14.1
Space	JS	..	1453 a–c	3.2 cd	..	39.7	..	–10.8	..	15.3
Significance		S	S	S	S	NS	S	NS	S	NS

^aAC = Alf Christianson Co., Mt. Vernon, Wash.; AS = Asgrow, Seminis Vegetable Seeds Inc., Oxnard, Calif.; RS = Royal Sluis, Seminis Vegetable Seeds Inc.; JS = Johnny's Selected Seeds, Winslow, Maine.

^yMarketable yield based on fresh weight of spinach harvested from 0.22 m² (1 g·m⁻² = 0.0033 oz/ft²).

^zVisual rating based on 1 to 5 rating scale with “1” having pale sparse foliage with little plant mass and “5” having dark, densely packed foliage with large foliage mass.

^wColor was analyzed using a chromometer. Meter readings were recorded for lightness, hue, and vividness.

^vData analyzed using analysis of variance (PROC MIXED) and means were separated using protected pairwise *t* tests at a 0.05 level of significance. Numbers within a column followed by the same letter were not significantly different at the 5% level. Numbers with an asterisk (*) next to letters indicate a significant difference between Fall 2005 and Spring 2006 plantings. Columns with S at the bottom indicate significant differences within a given column and those with NS indicate no significance in a given column.

for 'Padre', and 4.0 for 'Cypress'. Although other studies did not have ratings that combined color and plant mass, Brandenberger et al. (2004) reported 'Padre' and 'Cypress' as having significantly higher color ratings than a majority of cultivars included in field trials.

Bolting was not observed in the Fall 2005 study, but in Spring 2006, 'Samish' had 6.5% bolting, whereas all other cultivars had none. In 2 years of spring field trials in Oklahoma, 'Samish' had the highest amount of bolting of all cultivars (91%) (Brandenberger et al., 2004). Although bolting was less in the greenhouse than in field trials, premature bolting of 'Samish' occurred in both. It appears that the much shorter growth cycle in the greenhouse resulted in bolting being less of an issue than in field production.

Lightness readings for cultivars differed in Fall 2005 (Table 1). 'Bolero' was the lightest being similar to 'Samish', 'Catalina', 'Baker', and 'F-380'. 'Samish', 'Catalina', 'Baker', and 'F-380' were also similar in lightness to 'Olympia' and 'Padre'. 'Cypress' was darker than 'Bolero', 'Samish', 'Catalina', 'Baker', 'F-380', 'Olympia', and 'Padre'. 'F91-415' was the darkest of all cultivars. Lightness values for 'Space' were not recorded as a result of crop failure from poor germination. During Spring 2006, no differences were observed among cultivars for lightness values.

In Fall 2005, the hue of spinach cultivars varied such that 'F-380' received the highest value (Table 1). 'Baker', 'Padre', 'Olympia', and 'Catalina' received lower values but were similar to one another. 'Olympia' and 'Catalina' were also similar to 'Cypress', which was similar to 'Bolero'. 'Bolero' and 'Samish' were similar but received higher values than 'F91-415', which had the lowest values of all. Hue refers to the color family ranging from green to red. Although these differences were perceived by the chromometer, human evaluators would likely consider all the spinach cultivars to be green. During Spring 2006, no differences were observed for hue.

Vividness was highest for 'F-380' in Fall 2005 (Table 1). 'Baker', 'Olympia', 'Padre', and 'Catalina' were similar to one another and less saturated than 'F-380'. 'Olympia',

'Padre', and 'Catalina' were also similar to 'Cypress', which was similar to 'Bolero'. 'Bolero' and 'Samish' were similar and 'F91-415' was the least saturated (most gray) and similar to 'Samish'. During the Spring 2006 production, no differences were observed among cultivars for vividness values.

Pearson correlation coefficients were developed to relate chromometer readings with the visual ratings. However, no significant ($P = 0.05$) correlations were observed (data not shown).

Selection of cultivars for production is a complex decision based on many factors, of which yield is critical. 'F91-415' and 'Bolero' consistently yielded well in Fall 2005 and Spring 2006, whereas other cultivars yielded well in one season or the other. 'Olympia', 'Samish', and 'Padre' had high yields in Fall 2005, whereas top-yielding cultivars in Spring 2006 also included 'Baker', 'F-380', 'Padre', and 'Space'. Although visual ratings were only recorded in Spring 2006, they are an indicator of what consumers desire in fresh spinach and help complete the information needed for cultivar selection. 'Samish', 'Padre', and 'Olympia' had some of the highest visual ratings while still yielding well, particularly for fall production. 'F91-415', the highest average yielding cultivar for both seasons, had visual ratings near the middle of the cultivar list. Color readings varied in fall production but not the spring. Although not recorded, this could be incited by a difference in light quality during the production periods that resulted in different plant pigment production.

Number of days required for production in these studies was comparable to those reported by Ikeda et al. (1995). Overall, the cropping period was shorter in the spring than in the fall. This was likely the result of variation in temperatures and longer daylengths in the spring. When considering crop production cost, spring production would be less expensive as a result of shorter cropping cycles.

This study demonstrates that greenhouse spinach production has potential to become a viable enterprise regardless of time of year. The float bed system performed well in these studies. This system was chosen because of its potential for labor

savings, uniform plant densities, and ease of harvest (Pearce et al., 1999). Based on yield and quality factors, the authors recommend further commercial trials of 'Olympia', 'Samish', 'Padre', and 'F91-415' for fall greenhouse production and 'F91-415' and 'Padre' for spring production.

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