HORTICULTURAL STUDIES 2002

Edited by Michael R. Evans
and Douglas E. Karcher

ARKANSAS AGRICULTURAL EXPERIMENT STATION
Division of Agriculture University of Arkansas
September 2003 Research Series 506

This publication is available on the Internet at www.uark.edu/depts/agripub/publications

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Technical editing and cover design by Cam Romund; cover photo: Paradise Valley golf-links by John V. Crone, ASLA

Arkansas Agricultural Experiment Station, University of Arkansas Division of Agriculture, Fayetteville. Milo J. Shult, Vice President for Agriculture and Director; Gregory J. Weidemann, Dean, Dale Bumpers College of Agricultural, Food and Life Sciences and Associate Vice President for Agriculture–Research, University of Arkansas Division of Agriculture. PS1000QX6. The University of Arkansas Division of Agriculture follows a nondiscriminatory policy in programs and employment.
ISSN:1051-3140 CODEN:AKAMA6

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EVANS AND KARCHER

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UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

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PREFACE

We are pleased to bring you the fifth edition of *Horticultural Studies*. This publication, beginning with *Horticultural Studies 1998*, has continued to bring to the citizens of Arkansas the latest reports about horticultural crop research being conducted throughout the University of Arkansas Division of Agriculture.

Our goal with this publication was to bring annual up-to-date findings to the horticultural community in Arkansas so that you could utilize these new findings and/or contact the researchers for further information. We hope that this goal is being met. As editors, we strive to make this publication reader-friendly, timely, and hopefully of value to you, a user of the resulting technology, who we in the Department of Horticulture are working to serve.

Finally, several people should be commended for work on this publication. Cindy Kuhns, Shirl St. Clair, and Jo Salazar in the Horticulture Department office worked diligently in the manuscript revision process and their efforts are much appreciated. Likewise, many thanks to Camilla Romund and Howell Medders in the Agricultural Communications Unit for the technical editing, design, and printing of this document.

We hope you find value in *Horticultural Studies 2002*. Contact us with any comments or questions!

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SPECIAL THANKS

Thanks are expressed to the donors listed below who contributed to horticulture programs in 2002. External support of all programs is critical to the continuing enhancement of horticultural industries in Arkansas.

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Landscape Performance of Birch in Arkansas

Mengmeng Gu[1], *Curt R. Rom*[1], *James A. Robbins*[2]

Additional index words: trees, environmental stress

Summary. Twenty-three birch accessions were field planted at Fayetteville and Hope Arkansas in 2002 to evaluate survival and growth rate. *Betula nigra* L., the only birch native to Arkansas, and its cultivars, 'Dura-Heat' and 'Heritage', had good survival and growth at both locations. *Betula pendula* Roth. 'Trost's Dwarf', *B. ermanii* Cham., and *B. albosinensis* Burkill. were among trees with the worst landscape performance.

Betula is a genus of approximately 50 species distributed throughout temperate America, Europe, and Asia (Atkinson, 1992) (USDA Hardiness Zone 3-5). Their natural habits are usually humid and cool temperature sites. *Betula nigra*, river birch, is the only birch species native to Arkansas.

Birches, especially white-barked taxa, are very popular ornamental plants in the northern United States. In general, white-barked birches generally perform poorly in the southern U.S. due to intense summer heat and periodic drought. These environmental stresses increase birches' susceptibility to bronze birch borer. Besides anecdotal observations, performance data of white-barked birches or other birch options are not available under southern conditions.

Urban trees are exposed to both excess and deficit soil moisture, but drought generally is considered the more serious threat (Clark and Kjelgren, 1990). When birches are grown in Arkansas (USDA Hardiness Zone 6-8), heat stress and drought stress may be a limiting factor in the adaptability and productivity of many birch taxa. The objective of this study was to evaluate survival and growth of birch taxa in Arkansas.

Materials and methods

Twenty three birch accessions obtained from commercial nurseries (Table 1) as rooted cuttings or bare root plants were potted into 3.8 L (1 gallon) pots filled with SunGro SB300 Universal Mix (Pine Bluff, Ark.) in winter, 2001. Container plants were grown in an outdoor lathe house until they were planted out in April 2002. Birches were planted at the Agriculture Research and Extension Center, Fayetteville and Southwest Research and Extension Center, Hope, Arkansas on April, 12 and 5, respectively. Soil type at the Fayetteville site was a Captina silt loam (pH=6.2) and at Hope a Bowie fine sandy loam (pH=5.5). Trees were planted 2.5 m (8.2 ft) apart in a row and distance between two rows of trees was 4.5 m (14.8 ft). Trees were mulched with wood chips to a depth of 10 cm (4 in.). From June to September trees were watered as required using a drip system with Rainbird EM-L20 SSP Lady Bug emitters (nominal flow rate =2.0 L.h-1) and fertilized with 10 g (0.35 oz) 10-20-10 fertilizer per tree monthly from May to September, 2002.

The experimental design was a completely randomized design at both locations.

Growth data collected included initial and final shoot height and trunk caliper. Year-end measurements were taken at Fayetteville and Hope on October 29 and 17, respectively. Mortality was recorded at both locations.

Results and discussion

Survival: Of the 23 birch accessions planted at both locations, 21 had higher mortality rates at Hope than Fayetteville (Table 1). Higher mortality at Hope might be attributed to warmer temperature associated with USDA Hardiness zone 8. Two taxa with lower mortality (≤10%) at Hope than Fayetteville were both cultivars of *B. nigra*, 'Dura-Heat' and 'Heritage' (Hill Nursery).

Birch taxa with low mortality (≤10%) at Fayetteville included 'Dura-Heat', *B. papyrifera* 'Renaissance Reflection', *B. nigra* (Schmidt Nursery), *B. populifolia* 'Whitespire', *B. populifolia*, *B. pendula* 'Laciniata', *B. papyrifera*, 'Heritage', *B. pendula*, *B. davurica*, and *B. x* 'Royal Frost' .

At Hope, five taxa with 100% mortality were *B. pendula* 'Trost's Dwarf', *B. ermanii*, *B. papyrifera* 'Renaissance Reflection', *B. pedula* 'Laciniata' and *B. albosinensis*.

Growth: At the end of the first growing season (Table 2), the tallest birch taxa growing at Fayetteville (>150 cm) were 'Laciniata', 'Dura-Heat', 'Heritage' and 'Renaissance Upright' and at Hope (>100 cm)

Thanks to Manjula Carter for assistance at Southwest Research and Extension Center, Hope, Ark. Gratitude to the Research Incentive Grant Program for funding materials and equipments.

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'Heritage' and *B. nigra* (data not shown). *Betula papyrifera*, *B. nigra* (Evergreen), and *B. utilis var. jacquemontii* at Fayetteville and *B. nigra* (Evergreen) and 'Heritage' (Hill) at Hope had largest increase in height (>500%).

Betula maximowicziana, B. alleghaniensis, and *B. ermanii* at Fayetteville had the smallest increase in height (<50%). At Hope, five taxa with negative growth (shoot dieback) were *B. maximowicziana*, *B. alleghaniensis, B. lenta, B. papyrifera,* and 'Whitespire'.

Betula davurica, B. nigra, ' Heritage' and 'Fargo' at Fayetteville, and *B. nigra* and 'Heritage' at Hope had the greatest increase in trunk caliper (>400%) while *B. ermanii* at Fayetteville, *B. papyrifera*, 'Renaissance Upright', 'Whitespire' and *B. alleghaniensis* at Hope had the smallest increase (<50%).

Betula nigra and its cultivars are widely adapted birches that have been grown in southern states. They displayed better landscape performance than the other taxa. In contrast, *B. pendula* 'Trost's Dwarf', *B. ermanii*, *B. papyrifera*, 'Renaissance Upright', 'Whitespire', *B. alleghaniensis*, *B. pedula* 'Laciniata', *B. albosinensis, B.maximowicziana, B. alleghaniensis*, and *B. lenta* were among birch taxa that did not show good landscape performance as indicated by either high mortality or low growth rate in height or trunk caliper.

Distinct taxa with different response to Arkansas environment were detected in this study. However, data of several years' performance are needed for more precise conclusion about birches' growth potential and adaptation to Arkansas environment.

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Table 1. Birch accessions, nursery source, and mortality for trees evaluated at Fayetteville and Hope, Ark., during 2002.

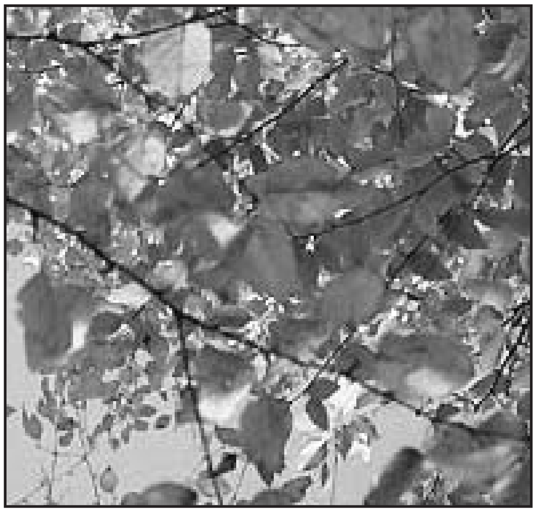
		Fayetteville		Hope	
Taxa	Nursery source	No. trees planted	Mortality (%)	No. trees planted	Mortality (%)
B. pendula 'Trost's Dwarf'	Briggs	14	36	6	100
B. nigra	Evergreen	14	36	6	83
B. ermanii	Meadow Lake	14	36	6	100
B. lenta	Lawyer	14	29	6	50
B.albosinensis	Heritage Seedlings	14	29	6	100
B. platyphylla 'Fargo'	Meadow Lake	16	25	6	67
B. utilis var. jacquemontii	Briggs	14	21	6	83
B. alleghaniensis	Lawyer	14	21	6	83
B. maximowicziana	Lawyer	14	21	6	83
B. pendula	Schmidt	19	21	0	--
B. papyrifera 'Renaissance Upright'	Evergreen	14	14	6	50
B. nigra 'Dura-Heat'	Moon River	14	7	6	0
B. papyrifera 'Renaissance Reflection'	Evergreen	14	7	6	100
B. nigra	Schmidt	14	7	6	67
B. populifolia 'Whitespire'	Briggs	14	7	6	33
B. populifolia	ForestFarm	14	7	6	17
B. pendula 'Laciniata'	Briggs	14	7	6	100
B. papyrifera	Schmidt	15	7	6	83
B. nigra 'Heritage'	Hill	16	6	6	0
B. pendula	Meadow Lake	14	0	6	50
B. davurica	ForestFarm	14	0	6	67
B. x 'Royal Frost'	Evergreen	14	0	6	50
B. nigra 'Heritage'	Heritage Seedlings	14	0	6	17

Table 2. Change in shoot height and trunk caliper of birch planted at Fayetteville and Hope, Ark., in 2002.

Taxa	Change in shoot height during 2002				Change in trunk caliper during 2002			
	Fayetteville		Hope		Fayetteville		Hope	
	cm[z]	%	cm	%	mm	%	mm	%
B. albo-sinensis	47 efg[y]	164 de	--	--	1.0 efg	396 cdef	--	--
B. alleghaniensis	32 ghi	46 e	-25 e	-42 e	0.7 fghi	199 ghij	0.0 de	0 e
B. davurica	54 ef	261 de	20 de	153 cd	1.0 efg	569 ab	0.2 de	200 cde
B. ermanii	9 j	26 e	--	--	0.1 j	42 k	--	--
B. lenta	38 fghi	53 e	-6 e	-7 de	0.6 f-i	142 ijk	0.3 cde	80 cde
B. maximowicziana	26 hij	35 e	-4 e	-5 de	0.8 e-h	237 g-j	0.2 de	50 de
B. nigra (Evergreen)	62 de	838 ab	106 ab	1767 a	0.9 efg	324 d-g	1.5 abc	500 ab
B. nigra (Schmidt)	48 efg	91 e	80 abc	197 c	1.4 bc	624 a	1.1 b-e	317 bcd
B. nigra 'Dura-Heat'	97 abc	149 de	69 bc	104 cde	2.1 a	249 ghi	1.6 ab	196 cde
B. nigra 'Heritage' (Hill)	106 ab	153 de	75 bc	105 cde	1.7 ab	408 cde	1.8 ab	354 bc
B. nigra 'Heritage' (Heritage Seedlings)	114 a	423 cd	124 a	570 b	1.6 b	453 bcd	2.5 a	755 a
B. papyrifera	81 cd	1,088 a	-4 e	-8 de	0.5 hij	141 ijk	0.0 e	0 e
B. papyrifera 'Renaissance Reflection'	77 cd	254 de	--	--	0.9 efg	171 hijk	--	--
B. papyrifera 'Renaissance Upright'	87 bc	136 e	17 de	26 de	1.0 def	220 ghij	0.2 de	40 de
B. pendula (Meadow Lake)	39 fgh	66 e	12 de	21 de	0.9 e-h	238 ghij	0.6 b-e	211 b-e
B. pendula (Schmidt)	40 gh	91 e	--	--	0.5 hij	128 ijk	--	--
B. pendula 'Laciniata'	78 cd	85 e	--	--	1.1 cde	256 fghi	--	--
B. pendula 'Trost's Dwarf'	13 ij	151 de	--	--	--	--	--	--
B. platyphylla 'Fargo'	45 efgh	260 de	--	--	0.7 fgh	504 abc	--	--
B. populifolia	55 ef	79 e	18 de	24 de	1.0 def	297 efgh	0.7 bcd	170 cde
B. populifolia 'Whitespire'	30 ghi	134 e	-22 e	-29 e	0.6 ghi	123 ijk	0.2 de	29 de
B. 'Royal Frost'	83 c	134.1e	47 cd	76 cde	1.4 bcd	307 e-h	1.3 a-d	313 bcd
B. utilis var. jacquemontii	56 ef	552.9 bc	21 de	55 cde	0.3 ij	100 jk	0.3 de	100 cde

[z] 1 cm= 0.39 inch.

[y]Numbers followed by the same letters were not significantly different according to LSD test at level of 0.05.



Leaf Gas Exchange and Stomatal Characteristics of Six Birch Taxa Under Different Irrigation Regimes

Mengmeng Gu[1], *Curt R. Rom*[1], *and James A. Robbins*[2]

Additional index words: birch, gas exchange, drought

Summary. The effect of container media moisture status on leaf gas exchange and stomatal characteristics of six birch taxa (*Betula. nigra L., B. nigra L.* 'Heritage', *B. papyrifera* Marsh., *B. pendula* Roth, *B. populifolia* (Regel) Nakai 'Whitespire', and *B. utilis* var. *jacquemontii* Spach.) was evaluated. Trees were grown in a greenhouse and watered when the combined mass of six indicator pots of each taxa decreased by 25% (well-watered/control), 45% (moderate drought) or 60% (severe drought). Plants in the drought stress treatment group had lower CO_2 assimilation rate, evapotranspiration and stomatal conductance than plants in well-watered group. *Betula nigra* exposed to severe drought maintained higher CO_2 assimilation rate while *B. nigra* 'Heritage' had higher evapotranspiration and stomatal conductance. Taxa variance had a more significant effect on the stomatal parameters than drought treatments.

Interest has increased in recent years in the use of birch as a landscape plant in the southern U.S. In their natural habitats, birches inhabit moist regions, including bogs, stream banks, lakeshores, cool and damp woods, and moist slopes in cool coves (Farrar, 1995). However, when grown as a landscape tree, birches must deal with environmental stresses such as drought, which is a major factor limiting their use in many areas.

Water stress affects many physiological processes in trees. Plants can adapt to water stress by increasing water uptake and reducing water loss which will cause differences in the leaf gas exchange and stomatal characteristics (Fort et al., 1998). In tall fescue cultivars (*Festuca spp*.), maintenance of high CO_2 assimilation (A), evapotranspiration (ET) and stomatal conductance (g_s) was found to facilitate drought tolerance (Huang and Gao, 1999). Schurr, et al. (2000) reported that leaf gas exchange was dominated by physiological rather than by anatomical properties (stomatal density) in *Ricinus communis* L. during water stress. The effect of soil drying on leaf gas exchange and associated stomatal characteristics is not well understood in birch taxa. The objectives of this study were to: (1) determine and compare the response of leaf gas exchange in six birch taxa differing in drought tolerance; (2) investigate the relationship between leaf gas exchange and stomata characteristics under drought stresses.

Materials and methods

Six birch taxa obtained from commercial nurseries as rooted cuttings or bare root plants, were potted into 3.8L (one gallon) pots filled with SunGrow SB300 Universal Mix (Pine Bluff, Ark.) (pine bark compost, peat, vermiculite and perlite) in winter 2001, and grown in an outdoor lathe house. In June, 2002, thirty plants of each taxa were transported to a greenhouse at the Rosen Alternative Pest Control Center (APC). Each plant was fertilized with five grams of Osmocote® 18-5-10 (18N-2.6P-9.9K).

Eight replicate trees were randomly assigned to one of three irrigation regimes (well-watered/control, moderate drought and severe drought). Six seedlings of each taxa were randomly selected as indicator plants to determine when to irrigate all seedlings within treatment combination. Containers were watered and allowed to drain for 1 hour. The combined mass of the six indicator pots was measured. Control plants, plants assigned to the moderate drought and severe drought treatment were irrigated when the mass of the indicator pots decreased by 25%, 45% and 60%, respectively. In a preliminary experiment, wilting symptoms were observed in all six taxa when the combined mass of the indicator pots decreased by approximately 60%. An irrigation cycle was considered complete when all groups assigned to the severe drought treatment were irrigated. Treatments ended after all groups completed at least five consecutive cycles of drought. Measurements were taken after the conclusion of 5 cycles of treatment.

Carbon dioxide assimilation (A), evapotranspiration (ET), and stomatal conductance (g_s) on the fourth and fifth unfolded leaves of individual tree were measured under steady-state conditions utilizing a portable gas analyzer (CIRAS-II Analyzer, PP Systems, Inc). Standard conditions were set as 25ºC, 350 ppm CO_2, 50% relative humidity and 1,200 $\mu mols \cdot m^{-2} \cdot s^{-1}$ light intensity. Clear nail polish was applied to one side of the leaf discs and peeled to measure the stomatal density, and length and width of guard cells under Olympus BX41 phase microscope.

The experimental design was a two-factor completely randomized design. Fixed factors were taxa and drought treatment.

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Results and discussion

For the leaf gas exchange, both of the taxa and drought treatments had a significant effect on A, ET and gs, (*P*<0.0001) (Table 1). Stomatal closure and the subsequent reduced stomatal conductance is a direct response adopted by plants when exposed to water deficiency (Bahrun, et al. 2002). *Betula nigra* 'Heritage' and *B. nigra* had higher values for A, ET and g_s than the other taxa. Plants exposed to a more severe drought had lower A, ET and g_s than plants from the control and moderate drought stress groups except for A in *B. nigra* and the ET and g_s measurements in *B. papyrifera* (Fig. 1). *Betula nigra* plants exposed to severe drought had higher A than plants exposed to moderate drought (Fig. 1). Plants of *B. papyrifera* in the moderate drought group had a slightly higher g_s than plants in well-watered group. However, three values dropped dramatically in the severe drought group (Fig. 1 C). In all three irrigation groups, *B. nigra* 'Heritage' and *B. nigra* had higher values for A, ET and g_s than all the other taxa except *B. papyrifera* in moderate drought group had the highest g_s value. *Betula utilis var. jacqumontii* had the lowest A value in well-watered groups and lowest value of ET and g_s in the moderate drought groups. *Betula pendula* had lowest value of ET and g_s in well-watered groups (Fig. 1 B) and lowest A value in the moderate drought groups (Fig. 1 A). In the severe drought stress groups, *B. papyrifera* had lowest value of A, ET and g_s (Fig. 1).

For stomatal parameters (density, length and width, and the ratio of length to width.), taxa had a significant effect (*P*<0.0001) while drought stress treatment had no significant effect on stomatal density (*P*=0.2579) or stomatal width (*P*=0.2051) or little significant effect on stomatal length (*P*=0.0341) or the ration of stomatal length to width (*P*=0.0410). Similar trends in stomatal length were observed in all taxa. *Betula pendula* showed greater change in the stomatal density from well-watered group to severe-stressed group than the other taxa. However, the other taxa showed similar change.

Betula nigra is a widely grown birch in southern states, and 'Heritage' is the most popular. Both taxa maintained higher CO_2 assimilation than the other birch taxa in the study. However, the results of the other white-barked birches were consistent with the observation that they performed poorly in the southern states landscape if water deficiency was considered as one of the factors.

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Table 1. Gas exchange and stomatal characteristics for each birch taxa exposed to three levels of soil drying prior to irrigation.

	Factors	A ($\mu mols \cdot m^{-2} \cdot s^{-1}$)	ET ($\mu mols \cdot m^{-2} \cdot s^{-1}$)	g_s ($\mu mols \cdot m^{-2} \cdot s^{-1}$)	Stomatal density (no./mm^2)	Stomatal Length (µm)	Stomatal width (µm)	Ratio of Stomatal length to width
Taxa effect	*B. nigra*	9.52 a[z]	3.58 a	325 ab	120 b	27 b	16 c	1.7 a
	B. nigra 'Heritage'	8.28 b	3.62 a	329 a	142 a	24 c	16 c	1.5 b
	B. utilis var. jacquemontii	5.13 c	1.96 d	138 d	86 c	34 a	23 a	1.5 b
	B. papyrifera	5.26 c	2.89 b	283 b	85 c	37 a	24 a	1.6 ab
	B. pendula	5.53 c	1.94 d	127 d	141 a	24 c	22 ab	1.2 c
	B. populifolia 'Whitespire'	7.39 b	2.57 c	197 c	156 a	29 b	20 b	1.5 b
	P>f	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Effect of change in container weight (%)	25	9.06 a	3.45 a	321 a	128	28 b	19 a	1.5 a
	45	6.64 b	3.14 b	275 b	124	30 a	20 a	1.6 a
	60	4.99 c	1.79 c	116 c	115	28 b	21 a	1.4 b
	P>f	<0.0001	<0.0001	<0.0001	0.2579	0.0341	0.2051	0.0410

[z] Significant differences among taxa and drought treatments are indicated by lowercase letters. Means with the same letter are not significantly different according to Fisher's LSD test at 0.05 level.

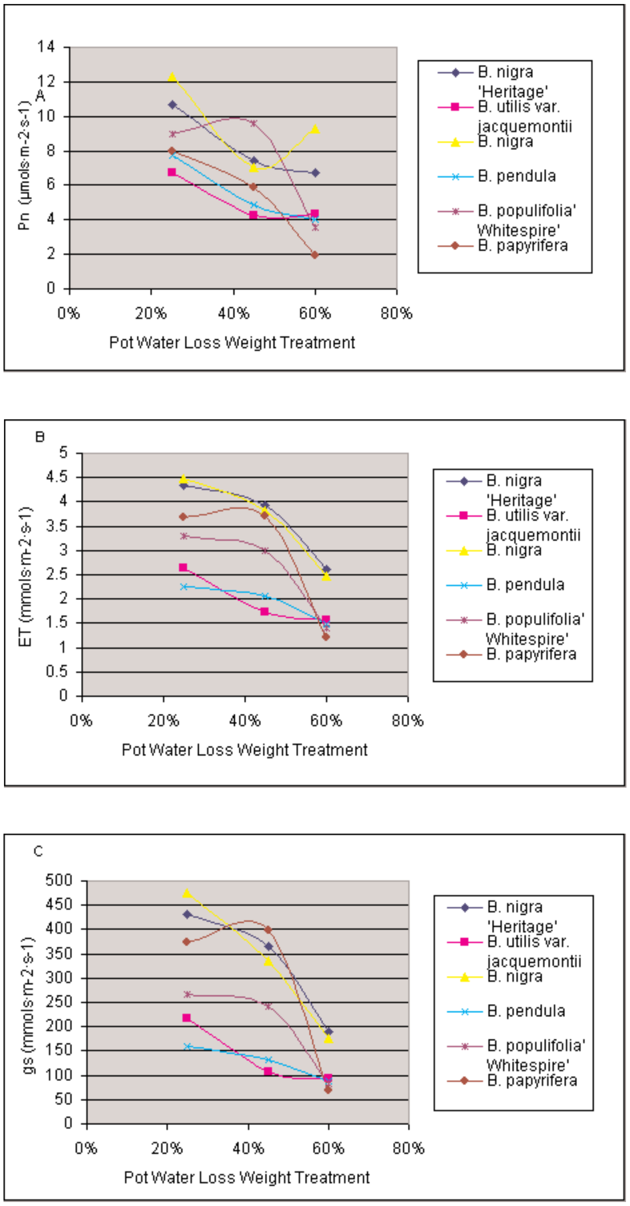

Fig. 1. The effect of three levels of soil drying prior to irrigation on (A). CO_2 Assimilation (Pn), (B) Evapotranspiration (ET) and (C) Stomatal Conductance (g_s) of six birch (*Betula spp.)* taxa grown in the greenhouse. N=5.

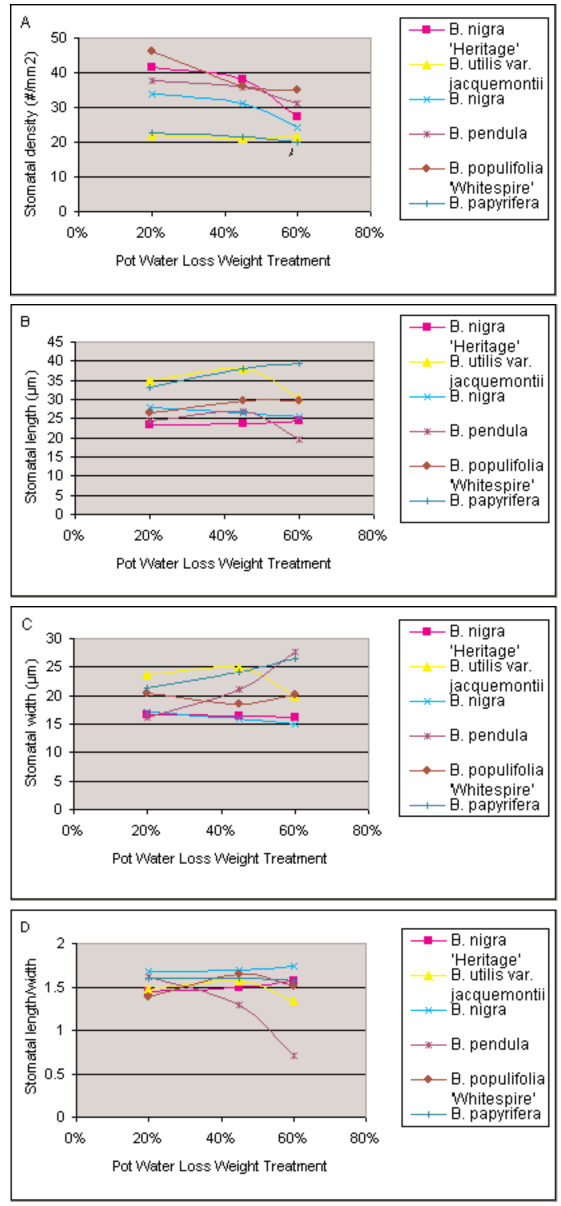

Fig. 2. The effect of three levels of soil drying prior to irrigation on birch leaf stomatal characteristics. (A). stomatal density (#/mm²); (B) stomatal length (µm); (C) stomatal width (µm); and (D) stomatal length/width.

Leaf Gas Exchange Response to Photon Flux Density of Six Birch Taxa

Mengmeng Gu[1], *Curt R. Rom*[1], *James A. Robbins*[2]

Additional index words: photosynthesis, *Betula*

Summary. The response of leaf gas exchange to varying photon flux density (PFD) was evaluated for six birch taxa (*B. nigra* L., *B. nigra* 'Heritage', *B. papyrifera* Marsh., *B. pendula* Roth, *B. populifolia* (Regel) Nakai 'Whitespire', and *B. utilis var. jacquemontii* Spach.) grown under greenhouse conditions. Net CO_2 assimilation (A), stomatal conductance (g_s), and evapotranspiration (Et) were measured with varying PFD. Changing the PFD had no significant effect on stomatal conductance or evapotranspiration in each species. *Betula utilis var jacquemontii* had a higher CO_2 assimilation rate and maximum quantum efficiency than other birch species while *B. nigra* and its cultivar, 'Heritage' had the lowest.

Most birches are considered as pioneer tree species in their natural habitat (Farrar, 1995). Photon flux density (PFD) is one of the factors affecting growth and many physiological processes in plants (Krall et al., 1995). Dragar and Menary (1994) found that high PFD resulted in significant increased in plant height, stem diameter and percentage oil yield in *Olearia phlogopappa* Labill. Similar results were found in Pisum sativum L. (Wimmers and Turgeon, 1991) as size and number of wall ingrowths were positively correlated to the photon flux density (PFD) and the solute influx was greater in leaves of plants grown at high than those grown in low PFD. Birch, which is typically grows in full sun, may be more sensitive to changing PFD than more shade tolerant species (Aphalo and Lehto, 1997). PFD varies in both field and greenhouse environments. Within a certain PFD range, plant CO_2 assimilation (A) increases with PFD and plants respond to this change with different quantum efficiency (Lloyd et al., 1995). Plant species vary in the maximum photon flux density-saturated CO_2 assimilation rates (Zipperlen and Press, 1996). Research has not been conducted on birch to investigate the effect of leaf gas exchange to changing PFD. The objective of the study was to evaluate gas exchange of six birch taxa in response to varying PFD.

Materials and methods

Six birch taxa (*B. nigra* L., *B. nigra* 'Heritage', *B. papyrifera* Marsh., *B. pendula* Roth, *B. populifolia* (Regel) Nakai 'Whitespire', and *B. utilis var. jacquemontii* Spach.) obtained from nurseries as rooted cuttings or bare root plants were potted in 3.8 L (1 gal.) pots with Sungrow SB300 Universal Mix (Pine Bluff, Ark.) in winter, 2001 and placed in an outdoor lathe house at the Arkansas Agriculture Research and Extension Center in Fayetteville until they were transported to the greenhouse at the Rosen Alternative Pest Control Center (APC), in June, 2002. Five grams (0.18 oz) of Osmocote® 18-5-10 (18N-2.6P-9.9K) were applied to each pot. Trees were pruned back on September 30 to leave 2 to 3 lateral buds. Experiments were initiated on December 18 when shoots of all trees had re-grown to a height above 50 cm (20 in.).

Measurements were taken on one of the five trees from each taxa every day between 0800 and 1230 hours from December 18 to December 22, 2002. Plants were watered to container capacity every evening prior to measurement. Carbon dioxide assimilation (A), evapotranspiration (ET) and stomatal conductance (g_s) were measured on the fourth and fifth unfolded leaves under steady-state conditions utilizing a portable gas analyzer (CIRAS-II Analyzer, PP Systems, Inc) with a Parkinson's leaf cuvette (2.5 cm2/0.39 in2) . Standard conditions of leaf cuvette were set as 25ºC (77ºF), 350 ppm CO_2, and 50% relative humidity. Light on the Parkinson's leaf cuvette was turned off and the cuvette head was enclosed in aluminum foil to exclude light to measure dark respiration (R_d). After R_d was measured, light on the leaf cuvette was turned on and photosynthetic active radiation (PAR) adjusted to PFD of 10, 50, 100, 250, 500, 1000, and 1500 $\mu mol \cdot m^{-2} \cdot s^{-1}$ to test gas exchange response of birches.

The experimental design was completely random design with five replications of single trees. A Gauss-Newton model was used to develop a PAR response curve. Maximum CO_2 Assimilation (A_{max}) was estimated for each taxa from each Gauss-Newton model. Dark respiration was calculated as the intercept on Y axis (assimilation value) from Gauss-Newton model (when x = 0). Saturated PFD was calculated when CO_2 assimilation reached 90% of A_{max}.

Results and discussion

All six taxa showed similar response to increasing PFD (Fig. 1). Initially, photosynthesis increased in an almost linear relationship to PFD. The relationship between PFD and CO_2 assimilation became nonlinear at higher PFD (>200 $\mu mols \cdot m^{-2} \cdot s^{-1}$). Net CO_2 assimilation was eventually light saturated and remained constant with increasing irradiance.

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Maximum CO_2 assimilation potential (A_{max}) under increasing PFD was calculated from the Gauss-Newton model. For A_{max}, the taxa effect was significant (*P*=0.0002). *Betula utilis var. jacquemontii* had the highest A_{max} value (10.46 mmol.m-2.s-1) while *B. nigra* had the lowest (4.88 mmol.m-2.s-1) (Table 1.).

Dark respiration was calculated when PFD was set to 0 µmol·m^{-2}·s^{-1}. The variance for R_d among taxa was not significantly different (*P* =0.1099). *Betula utilis var. jacquemontii* had the highest R_d (-2.71 mmol.m-2.s-1), and *B. nigra* and 'Heritage" had lowest R_d in the experiment (-1.51 mmol.m-2.s-1 and -1.77 mmol.m-2.s-1). The ranked order of taxa for A_{max} from highest to lowest was the same for dark respiration which indicates that *B. utilis var. jacquemontii* maintained the highest gas exchange rate and *B. nigra* the lowest (Table 1.).

The maximum quantum efficiency of CO_2 assimilation (fmax) was determined from the initial slope of the response curve. The six taxa had significantly different fmax *(P* =0.0001). Similar to the observations for A_{max} and dark respiration, *B. utilis var. jacquemontii* utilized light more efficiently than the other taxa (13.17 mmol.m-2.s-1 /µmol·m^{-2}·s^{-1}) and *B. nigra* was the least efficient (6.40 mmol.m-2.s-1 /µmol·m^{-2}·s^{-1}) (Fig. 1.). Net CO_2 assimilation was considered light saturated when the value reached 90% of the A_{max} value. The PFD values at this light saturated point were not significantly different among the six taxa (*P* =0.5975), and all were saturated at approximately 1200 µmol·m^{-2}·s^{-1}. This value may be useful in future birch gas exchange studies.

Changing the PFD had no significant effect on stomatal conductance or evapotranspiration rates in each species (data not shown).

Overall, under greenhouse conditions, *B. utilis var. jacquemontii* had greater CO_2 assimilation rate and maximum quantum efficiency than the other birch taxa, while *B. nigra* and its cultivar, Heritage birch, ranked at the bottom of both parameters. This was contradictory to the result of previous experiments using the same taxa, in which greater CO_2 assimilation was observed in *B. nigra* and Heritage birch. In this experiment, the survival and growth rate of these two taxa were also lower than the others except the lower CO_2 assimilation rate and maximum quantum efficiency. Cutting-back pruning in late September might cause the vigor reverse of both taxa. More study is needed to investigate these phenomena.

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Table 1. Maximum CO_2 Assimilation (A_{max}) calculated from Gauss-Newton model, Dark Respiration (Rd), photon flux density (PFD) when trees of each taxa reached 90% of the maximum CO_2 Assimilation, quantum efficiency (fmax) and estimated gross Photosynthesis rate (P). Each number was the mean of five replications.

	Birch taxa						P<f
	B.nigra 'Heritage'	*B. nigra*	*B. papyrifera*	*B. pendula*	*B. populifolia* 'Whitespire'	*B. utilis var. jacquemontii*	
A_{max} µmols·m^{-2}·s^{-1}	6.34d[z]	4.88d	5.90cd	7.51c	9.23b	10.46a	0.0002
R_d µmols·m^{-2}·s^{-1}	-1.77	-1.51	-2.17	-2.19	-2.68	-2.71	0.1099
PFD of 90%A_{max} µmols·m^{-2}·s^{-1}	1322.6	1018.2	1038.1	1339.7	1231.5	1281.0	0.5975
ϕmax µmols·m^{-2}·s^{-1} /µmols·m^{-2}·s^{-1}	8.11cd	6.40d	8.07cd	9.70bc	11.91ab	13.17a	0.0001
P µmols·m^{-2}·s^{-1}	8.11cd	6.40d	8.07cd	9.70bc	11.91ab	13.17a	0.0001

[z] Numbers followed by the same letters were not significantly different according to LSD test at level of 0.05.

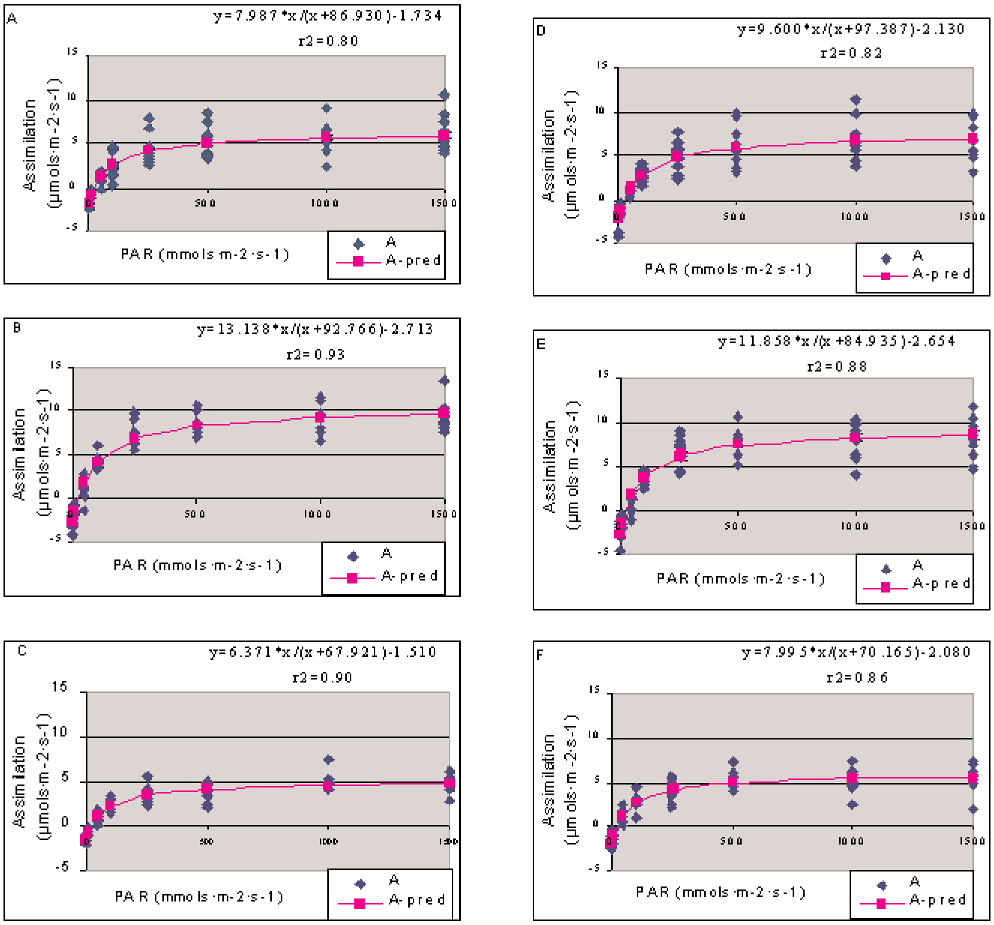

Fig. 1. CO_2 Assimilation-PAR response curve from Gauss-Newton model. (A). *Betula nigra* 'Heritage'; (B). *Betula utilis var. Jacqumontii*; (C). *Betula nigra*; (D). *Betula pendula*; (E). *Betula populifolia* 'Whitespire'; (F). *Betula papyrifera*. Legend: A: value of Assimilation measured (µmols·m^{-2}·s^{-1}) in the experiment; A-pred: value of Assimilation predicted from the Gauss-Newton model (µmols·m^{-2}·s^{-1}).

Moss Control in Creeping Bentgrass Putting Greens

J.H. McCalla Jr.[1]*, M.D. Richardson*[1]*, D.E. Karcher*[1]*, and L.R. Fry*[1]

Additional index words: *Bryum argenteum, Agrostis palustris*

Summary. Moss (*Bryum argenteum*) continues to become one of the most problematic weeds in creeping bentgrass (*Agrostis palustris*) putting greens. Control of moss can be approached in many different ways, including chemical applications, and cultural practices such as correcting shading or poor drainage. A study was conducted at Springdale Country Club (Springdale, Ark.) to evaluate the effectiveness of several different chemical products for the control of moss in a creeping bentgrass putting green. Daconil Zn®, Junction®, Fore®, Zerotol®, ferrous ammonium sulfate, Dawn Ultra®, and DeMoss® were applied every 14 days beginning in early June 2002 for a period of eight weeks. Visual moss control ratings were taken prior to the third application and then every 14 days. Excellent moss control was observed in plots treated with Daconil Zn® and this control was consistent for the remainder of the evaluation period. Limited moss control was observed in plots treated with Junction®, Fore®, and Zerotol®. There was no control of moss using Dawn Ultra®, DeMoss®, or ferrous ammonium sulfate.

The control of moss in putting greens is an issue on golf courses across North America. There are several types of moss that are associated with turf (Cook et al., 2002). *Bryum argenteum* is the moss species that is most often found on putting greens and is commonly referred to as silvery thread moss. Occurrence of moss is usually highest in areas of poor drainage and high shade (McCarty, 2001). The demand for faster and firmer putting greens has led to practices such as reduced mowing heights and reduced fertility that causes decreased turf density and allows moss to invade (Mahady, 2002). Once moss is established, it forms a thick mat over the soil that will continue to spread to weak turf areas if left untreated.

Moss control can be approached in several different ways. The best way to control moss is to have a healthy turf with a good fertility program. Once moss develops, there are several control approaches that can be taken. The first and most aggressive approach is to physically abrade the moss and then topdress it with sand to desiccate the moss (Cook et al., 2002). Since moss is most commonly found in areas of poor drainage and high shade, improving the surface and subsurface drainage, as well as pruning of shade trees to increase exposure to light, can reduce moss infestations. However, if drainage is sufficient and light is not limiting, then other approaches to control must be initiated.

There are several compounds that have been reported to control moss. Dishwashing soaps such as Dawn, Ajax, and Palmolive have shown to reduce moss growth when applied at rates ranging from 4-10 oz 1000 ft^{-2} (1.3 – 1.91/ha). Unfortunately, these treatments can also lead to turf injury. Iron containing compounds such as ferrous ammonium sulfate and granular iron sulfate have demonstrated some moss control when applied at 4-7 oz/1000 ft^2 (1.3 – 2.2 1/ha) and 3 lb/1000 ft^2 (15.0 1/ha), respectively. Specific turfgrass fungicides have also been shown to suppress moss. Chlorothalonil (tradename Daconil), when applied at 4-8 oz/1000 ft^2 (1.3 – 2.6 1/ha), has exhibited good moss control when applied during warmer temperatures (Burnell et al., 2000).

Several studies have investigated various strategies of moss control in recent years, but the majority of these studies produced confounding results. Cook et al. (2002) performed a moss control study in Oregon and found that Dawn® dishwashing soap showed no control of moss during cool, wet conditions. In contrast, Burnell et al. (2000) found that Dawn provided ~74% control when applied at weekly intervals for three weeks, but control subsided to less than 30% by six weeks after the first treatment. Although the moss was controlled well in the first three applications, turf injury was unacceptable and the Dawn® treatments had to be stopped. In this study it was also found that the application of iron-containing products offered some control but was reduced to less than 40% by 10 weeks after the first treatment. Cook et al. (2002) found that products containing copper hydroxide, fatty acid soaps, or iron offered the best moss control in the cool, moist, Pacific Northwest.

Moss is becoming a more serious problem across Northwest Arkansas each year and there has been no local research to identify control strategies for this region. The objective of this study was to evaluate the moss control capabilities of several different products.

Materials and methods.

This study was conducted on a putting green at Springdale Country Club, Springdale, Ark. The green had several moss infestations that ranged in size from a few square meters to an area of approximately 14 m^2 (151 ft^2). The green was built to USGA specification and had been established with 'G-2' creeping bentgrass (*Agrostis palustris*) for approximately 5 years (Anonymous, 1993). The green was mowed daily at 3.3 mm (0.13 in.). All irrigation, fertilizer, and pesticide applications were made consistent with the remainder of the golf course.

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Treatments used in this study included Daconil Zn® (chlorothalonil) at 317 ml 100 m^{-2} (10 oz/1000 ft^2), Junction® (mancozeb + CuOH) at 121.5 g 100 m^{-2} (.2 lb/1000 ft^2 Fore® (mancozeb) at 182.8 g 100 m^{-2} (0.4 lb/1000 ft^2) , Dawn Ultrex® (household detergent) at 126.9 ml 100 m^{-2} (4 oz/1000 ft^2), DeMoss® (Fatty acid soap) at 95.2 ml 100 m^{-2} (3 oz/1000 ft^2), Zerotol® (hydrogen dioxide) at 396.5 ml 100 m^{-2} (12 oz/1000 ft^2), and ferrous ammonium sulfate at 317 ml 100 m^{-2} (10 oz/1000 ft^2). Initial treatments were made on 18 June 2002 and reapplied every 14 days. All treatments were applied to plots using a CO_2-powered sprayer equipped with a single nozzle spray wand with an even flat fan nozzle. Treatments were applied at a spray volume of 1505 l/ha-1 160 gal/A). Plot size was 0.3 m x 1.5 m (1 ft x 5 ft) and each treatment was replicated four times. The experiment was a completely randomized block design. Visual ratings of percent moss control were taken after two applications and then every 14 days throughout the study.

Results and discussion.

Throughout the duration of this study, the only treatment that provided acceptable control was Daconil® Zn, as it provided almost 100% control after two applications (Table 1). Junction® and Fore® provided 24.7 and 16.5% control, respectively, but never fully eradicated the problem. Zerotol®, Dawn®, DeMoss®, and ferrous ammonium sulfate offered minimal or no control. The turf showed no signs of injury from any of the treatments.

The results of this study were consistent with earlier reports in that Daconil® offered good control of silvery thread moss (Burnell et al., 2000; Gelertner and Stowell, 1999). However, it remains unclear why the effect of Daconil in other trials has been inconsistent (Cook et al., 2002). Treatments that had a label for moss control, such as Junction, Zerotol, and DeMoss were not effective in this study. In addition, treatments that had been reported to suppress moss, such as Dawn detergent (Kind, 1998), Junction (Cook et al., 2002) and Zerotol (Carson, 2001), were not effective in this study. Fore® and Junction® are products that both contain the active ingredient, mancozeb, but in addition to mancozeb Junction® also contains copper hydroxide which may explain its greater effectiveness for moss control. Studies have shown that copper hydroxide is an effective control for moss when applied during cool weather (Cook et al., 2002). Since this study was not initiated until warmer temperatures had occurred, it may explain the ineffectiveness of these products. Future studies on moss control are being planned for the upcoming growing season and will be reported in future issues of this research series.

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Table 1. Percent control of moss on a creeping bentgrass putting green using several commercially available products

	% Control			
Treatment	4 WAT[z]	6 WAT	8 WAT	Avg.
Daconil Zn	93.5	93.5	99.0	95.3
Junction	24.7	27.5	22.0	24.7
Fore	16.5	16.5	16.5	16.5
Zerotol	2.7	2.7	0	1.8
Fe NH4SO4	0	0	0	0
Dawn	0	0	0	0
DeMoss	0	0	0	0
LSD (0.05)	14.9	14.3	11.1	12.8

[z] WAT - weeks after initial treatment

Report from the 2001 NTEP Tall Fescue Trial

M.D. Richardson[1], D.E. Karcher[1], J.H. McCalla[1], and C.T. Weight[1]

Additional index words: turfgrass, *Festuca arundinacea*

Summary. Tall fescue (*Festuca arundinacea*) is a very popular grass for lawn areas in northern Arkansas and throughout the transition zone. Identifying adapted cultivars for the region remains a central focus of the University of Arkansas turfgrass research program. The National Turfgrass Evaluation Program is the predominant means by which cultivars are tested throughout North America. A tall fescue cultivar trial was planted in the summer of 2002 at Fayetteville, Ark. Significant differences in percent cover during grow-in, turf quality, and turf color were present among the cultivars tested in Fayetteville. However, there were no differences in seedling vigor and brown patch disease incidence detected among the varieties.

Tall fescue (*Festuca arundinacea*) is one of the most popular cool-season turfgrasses in the transition zone regions of the United States, as it is widely used in lawns, sports fields and on utility turf in the region. Tall fescue is know for it superior drought tolerance, good shade tolerance, and ability to grow on poor soils. Breeding efforts in the past three decades have made tremendous strides in improving the overall quality of this species.

The National Turfgrass Evaluation Program (NTEP) is an organization within the US Dept. of Agriculture that annually oversees turfgrass cultivar evaluation experiments at various sites throughout the U.S. and Canada. Each turfgrass species is tested on a four to five year cycle at sites throughout the growing region for that particular species. The University of Arkansas has been an active participant in the NTEP and has conducted several tests on tall fescue cultivars over the past 15 years. This report will describe the establishment data and the first-year performance data for the 2001 NTEP tall fescue trial at Fayetteville, Ark.

Materials and methods

The cultivar experiment was planted on 20 Oct. 2001 at the University of Arkansas Research and Extension Center in Fayetteville. The plot size was 4 x 5 ft (1.2 x 1.5 m) and there were three replications of each cultivar. The cultivars were broadcast planted at a seeding rate of 4.0 lb / 1000 ft^2 (192 kg / ha). Plots were maintained under lawn conditions for the duration of the study. Mowing height was varied during the year, going from 1.5 in. (3.8 cm) from October until May and then raised to 2.5 in. (6.3 cm) for the summer season. Nitrogen applications consist of three applications per season with 1.0 lb N / 1000 ft^2 (48 kg N / ha) applied in September and May and 2.0 lb N / 1000 ft^2 (96 kg / ha) applied in November. Irrigation was supplied as needed to prevent stress and maintain vigorous growth. Turfgrass establishment rates of the various cultivars were determined using digital image analysis (Richardson et al., 2000). Data on monthly turfgrass quality, genetic color, and brown patch (*Rhizoctonia solani*) were assessed by visual ratings during the growing season and data on percent brown patch were collected two times in late summer using digital image analysis.

Results and discussion

Tall fescue varieties averaged 26 percent cover and 19 days after seeding (8 Nov. 2001) and increased to an average of 95 percent cover at 46 days after seeding (5 Dec. 2001) (Table 1). On the first evaluation date, 8 Nov 2001, percent cover ranged from 10.3 to 45.1, and by the final evaluation date, 5 Dec 2001, percent cover ranged from 87.8 to 98.7. 'Watchdog' and 'Elisa' consistently ranked the lowest and highest, respectively, in percent cover during grow-in. After seeding, significant differences in percent cover among cultivars were present by 8 Nov. 2001 and 14 Nov. 2001. In the second growing season, there were no significant differences among varieties with regard to percent cover (Table 1).

Significant differences in turf quality were present among varieties on three of seven evaluation dates (16 May 2003, 11 June 2003, and16 Sept. 2003) (Table 2). Overall quality decreased from July through October due to a significant presence of brown patch disease across the experimental area. When averaged across evaluation dates, '2nd Millennium', 'Rebel Exceda' and 'Coyote' had the best turf quality, while 'Ky-31', 'Pure Gold', and 'Titanium' had the lowest turf quality.

On 1 Oct. 2002, there were significant differences among varieties in turfgrass color (Table 3). 'Barrington' and 'Rebel Sentry' had the highest color ratings of 7.0. 'Barlexas', 'Cayenne', 'Dynasty', 'Focus', 'Legitimate, 'Quest', and 'Tomahawk RT' all had high color rating means of 6.7. 'K-31 E+' had a color rating mean of 3.3, which was significantly lower than all of the other varieties.

There were no significant differences among tall fescue varieties with regard to seedling vigor or brown patch incidence (Table 3). Across varieties, seedling vigor ratings averaged 4.7 and 6.9 on 8 Nov 2001 and 14 Nov 2001, respectively. Average brown patch incidence was 27 and 22 percent on 14 Aug. 2002 and 5 Sept. 2002, respectively.

Data will continue to be collected on these varieties throughout the 2004 growing season and will be published by NTEP.

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Table 1. Turfgrass cover means from the 2001 NTEP Tall Fescue Trial.

	Turfgrass Cover					
	Evaluation date					
Variety	11/08/01	11/14/01	11/26/01	12/05/01	08/01/02	10/01/02
	%					
2nd Millennium	25.2	79.8	92.3	97.4	71.7	81.7
Adam's Valley	23.4	80.8	90.7	94.7	83.3	81.7
Barlexas	29.6	79.5	89.3	96.7	66.7	78.3
Barlexas II	21.6	73.6	91.3	93.8	68.3	71.7
Barrera	21.0	70.1	91.0	94.9	63.3	80.0
Barrington	32.6	80.3	93.2	96.7	63.3	65.0
Biltmore	30.4	82.6	92.0	96.7	80.0	75.0
Bingo	19.9	67.6	87.4	95.4	78.3	83.3
Bonsai	31.2	75.6	92.6	95.6	65.0	65.0
Bravo	32.3	84.7	91.4	97.9	71.7	78.3
Cayenne	39.3	79.8	90.5	97.2	78.3	76.7
Coyote	19.0	72.0	91.5	95.1	78.3	81.7
Dominion	21.3	82.1	91.8	96.0	78.3	76.7
Dynasty	28.0	85.3	91.3	97.2	50.0	83.3
Elisa	45.1	87.8	93.9	98.7	75.0	73.3
Endeavor	32.4	77.3	93.8	97.0	80.0	86.7
Falcon II	29.1	69.5	86.3	91.8	90.0	80.0
Finesse II	29.9	76.7	91.3	94.8	60.0	88.3
Focus	31.5	81.4	94.0	96.9	68.3	81.7
Grande II	23.7	69.8	87.5	93.5	73.3	90.0
Jaguar 3	39.0	81.4	92.0	97.9	75.0	78.3
Kalahari	27.5	76.4	92.4	96.6	65.0	88.3
Kitty Hawk 2000	26.6	68.3	83.4	90.2	60.0	85.0
Ky-31 E+	30.3	73.1	90.6	94.8	86.7	83.3
Lancer E	28.1	78.2	91.2	95.9	65.0	85.0
Laramie	34.2	85.0	93.4	97.8	68.3	83.3
Legitimate	27.8	81.5	91.2	96.2	80.0	80.0
Masterpiece	16.4	68.3	86.6	90.8	83.3	88.3
Matador	30.5	81.1	89.2	96.0	65.0	80.0
Millennium	25.1	70.4	87.2	94.4	86.7	85.0
Mustang 3	21.5	56.8	84.2	88.1	78.3	76.7
Olympic Gold	32.8	76.6	92.7	96.7	80.0	83.3
Picasso	17.6	60.5	74.8	88.1	86.7	83.3
Plantation	22.3	67.9	83.3	89.4	85.0	80.0
Prospect	24.6	70.9	90.1	94.8	71.7	76.7
Pure Gold	23.0	71.9	91.0	96.0	75.0	76.7
Quest	15.0	70.1	92.2	93.8	73.3	81.7
Rebel Exeda	18.1	66.5	85.5	91.3	81.7	78.3
Rebel Sentry	23.8	73.4	92.6	97.6	68.3	76.7
Rembrandt	21.8	66.3	87.3	92.7	71.7	90.0
Rendition	21.6	61.9	89.6	93.5	83.3	78.3
Scorpion	37.0	81.9	91.3	96.9	86.7	73.3
Signia	25.3	73.1	87.9	94.6	78.3	80.0
South. Choice II	37.1	74.9	86.4	94.7	78.3	85.0
SR 8250	23.2	73.5	87.5	96.1	83.3	85.0
SR 8600	35.4	83.1	92.7	96.8	85.0	83.3
Stetson	25.1	71.2	87.5	95.2	83.3	85.0
Tar Heel	24.5	79.7	91.3	96.1	81.7	80.0
Tempest	24.1	74.5	91.0	94.7	85.0	80.0
Titan Ltd.	32.1	81.0	90.3	97.2	90.0	78.3
Titanium	19.5	73.5	86.9	89.9	76.7	78.3
Tomahawk RT	25.6	71.3	86.2	93.7	80.0	75.0
Tracer	15.2	65.2	85.2	91.7	75.0	75.0
Watchdog	10.3	56.0	86.3	87.8	66.7	80.0
Wolfpack	28.8	67.3	89.5	96.8	70.0	88.3
Wyatt	25.7	74.3	92.8	97.5	80.0	83.3
$LSD_{0.05}$[z]	16.0	16.0	—	—	—	—
Significance	*	*	NS	NS	NS	NS

* Significant at the 0.05 probability level.

[z] Fisher's protected least significant difference values at $P = 0.05$.

Table 2. Turfgrass quality means from the 2001 NTEP Tall Fescue Trial.

Variety	Turfgrass quality							
	Evaluation date							
	04/08/02	05/16/02	06/11/02	07/03/02	08/26/02	09/16/02	10/15/02	Avg.
	rating value[z]							
2nd Millennium	6.3	6.3	6.7	5.7	4.3	4.3	4.3	5.4
Adam's Valley	5.7	6.7	6.7	5.0	3.0	3.3	3.2	4.8
Barlexas	4.7	5.3	5.7	5.3	4.0	3.0	3.5	4.5
Barlexas II	5.7	6.3	6.7	4.7	3.0	3.0	3.0	4.6
Barrera	5.3	6.0	6.7	5.7	4.0	4.0	4.0	5.1
Barrington	5.3	5.7	5.7	4.7	3.3	2.7	3.0	4.3
Biltmore	5.3	5.3	6.0	5.7	4.0	3.7	3.8	4.8
Bingo	5.0	5.7	6.7	5.3	3.7	4.0	3.8	4.9
Bonsai	3.0	3.3	3.7	4.0	3.0	2.0	2.5	3.1
Bravo	6.0	5.7	5.3	5.3	3.7	3.7	3.7	4.8
Cayenne	5.3	6.3	6.3	5.3	3.3	3.7	3.5	4.8
Coyote	5.7	6.3	6.3	5.7	4.3	4.3	4.3	5.3
Dominion	4.7	5.3	5.3	5.3	4.7	3.0	3.8	4.6
Dynasty	4.3	5.7	5.7	5.7	3.7	3.7	3.7	4.6
Elisa	4.3	4.7	4.7	5.0	2.7	2.3	2.5	3.7
Endeavor	5.0	5.0	5.0	4.7	4.7	4.3	4.5	4.7
Falcon II	4.7	5.0	4.7	5.0	5.0	4.0	4.5	4.7
Finesse II	5.7	6.3	6.7	5.7	3.0	3.7	3.3	4.9
Focus	5.3	5.7	5.7	5.7	4.0	4.0	4.0	4.9
Grande II	5.3	6.0	6.7	5.3	4.0	4.3	4.2	5.1
Jaguar 3	5.7	5.3	5.7	4.7	3.7	3.3	3.5	4.5
Kalahari	5.3	6.0	5.3	6.0	3.3	5.0	4.2	5.0
Kitty Hawk 2000	4.3	4.7	5.0	4.7	4.0	3.7	3.8	4.3
Ky-31 E+	3.0	2.7	3.0	3.7	3.3	2.3	2.8	3.0
Lancer E	5.0	4.7	5.3	5.0	3.7	4.0	3.8	4.5
Laramie	5.0	6.0	5.3	5.0	3.3	3.3	3.3	4.5
Legitimate	4.7	5.3	6.0	4.7	4.0	3.3	3.7	4.5
Masterpiece	5.0	5.3	5.3	5.7	4.7	4.7	4.7	5.0
Matador	4.7	5.3	6.3	5.0	3.7	3.3	3.5	4.5
Millennium	5.7	6.0	6.3	6.0	4.3	3.7	4.0	5.1
Mustang 3	4.7	5.7	5.7	5.7	4.7	4.7	4.7	5.1
Olympic Gold	4.7	4.7	5.7	5.3	4.3	4.3	4.3	4.8
Picasso	4.7	5.0	5.7	5.0	4.3	4.7	4.5	4.8
Plantation	5.3	5.7	6.0	5.7	5.0	4.0	4.5	5.2
Prospect	5.0	5.0	5.7	4.3	3.3	3.3	3.3	4.3
Pure Gold	4.7	5.0	5.7	4.0	3.0	2.3	2.7	3.9
Quest	5.0	6.0	6.3	5.3	3.7	4.0	3.8	4.9
Rebel Exeda	5.3	6.0	6.0	5.7	4.3	5.3	4.8	5.4
Rebel Sentry	5.3	6.3	6.0	5.3	3.7	4.0	3.8	4.9
Rembrandt	5.0	5.3	6.0	6.3	3.7	4.0	3.8	4.9
Rendition	5.7	6.3	5.7	5.7	3.3	3.3	3.3	4.8
Scorpion	4.7	5.3	4.7	5.0	3.7	3.7	3.7	4.4
Signia	4.7	5.0	5.7	5.0	4.7	4.7	4.7	4.9
South. Choice II	5.0	6.0	6.0	6.0	4.0	3.3	3.7	4.9
SR 8250	6.0	6.3	6.3	5.0	4.3	3.7	4.0	5.1
SR 8600	5.3	6.0	6.3	5.7	3.3	3.7	3.5	4.8
Stetson	4.7	4.3	4.3	5.0	3.7	2.7	3.2	4.0
Tar Heel	5.0	5.0	5.7	6.0	4.0	3.7	3.8	4.7
Tempest	5.0	5.3	6.3	4.7	4.3	4.3	4.3	4.9
Titan Ltd.	4.7	3.7	4.0	4.3	3.3	2.7	3.0	3.7
Titanium	4.3	4.7	5.7	6.0	4.0	4.3	4.2	4.7
Tomahawk RT	5.7	6.0	6.0	6.3	3.3	2.7	3.0	4.7
Tracer	5.0	5.7	6.7	6.0	3.7	3.3	3.5	4.8
Watchdog	4.0	5.0	5.7	5.3	3.7	4.0	3.8	4.5
Wolfpack	5.3	5.7	6.0	6.0	4.0	4.0	4.0	5.0
Wyatt	5.7	5.0	5.3	5.7	3.7	3.0	3.3	4.5
LSD0.05[y]	NS	1.6	1.6	NS	NS	1.6	NS	0.7
Significance	—	***	***	—	—	**	—	***

,* Significant at the 0.01 and 0.001 probability levels, respectively.
[z] Quality was rated on a scale of 1 to 9 (6 equals minimum acceptable quality).
[y] Fisher's protected least significant difference values at *P* = 0.05.

Table 3. Seedling vigor, brown patch incidence, and turf color means from the 2001 NTEP Tall Fescue Trial.

	Seedling vigor		Brown patch incidence				Turf color
	Evaluation date						
Variety	11/08/01	11/14/01	08/14/02		09/05/02		10/01/02
	Rating[z]		Percent	Rating[y]	Percent	Rating	Rating[x]
2nd Millennium	4.7	7.7	30.8	3.7	20.7	2.7	6.0
Adam's Valley	4.3	7.3	19.0	2.3	21.4	2.3	5.3
Barlexas	5.0	7.3	36.4	4.0	24.5	3.0	6.3
Barlexas II	4.0	6.7	33.0	3.7	30.9	3.3	6.7
Barrera	4.0	6.7	38.8	4.3	21.7	2.7	6.0
Barrington	5.3	7.7	39.9	4.7	36.5	4.0	7.0
Biltmore	5.0	7.7	22.9	2.7	26.5	3.3	6.3
Bingo	4.0	6.0	24.9	3.0	18.8	2.3	6.0
Bonsai	5.3	7.3	36.7	4.3	36.5	4.3	6.0
Bravo	5.3	8.0	30.6	3.7	23.4	3.0	6.3
Cayenne	6.0	7.3	23.9	3.0	25.6	3.3	6.7
Coyote	4.0	6.7	25.0	3.0	20.4	2.7	6.3
Dominion	4.3	7.7	24.7	3.0	25.8	3.0	6.0
Dynasty	4.7	8.0	53.3	5.7	19.2	2.3	6.7
Elisa	6.3	8.0	28.1	3.3	28.7	3.3	5.0
Endeavor	5.3	7.3	23.2	2.7	16.8	2.0	6.0
Falcon II	4.7	6.3	11.9	2.0	22.0	2.7	6.0
Finesse II	5.0	7.0	42.3	4.7	14.4	2.0	5.7
Focus	5.3	7.7	34.4	4.0	22.0	2.7	6.7
Grande II	4.3	6.3	29.3	3.3	11.4	1.7	6.3
Jaguar 3	5.7	7.3	27.7	3.3	25.1	3.0	6.3
Kalahari	5.0	7.0	37.8	4.3	13.5	2.0	5.3
Kitty Hawk 2000	4.7	6.3	42.1	4.7	17.7	2.3	5.7
Ky-31 E+	5.3	7.0	15.9	2.0	18.4	2.3	3.3
Lancer E	5.0	7.3	37.1	4.3	18.1	2.0	5.7
Laramie	5.7	8.0	35.1	4.0	18.7	2.3	5.3
Legitimate	4.7	7.7	22.0	2.7	22.5	2.7	6.7
Masterpiece	3.7	6.3	19.4	2.3	13.8	2.0	5.0
Matador	5.0	7.3	38.0	4.3	23.3	2.7	6.0
Millennium	4.7	6.3	16.0	2.0	18.5	2.3	6.3
Mustang 3	4.3	5.0	23.3	3.0	27.2	3.0	6.3
Olympic Gold	5.3	7.0	22.2	3.0	20.0	2.7	5.7
Picasso	4.0	5.3	16.0	2.0	20.7	2.3	6.0
Plantation	4.3	6.3	18.3	2.3	22.1	2.7	6.3
Prospect	4.3	6.3	32.1	3.3	27.8	3.0	5.7
Pure Gold	4.3	6.3	26.4	3.0	24.2	3.0	6.0
Quest	3.3	6.3	29.1	3.7	22.1	2.7	6.7
Rebel Exeda	3.7	6.0	20.9	2.7	23.4	3.0	6.3
Rebel Sentry	4.3	7.0	34.5	3.7	24.2	3.0	7.0
Rembrandt	4.3	6.0	31.9	3.3	13.1	1.7	5.7
Rendition	4.0	5.7	20.1	2.3	22.7	3.0	6.0
Scorpion	5.7	7.7	15.5	2.0	30.1	3.3	6.3
Signia	4.7	7.0	24.2	3.0	21.8	2.7	6.0
South. Choice II	5.3	7.0	25.3	3.0	17.9	2.0	5.7
SR 8250	4.3	6.7	18.5	2.3	17.9	2.3	5.3
SR 8600	5.7	7.7	17.9	2.3	19.7	2.3	6.3
Stetson	4.7	6.7	20.0	2.3	16.7	2.3	6.3
Tar Heel	4.3	7.7	20.2	2.7	21.8	3.0	5.7
Tempest	4.0	7.0	18.4	2.3	21.8	2.7	5.7
Titan Ltd.	5.3	7.7	12.0	2.0	22.4	3.0	6.3
Titanium	4.0	6.7	26.4	3.0	25.4	3.0	6.3
Tomahawk RT	4.3	6.7	21.5	2.7	27.5	3.3	6.7
Tracer	3.7	6.0	26.6	3.3	26.5	3.3	6.0
Watchdog	2.7	5.3	35.4	4.0	24.0	2.7	5.3
Wolfpack	5.0	6.3	32.1	3.7	14.9	2.0	5.3
Wyatt	4.7	6.7	23.5	2.7	19.1	2.3	6.0
LSD0.05[w]	NS	NS	NS	NS	NS	NS	1.0
Significance	—	—	—	—	—	—	***

,* Significant at the 0.01 and 0.001 probability levels, respectively.
[z] Seedling vigor was rated on a scale of 1 to 9.
[y] Brown patch incidence was rated on a scale of 1 to 9 (9 = severe, 1 = none).
[x] Turf color was rated on a scale of 1 to 9 (9 = ideal dark green color, 1= brown).
[w] Fisher's protected least significant difference values at $P = 0.05$.

Report from the 2002 NTEP Bermudagrass Trial-Establishment Data

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Additional index words: turfgrass, *Cynodon dactylon*

Summary. Bermudagrass (*Cynodon dactylon*) continues to be the predominate turfgrass species used in Arkansas for golf courses, sports fields, home lawns and utility turf situations. Identifying adapted cultivars for the region remains a central focus of the University of Arkansas turfgrass research program. The National Turfgrass Evaluation Program is the predominant means by which cultivars are tested throughout North America. A bermudagrass cultivar trial was planted in the summer of 2002 at Fayetteville, Ark. This trial was maintained under golf course fairway conditions and data on turfgrass establishment, color, and texture were collected in the first growing season. Seeded varieties reached 90% cover 25 days earlier than vegetatively propagated varieties. 'Tifway', 'Tifsport', and 'Tift No. 4' had the lowest percent cover throughout most of the growing seasons. There were no significant differences among varieties with regard to leaf color or texture.

Bermudagrass remains the most commonly-used species for golf and sports turf, lawns and other activities in Arkansas and throughout southern and transition zone environments. Bermudagrass has many positive attributes that have made it a successful turfgrass species, including good heat and drought tolerance, pest resistance, traffic tolerance and tolerance to a wide range of soil types and water quality.

The National Turfgrass Evaluation Program (NTEP) is an organization within the U.S. Department of Agriculture that annually oversees turfgrass cultivar evaluation experiments at various sites throughout the U.S. and Canada. Each turfgrass species is tested on a four to five year cycle at sites throughout the growing region for the particular species. The University of Arkansas has been an active participant in the NTEP and has conducted several tests on bermudagrass cultivars over the past 15 years. This report will describe the establishment data for the 2002 NTEP Bermudagrass Trial at Fayetteville, Ark.

Materials and methods

The cultivar experiment was planted on 2 July 2002 at the University of Arkansas Research and Extension Center in Fayetteville. The plot size was 8 x 8 ft (2.4 x 2.4 m) and there were three replications of each cultivar. The vegetative cultivars were planted as 2 in. (5 cm) diameter plugs on 12 in. (30 cm) spacing within the plots, while the seeded cultivars were broadcast planted at a seeding ate of 1.0 lb / 1000 ft^2 (48 kg / ha) during the growing season. Irrigation was applied as needed to promote germination and establishment and to prevent stress.

Turfgrass establishment rates of the various cultivars were determined several times during the growing season using digital image analysis (Richardson et al., 2000). Data on turfgrass color and leaf textures were also collected. Color was visually rated on a scale of 1 to 9, with 9 representing ideal, dark green turf and 1 representing brown turf. Texture was visually rated on a scale of 1 to 9, with 9 representing extremely fine turf texture and 1 representing extremely coarse turf texture.

Results and discussion

On average, the seeded varieties had greater percent cover than the vegetatively established varieties on all evaluation dates (Table 1). On 29 July, all of the seeded varieties had greater than 88 percent cover, while the vegetative varieties ranged form 1 to 13 percent cover. On 3 Sept., all varieties had greater than 95 percent cover except for 'Tifway', which was an 80 percent cover.

The only significant difference in percent cover among seeded varieties was 'Panama' having lower cover than most other varieties on 29 July (Table 1). Among the vegetative varieties, 'Tifway' had the least percent cover across all evaluation dates. 'Tifsport' and 'Tift No. 4' had significantly less cover than other varieties on several dates. 'Aussie Green', 'GN-1', 'Patriot', and 'Tift No. 3' consistently had the greatest percent cover among the vegetative varieties.

There were no statistically significant differences in turfgrass color or texture among all cultivars (Table 1). Mean color rating values ranged from a high of 6.3 ('Patriot') to a low of 3.3 ('MS-Choice'), while mean texture rating values ranged form highs of 4.7 ('Tifway' and 'Transcontinental') to lows of 3.0 ('NuMex Sahara' and 'Sundevil').

Turf quality data will continue to be collected on these varieties throughout the 2005 growing season and will be published by NTEP.

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Literature Cited

Richardson, M.D., D.E. Karcher, and L.A. Purcell. 2001. Using digital image analysis to quantify percentage turfgrass cover. Crop Science 41: 1884-1888.

Table 1. Percent turf cover, color, and texture means for cultivars from the 2002 NTEP Bermudagrass Trial.

	Turfgrass Cover					Color	Texture
	Evaluation date						
Variety[z]	07/30/06	08/03/06	08/13/06	08/25/06	09/04/06	08/16/06	
	%					rating value	
Seeded							
Arizona Common	97.9	91.7	98.8	95.1	96.6	4.7	3.7
Mohawk	95.7	92.4	97.8	96.1	97.5	4.0	4.3
NuMex Sahara	96.0	89.5	98.6	94.4	97.0	4.3	3.0
Panama	88.2	89.7	98.3	96.6	97.2	4.3	3.7
Princess 77	96.8	97.2	99.5	97.2	98.3	3.7	3.3
Riviera	93.2	96.6	99.2	95.8	98.4	4.0	3.7
Southern Star	95.6	94.8	99.0	96.5	97.6	4.7	4.0
Sundevil	98.2	92.4	98.8	96.7	97.7	3.7	3.0
Sunstar	96.5	92.7	98.2	95.9	97.1	4.7	3.3
Tift No. 1	98.5	95.9	99.2	96.3	98.2	5.0	4.3
Tift No. 2	92.3	93.7	98.8	96.3	98.2	5.0	4.0
Transcontinental	94.7	95.0	99.3	95.1	97.7	5.3	4.7
Yukon	95.0	93.6	99.4	96.1	97.4	5.0	3.3
Vegetative							
Ashmore	8.9	31.0	75.7	97.4	99.4	4.0	4.0
Aussie Green	12.3	55.8	89.8	97.2	98.7	6.0	4.3
Celebration	8.7	48.3	74.8	92.7	97.0	5.0	3.3
GN-1	12.6	59.8	87.1	96.1	97.7	4.0	3.3
MS-Choice	9.5	37.8	67.4	89.6	97.9	3.3	3.3
Midlawn	13.1	36.5	71.1	92.5	97.9	3.7	3.3
Patriot	12.1	48.5	81.0	96.1	98.1	6.3	4.3
Tifsport	5.2	20.4	40.7	76.0	97.7	5.3	4.0
Tift No. 3	13.0	49.5	80.5	94.2	98.0	4.0	3.7
Tift No. 4	7.0	18.2	44.4	68.1	98.1	4.7	3.7
Tifway	1.0	6.3	10.2	36.4	80.3	5.3	4.7
LSD0.05†	7.5	7.5	7.5	7.5	7.5	—	—
Significance	***	***	***	***	*	NS	NS

*,*** Significant at the 0.05 and 0.001 probability levels, respectively.

[z] Fisher's protected least significant difference values at *P* = 0.05.

Effect of Media Type and Fertilizer on the Growth of Container-grown Woody Ornamentals

James A. Robbins[1]

Additional index words. Organic fertilizer, compost

Summary. The effect of fertilizer type was evaluated on the growth of 3 woody ornamental plants grown in two container media. A granular organic fertilizer derived from poultry litter applied at different rates and time of application was compared to a standard slow-release fertilizer. During the first 2 weeks of the experiments, pour-through electrical conductivity values indicated a higher initial salt reading for the organic fertilizer compared to the slow-release fertilizer. These results indicated that the organic fertilizer can be used to successfully grow woody ornamental plants in containers.

While a majority of container growers use synthetic fertilizers, a number of organic alternatives are available. Limited research has been conducted on the effect of organic fertilizer in the production of ornamental plants (Bellamy et al. 1995; O'Brien et al. 1999). This study was conducted to assist Arkansas growers in selecting a fertilizer based on plant growth in two commonly used container media.

Materials and methods

Research was conducted at a commercial nursery in central Arkansas. Plants used in this study were *Styrax japonicus*, *Clethra barbinervis*, and *Itea virginicus* 'Henry's Garnet'. Plants were received as liners and potted on 19 April 2002 into 1-gal plastic containers filled with two different media: American Composting (Little Rock, Ark.) compost and Hope Agri (Hope, Ark.) Landscaper Mix. American Composting media are yard waste-based compost. Hope Agri Landscaper Mix consists of mainly composted fine bark amended with a small amount of peat and vermiculite.

Five fertilizer treatments were evaluated (Table 1). Honey Crest (HC) Farms Organic Fertilizer (Rogers, Ark.) is an organic fertilizer derived from poultry litter. Treatments consisted of eight single plant replications. Plants were watered as needed using an overhead irrigation system. Containers were placed in a completely randomized design with eight single plant replicates. The electrical conductivity (EC) of the container leachate was monitored for the first month.

Data were collected when a significant number of roots reached the outside of the media ball. Final data were collected on 27 September 2002. Data collection for all species included final shoot fresh weight. For *Clethra* and *Itea*, the media were washed from the roots, the roots dried, and the final dry weight measured. The relative chlorophyll content ('greenness') was measured (Minolta SPAD meter) for 3 randomly selected mature leaves from *Itea* plants.

Results and discussion

Electrical conductivity measurements were higher for the first week in the American Composting media than in the Hope Agri Landscaper Mix regardless of the fertilizer treatment (data not shown).

When the salt contribution from the media (i.e. leachate from media without fertilizer) was subtracted from the fertilizer treatments, all HC organic fertilizer treatments had higher leachate salt readings for the first week relative to the Multicote slow-release fertilizer (Figure 1). Although the leachate EC for the high rate of HC organic was high initially, this level would not have caused root damage to most plants. From weeks two through four all fertilizer treatments had low (<0.3 $dS \cdot m^{-1}$) E.C. levels.

All *Itea* plants were of marketable quality. Final shoot fresh weight (FW) for all fertilized plants was significantly larger than the control (Table 2). Shoots of plants fertilized with the slow-release fertilizer Multicote were significantly larger than those of any other fertilizer treatment. Shoot growth of plants fertilized with the high rate (2.2 lb N/yd^3, 1.3 kg N/m^3) of HC organic split into 3 applications was significantly greater than for plants fertilized with the low (0.8 lb N/yd^3, 0.5 kg N/m^3) rate of HC organic with or without minors. Regardless of fertilizer treatment, shoot growth for *Itea* plants grown in the Hope Agri media was significantly larger than plants grown in the American Composting media (data not shown).

Regardless of the media type, final root growth was significantly larger for the *Itea* plants fertilized with HC organic at the high rate split over 3 applications compared with other fertilizer treatments (Table 3). Final root growth for plants fertilized with HC organic fertilizer was larger than the control. Averaged over all fertilizer treatments, there was no effect of media type on root growth of *Itea* (data not shown).

Fertilizer treatments had a significant effect on the relative 'greenness' of *Itea* plants (Table 4). Multicote fertilized plants grown in either media were significantly 'greener' than other treatments. It would appear that this lighter foliage color is not a result of insufficient minor elements in the HC organic fertilizer since addition of a soluble minor package did not improve foliage color for this plant.

The author acknowledges the financial support of Honey Crest Farms and American Composting for donation of compost media. The author is extremely appreciative of the donation of production space and labor by Joel Stout at Cricket Hill Farms, Conway, Ark.

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Plant growth was very poor with *Clethra* and only a few treatments resulted in marketable plants. *Clethra* growth may have been more limited by sun exposure than fertilizer or media treatments. There was a significant interaction between the type of media and fertilizer treatments on the final shoot growth of *Clethra* (Table 5). For plants grown in American Composting media, only the HC organic fertilizer at a low rate plus minors had a significant effect on shoot growth. With the Hope Agri media, that treatment plus the HC organic high rate and the Multicote resulted in significantly greater shoot growth. Honey Crest organic applied to *Clethra* at the low rate plus minors or at the high rate had a significant effect on root growth (Table 6).

Styrax plants fertilized with the slow-release fertilizer Multicote or HC organic (low rate) plus minors resulted in larger plants than the control (Table 7).

Conclusion

Overall results suggest HC organic fertilizer can be used to successfully grow ornamental plants in containers. Based on the *Itea* and *Styrax* data, a recommendation of the HC organic low rate plus minors or HC organic high-rate split application might be a reasonable treatment for further investigation.

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Table 1. Fertilizer treatments, rates, and dates of application.

Treatment code	Fertilizer	Rate, each application date[z]	Application date(s)
HC + minors	HC organic 4-2-2 + Micromax	HC incorp. @ 0.8 lb N/yd3 + Micro. Incorp. @ 1.5 lb product/yd3	4/19/02
HC low	HC organic 4-2-2	HC incorp. @ 0.8 lb N/yd3	4/19/02
HC high	HC organic 4-2-2	HC incorp. @ 2.2 lb N/yd3	4/19/02
Mcote	Multicote 18-6-12 plus minors; 8-9 month	Mcote incorp. @ 2.2 lb N/yd3	4/19/02
HC split	HC organic 4-2-2	HC incorp. @ 0.8 lb N/yd3 + 0.7 lb N/yd3 topdressed on 2 later dates: 2.2 lb N/yd3 TOTAL	4/19/02 incorp. (0.8 lb N) 5/31/02 (40 days) topdress (0.7 lb N) 7/11/02 (80 days) topdress (0.7 lb N)
Control	No fertilizer	-	-

[z] 1 lb/yd^3 = 0.6 kg/m^3

Table 2. Effect of fertilizer treatment on the final shoot growth of *Itea virginica* 'Henry's Garnet'.

Fertilizer treatment	Final shoot FW[x] (g)
HC + minors	26 c[z]
HC low	28 c
HC high	30 bc
Mcote	58 a
HC split	40 b
Control	16 d

[z] Numbers within a column followed by the same letter are not significant at the 5% level; 454 g = 1 ab
[x] FW = fresh weight

Table 3. Effect of fertilizer treatment on final root growth of *Itea virginica* 'Henry's Garnet'.

Fertilizer treatment	Final root DW[x] (g)
HC + minors	33 b[z]
HC low	40 b
HC high	51 ab
Mcote	50 ab
HC split	63 a
Control	14 c

[z] Numbers within a column followed by the same letter are not significant at the 5% level; 454 g = 1 lb
[x] DW = dry weight

Table 4. Effect of fertilizer treatment on final SPAD reading of *Itea virginica* 'Henry's Garnet' grown in different media.

Fertilizer treatment	American Compost	Hope Agri
HC + minors	38 bc[z]	38 b
HC low	41 bc	41 b
HC high	39 bc	42 b
Mcote	52 a	51 a
HC split	43 b	43 b
Control	35 c	29 c

[z] Numbers within a column followed by the same letter are not significant at the 5% level.

Table 5. Effect of fertilizer treatment and media type on final shoot growth of *Clethra barbinervis*.

Fertilizer treatment	American Composting	Hope Agri
HC + minors	14 a[z]	12 a
HC low	5 b	7 ab
HC high	6 ab	11 a
Mcote	8 ab	13 a
HC split	1 b	9 ab
Control	1 b	1 b

[z] Numbers within a column followed by the same letter are not significant at the 5% level; 454 g = 1 lb

Table 6. Effect of fertilizer treatment on final root growth of *Clethra barbinervis*.

Fertilizer treatment	Final root DW[x] (g)
HC + minors	11 a[z]
HC low	4 bc
HC high	5 b
Mcote	4 bc
HC split	4 bc
Control	1 c

[z] Numbers within a column followed by the same letter are not significant at the 5% level; 454 g = 1 lb
[x] DW = dry weight

Table 7. Effect of fertilizer on the shoot growth of *Styrax japonicus*.

Fertilizer treatment	Final shoot FW[x] (g)
HC + minors	18 a[z]
HC low	9 ab
HC high	12 ab
Mcote	20 a
HC split	16 ab
Control	4 b

[z] Numbers within a column followed by the same letter are not significant at the 5% level; 454 g = 1 lb
[x] FW = fresh weight

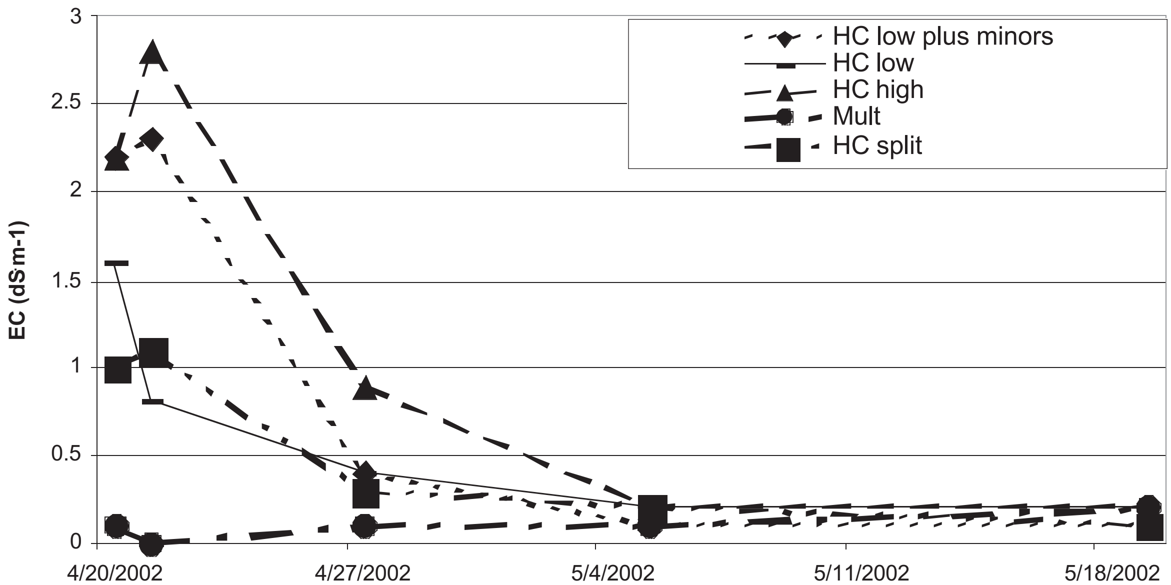

Fig. 1. Pour-through leachate conductivity values for fertilizer treatments.

Effect of Nitrogen Type and Rate on the Quality of Hybrid Bermudagrass Turf in Central Arkansas

James Robbins[1]

Additional index words: fertilizer, golf course, urea, sulfur-coated urea

Summary. The effect of nitrogen type and rate was evaluated on the quality of hybrid bermudagrass grown under golf course conditions. Nitrogen sources included ammonium sulfate and the slow-release nitrogen sources polymer-coated/sulfur-coated urea and polymer-coated urea. Nitrogen sources were applied individually, and in 1:1:1 ratios with each other, at rates of 0, 1, 1.5 and 2 lb N/1,000 ft^2 on 22 April. Both the nitrogen source type and rate had a significant effect on turf quality ratings relative to unfertilized turf. Ammonium sulfate or polymer-coated/sulfur-coated urea applied at any rate resulted in the fastest response to a nitrogen source as assessed by a change in turf quality. Although turf fertilized with polymer coated urea at any nitrogen rate was slow to respond initially, the turf responded with a steady rise in favorable quality ratings from 5 to 11 weeks after treatment.

A great deal of research has been conducted on cool- and warm-season turf to evaluate the effect of nitrogen sources and rates on turf color and growth (Carrow, 1997; Waddington and Duich, 1976; Zhang et al., 1998). Of the plant nutrients, nitrogen is often the most limiting. The extent and degree of response by turf to nitrogen depends on the turf species, the environment, and the type and rate of nitrogen applied. This study was conducted to assist Central Arkansas golf course superintendents in the proper selection of a nitrogen source and rate for quality bermudagrass turf .

Materials and methods

Research was conducted on a fairway at Pleasant Valley Country Club in Little Rock, Ark. The 'Tifway' bermudagrass was mowed at 0.5 inches and clippings were not collected. Nitrogen sources included ammonium sulfate (AS; 21% N), polymer coated sulfur-coated urea (SCU; 42% N), and polymer coated urea (PCU; 42% N). Nitrogen sources were applied individually and in ratios of 1/3 (e.g. 1/3 ammonium sulfate: 2/3 SCU) at rates of 0, 1, 1.5 and 2 lb N/1,000 ft^2 on 15 April, 2002. Plots were 3'x 6'. Air temperatures on 15 April were 85-90ºF. Turf quality ratings were made weekly by a single evaluator. Quality ratings considered turf growth and color. A rating of 6 was considered the minimum acceptable turf; a rating of 9 was not considered favorable from a management standpoint since growth was excessive and required frequent mowing. Ratings were terminated when the nitrogen treated plots could not be visually separated from the control. Treatments consisted of four single plot replications. The experimental design was a completely randomized design.

Results and discussion

Only results for the individual nitrogen sources will be discussed. Ammonium sulfate or SCU applied at any rate resulted in the fastest response to a nitrogen source as assessed by a change in turf quality (Figs. 1, 2, and 3). At the 1 lb N rate, turf quality ratings 3 weeks after treatment for the AS, SCU, and PCU were 8.3, 8.0, and 6.6, respectively. The overall shape of the response curve for AS or SCU was similar over the course of the experiment. Both nitrogen sources resulted in an increase in turf quality peaking about 4 weeks after application. The highest turf quality was followed by a slow decline in ratings over the next 10 weeks.

The polymer-coated urea applied at the 1 and 1.5 lb N rate did not result in a significant increase in turf quality until 4 weeks after application (Figs. 1 and 2). At the 2 lb N rate the PCU resulted in a significant increase in turf quality after 2 weeks (Fig. 3). In contrast to the SCU and AS, turf quality ratings for plots fertilized with PCU tended to increase until eleven weeks after treatment and then declined.

Unfertilized plots were rated as having acceptable quality over the entire experimental period (Fig. 1). The quality of unfertilized turf plots increased gradually from mid-April to mid-July. This increase in quality likely reflects the response of a warm season turf species to warmer weather. Differences in the effect of nitrogen source and rate on bermudagrass turf quality were observed.

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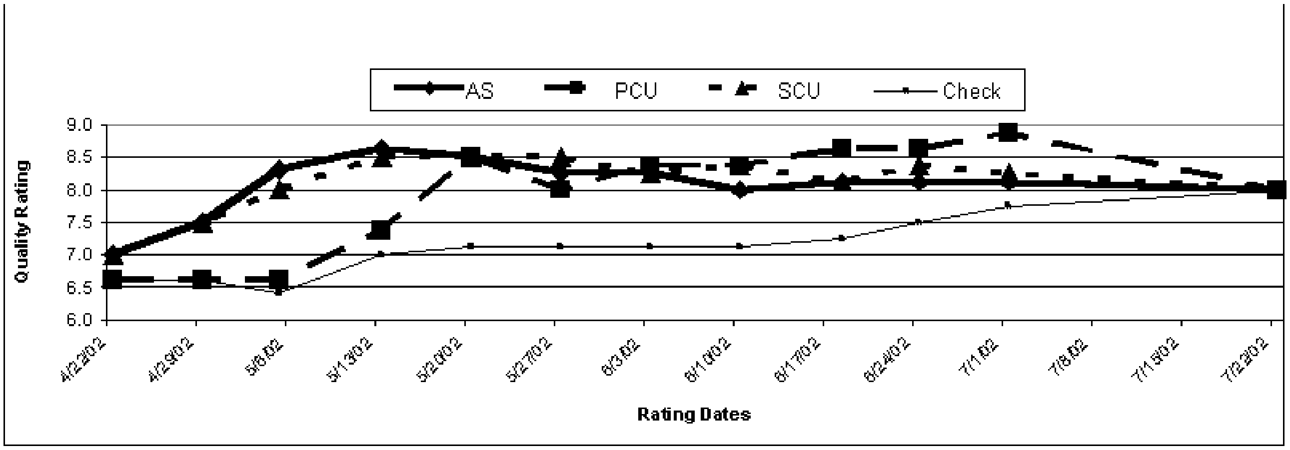

Fig. 1. Effect of nitrogen fertilizers on the quality of bermudagrass. Nitrogen sources were applied on 15 April 2002 at the rate of 1 lb N/1,000 ft^2. A rating of 6 is considered the minimum for acceptable turf.

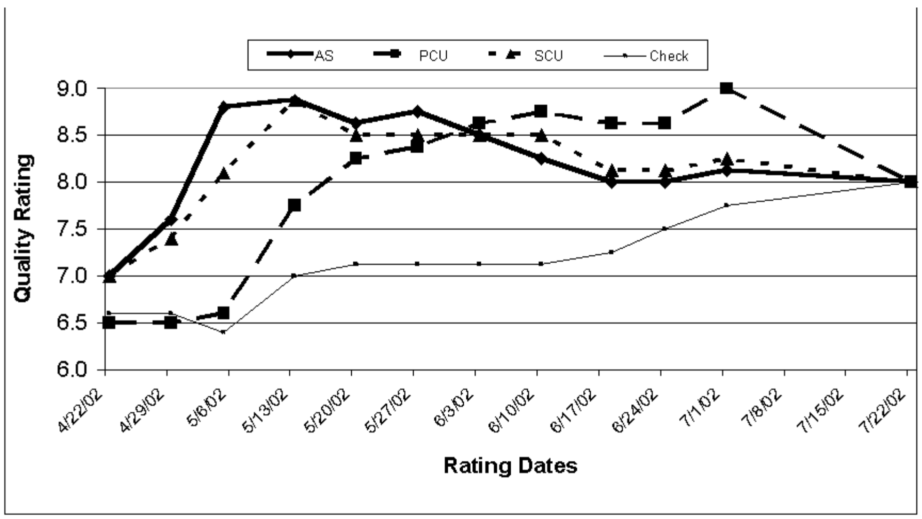

Fig. 2. Effect of nitrogen fertilizers on the quality of bermudagrass. Nitrogen sources were applied on 15 April 2002 at the rate of 1.5 lb N/1,000 ft^2. A rating of 6 is considered the minimum for acceptable turf.

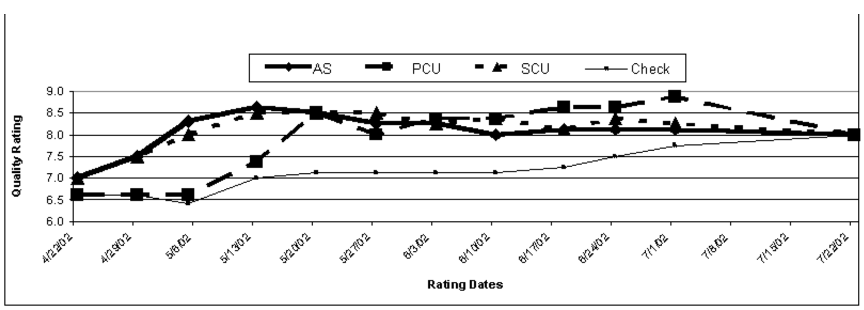

Fig. 3. Effect of nitrogen fertilizers on the quality of bermudagrass. Nitrogen sources were applied on 15 April 2002 at the rate of 2 lb N/1,000 ft^2. A rating of 6 is considered the minimum for acceptable turf.

Effect of Weed Control and Nitrogen on the Growth of Field-grown Shade Trees in Central Arkansas

James A. Robbins[1]

Additional index words: herbicides, fertilizer, red maple, Callery pear, willow oak

Summary. The effect of a vegetative ground cover and nitrogen rate was evaluated on the first year growth of 3 shade tree species at a field nursery in central Arkansas. Red maple, callery pear, and willow oak trees were planted in a mostly tall fescue covered nursery in the spring of 2002. A vegetative-free rectangle was maintained around one-half of the trees using chemical herbicides. Trees growing in a vegetation-free and in a sod area were fertilized with nitrogen rates from 0 to 29 g per tree. At the end of the first growing season, vegetative ground cover was found to have a significant effect on tree growth, however, nitrogen did not.

While the literature (Bullock, 1996; Mathers, 1999) encourages the use of a vegetative-free area around the base of shade trees in a field nursery, there are little data to document the impact on shade tree growth. Data have been published on the effect of vegetation-free zones in fruit crops (Smith, 1959; Smith, 2002).

A benefit from fertilizing field-grown plants with nitrogen was reported in previous research (Rose, 1999; Smith 1990). Specific results were dependent on the nitrogen rate, time of application, and species involved. This research was designed to evaluate the effect of nitrogen rate on the growth of shade trees during the first year of field production.

Materials and methods

Research was conducted at a commercial nursery in central Arkansas. Plants included in this study were *Acer rubrum*, *Pyrus calleryana* 'Cleveland Select', and *Quercus phellos*. Trees were planted in the field from containers (1-gal *Acer rubrum* (seedlings), 5-gal *Pyrus calleryana* 'Cleveland Select', and 5-gal *Quercus phellos*) on 22 April 2002. Plants were watered as needed using drip irrigation. The standard practice for this nursery was to mow the aisle between rows of trees but not to use any mechanical or chemical weed control within a row of trees. Tree spacing was on 8 ft centers. The pattern of tree row spacing was 3 rows of trees separated by a 10 ft wide bermudagrass/fescue aisle, an 18 ft grass aisle, and then another set of three tree rows each separated by a 10 ft grass aisle.

Granular urea was applied by broadcasting at 0, 9, 19, and 29 g N/tree.

Weed control consisted of two treatments: vegetation-free 1 ft on either side of the tree row (16 ft^2 rectangle) versus mostly tall fescue ground cover within the tree-row. Weed control was accomplished during 2002 using 1 application of pendimethalin (3 lb a.i./A) pre-emergent herbicide at planting and two spot applications during the growing season with glyphosate.

Treatments were assigned in a completely randomized design. For red maple and willow oak, there were 12 single plants replicates, and for Callery pear there were six single plant replicates.

Final growth was measured on 18 October 2002. Trunk caliper was measured for all three tree species, however, shoot height was only measured for red maple.

Results and discussion

Nitrogen Rate. Regardless of the tree species or fertilizer rate, nitrogen at any rate did not have a significant effect on the change in trunk caliper during the first growing season (data not shown). A change in tree height was only measured for red maple. Fertilizer rate had no effect on tree height for this species during the first year (data not shown). A similar study was conducted in 2002 at a different field nursery in Eastern Arkansas. Results (not shown) from that nursery also indicated no effect of nitrogen rate on tree growth during the first growing season. Tree species in that study included swamp white oak, red maple, and crabapple.

Weed Control. Use of weed control within the tree row resulted in a significant increase in trunk caliper by the end of the first growing season for callery pear and willow oak but not red maple seedlings (Table 1). Weed control within the row resulted in a significant increase in shoot height for red maple at the end of the first growing season (Table 2). The presence of a vegetative ground cover resulted in a decrease in shoot height (dieback) during the first growing season for red maple. Tree height was not measured for callery pear or willow oak.

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Table 1. Effect of vegetative ground cover within the tree row on the change in trunk caliper (cm) during 2002 for 3 tree species.

Vegetative ground cover around trees	Red Maple	Callery Pear	Willow Oak
no	0.4 a[z]	0.7 a	0.3 a
yes	0.3 a	0.3 b	0.2 b

[z]Numbers within a column followed by the same letter are not significant at the 5% level.

Table 2. Effect of weed control within the tree row on the change in shoot height during 2002 for Red Maple.

Vegetative ground cover around trees	Change in shoot height (cm)
no	8 a[z]
yes	-1 b

[z]Numbers within a column followed by the same letter are not significant at the 5% level. The use of vegetation control within the tree row had a significant effect on first year growth of shade trees. There was no effect of nitrogen rate on shade tree growth in the first year.

Effects of Osmopriming on Bermudagrass Germination and Establishment

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Additional index words: *Cynodon dactylon, turfgrass*

Summary. Bermudagrass (*Cynodon dactylon*) is one of the most frequently-used turfgrasses for golf, sport, and recreational turf throughout tropical, subtropical, and transition zone regions of the world. Recently, a number of seeded bermudagrass cultivars have been released into the turfgrass market and are quickly becoming a popular option for turfgrass managers. A major limitation with these seeded bermudagrasses is poor or slow germination. This can lead to weed-infestation, which can ultimately result in a weak turfgrass stand. One possible means to overcome slow germination is the use of a pre-germination treatment such as osmopriming. The following study was designed to investigate the effects of two osmotic priming agents, polyethylene glycol (PEG) and potassium nitrate (KNO_3) on the germination and establishment of a seeded bermudagrass. The cultivar, Jackpot, was exposed to seven different osmotic potential treatments within each solution, ranging from -0.20 to -0.5 MPa. Establishment after a 48 h exposure to these treatments was monitored for 6 weeks. Throughout the experiment, no conclusive evidence was obtained that priming of bermudagrass seed with varying osmotic solutions of PEG (avg. mol. wt. 10000) or KNO_3 was an effective means to promote faster germination and establishment. No statistical difference could be detected between KNO_3 and PEG and KNO_3 actually provided inferior results to the control. Further research is needed to determine if other priming methods would be more effective to enhance bermudagrass germination.

Bermudagrass (*Cynodon dactylon* L. Pers.) is a widely used turf and forage grass in the southern United States. While the majority of bermudagrasses are propagated by sod, plugs, or sprigging, recently developed seeded cultivars may be used for seeding or over-seeding lawns, golf courses and other turf areas. Seeding might be a more cost effective method of establishing new or over-seeded areas because plant material costs would be lower and easily available equipment could be used. To enhance the seeding process, methods to speed the germination and emergence of seed would be beneficial.

Osmopriming is a well-established practice used to enhance germination of field and row crops, but relativity few studies have applied this technique to turfgrasses. Mauromicale and Cavallaro (1996) demonstrated that osmotic solutions of KNO_3 and polyethylene glycol (PEG) enhanced the germination of a cool-season grass, tall fescue (*Festuca arundinacea* Schreb) and a warm-season grass, crabgrass (*Dactylis glomerata* L.). In addition, research on bahiagrass (*Paspalum notatum* Flügge) indicated a positive germination response to priming using PEG (Gates and Mullahey, 1997). Bush et al. (2000), working on the warm-season grasses, carpetgrass (*Axanopus affinis* Chase) and centipedegrass [*Eremochloa ophiuroides* Munro. (Kanz)], found that priming seed with KNO_3 had a very positive effect on days to germination and percentage germination in both of these species. Collectively, these studies suggest that priming may have applications with bermudagrass to enhance the germination and establishment of seeded cultivars.

Little specific work has been conducted on priming bermudagrass seed. In one study, Young et al. (1976) observed enhanced germination of common bermudagrass using solutions of KNO_3, as well as solutions containing KNO_3 and the plant growth regulator kinetin. In a study using 'Guymon' bermudagrass, hulled and unhulled seed were exposed to solutions of PEG (avg mol. wt. 8,000) and K_3PO_4. Hulled seed responded more favorably to the PEG solution while the un-hulled responded more to potassium phosphate (K_3PO_4) (Brede and Brede, 1986). In another study in which common bermudagrass seed was planted through a hydro-seeder (Kay et al., 1977), solutions of a kinitin, gibberellin (GA_3) and potassium nitrate (KNO_3) were used to osmoprime the seed. This study found that soaking seeds for 24 h in a combination of kinitin, gibberellin (GA_3) and potassium nitrate (KNO_3) yielded the most effective results.

Osmopriming and/or pre-germination of bermudagrass seed may allow for faster establishment, which will enhance the use of seeded bermudagrass cultivars. Unfortunately, there has been no research on many of the newer seeded bermudagrass cultivars. As such, the objective of this study was to determine if osmotic priming is an effective means to enhance the germination and establishment of bermudagrass.

Materials and methods

Studies were conducted in the greenhouse facilities of the University of Arkansas, Rosen Research Center (Fayetteville, Ark.). The greenhouse facility is atmospherically controlled with temperature and cooling equipment. Temperature in the greenhouse over the 36-day evaluation period varied from 25.0 – 26.7ºC in the daytime and 21.1 – 23.0ºC at night, while relative humidity ranged from 60-80% during the study. An overhead mist irrigation system was used to establish and maintain the crop. The bermudagrass cultivar, Jackpot, was used in the study. The seed was hulled and coated with a fungicide by Simplot-Jackpot Seed Division, Post Falls, ID.

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Potassium nitrate (KNO_3) and polyethylene glycol (avg. mol. wt. 10000) were selected as the germination solution for pre-soaking the 'Jackpot' seed. Each chemical was prepared in solutions corresponding to osmotic potentials of 0.20, 0.25, 0.30, 0.35, 0.40, and 0.50 MPa. The amount of PEG and KNO_3 needed for these osmotic potential solutions was calculated using the van't Hoff equation which calculates osmotic potential based on the modality of the solution. The van't Hoff equation reads as follows:

$$\prod = miRT$$

$\prod$ = osmotic potential
m = molality of the solution (moles solute / 1000 g H_2O)
i = ionization constant (= 1 for most solutions in H_2O)
R = gas constant (0.00831 L Mpa mol^{-1} K^{-1})
T = temperature ºK = degrees C + 273

For this application, the equation was re-adjusted to solve for molality. As previously identified, a range of solution osmotic potentials was desired. The temperature used for all calculations was 25ºC, or 298 °K.

A 500 mg (0.017 oz) sample of seed was used for each priming unit and represented approximately 2,170 seeds. These seeds were placed in an Erlenmyer flask containing 5.0 mL (0.169 oz.) of the various osmotic potential solutions and soaked for 48 h at 25°C (77°F). The seeds were removed from the flask, washed thoroughly in deionized water, placed in plastic weigh dishes and air dried for 96 h. For germination studies, a 100-seed sub-sample of the 500 mg treated seed sample was collected based on weight [23 mg (0.008 oz)]. An untreated, 100-seed sample was also weighed as the control. Each 100-seed sample was planted in a single cell of a planting flat that contained twenty-four cells [6 cm (2.36 in.) diam.] filled with a standard potting soil (Scotsman Standard No. 1). Vermiculite was lightly spread over the top of the seeded cells to preserve moisture during establishment. Four replications of each priming treatment were prepared and seeds were planted in a completely randomized design. The trays were randomly moved approximately every 5 to 9 days on the bench to minimize variability in the greenhouse.

Digital image analysis was used to monitor growth and establishment rates of the seed samples (Richardson et al., 2001). Digital images were obtained using an Olympus C3030Z (Olympus Optical Co., London, UK) digital camera mounted on a tripod. The tripod was set so that the camera was positioned 38 cm (15 in.) above each cell. For this study, a frame was used to isolate the area inside of the pot where the seeds were planted. The frame was constructed of red mat board in which a 6.0 cm (2.36 in.) circle was cut from the center of the board. The frame was placed over each cell so that the cell and seedlings were exposed to the camera while the remainder of the field was the red frame. The collected images were saved in the JPEG (joint photographic experts group, .jpg) format, with a color depth of 16.7 million colors, and an image size of 480 x 640 pixels. Camera settings included a shutter speed of 1/400 s, an aperture of F4.0, and a focal length of 32mm.

Digital images were downloaded to a personal computer and analyzed using SigmaScan Pro imaging software (v. 5.0, SPSS, Inc., Chicago, Ill, 60611). The color threshold feature in the SigmaScan software allows the user to search a digital image for a specific color or a range of color tones. The first step in the process is to determine the total number of pixels of information that are in the image, which for this study was 307,200 (480 x 640). The next step was to determine the number of pixels that fell in the red range (hue range from 210 to 255 and a saturation range from 25 to 100). Finally, a scan was made to determine the area of green in the image (hue range from 57 to 107 and a saturation range from 0 to 100). After developing an overlay of the red and green areas of the image, the measurement tools in the software package were used to count the total number of selected red and green pixels. From these values, the percentage turfgrass growth was determined by the following equations:

Number of pixels in cell = (total pixels in the image) - (red pixels)
% area of turf = (green pixels) / (number of pixels in the cell) x 100

Digital images were taken weekly for 6 weeks and batch-analyzed in SigmaScan software using a macro developed by Dr. Doug Karcher of the University of Arkansas. Data for turfgrass cover were analyzed as a completely randomized design using analysis of variance (PROC ANOVA) techniques in the SAS statistical analysis software program (SAS, Inc., Cary, NC). Means were separated according to Fishers protected least squares difference.

Results and discussion

The analysis of variance indicated a significant main effect of priming solution on the germination of the bermudagrass seed and no significant main effect of the osmotic potential of the solutions. There was no interaction between the type of solution and the osmotic potential of the solution and all data are therefore presented as the means of the main effects.

All seed treatments had some level of germination within 8 days after planting (DAP). At 10 DAP, there was no statistical difference in turfgrass cover based on either the osmotic potential of the solution or the type of solution (Table 1). However beginning at 16 DAP and continuing through 36 DAP, there was a statistical difference between the control seeds and those treated with KNO_3. On those dates, the control seeds actually out-performed the seeds treated with KNO_3. There was no statistical difference between the control and PEG 10000 or the PEG 10000 and KNO_3 on DAP 16 and DAP 21. Through the remaining evaluation dates, the control and PEG 10000 treatments had significantly greater cover than the KNO_3 treatment. There was no positive or negative effect of osmotic potential at any evaluation date.

Over the duration of the experiment, there was no conclusive evidence that priming of bermudagrass seed with varying osmotic solutions of PEG 10000 or KNO_3 was an effective means to promote faster germination and establishment. When comparing the two priming solutions, no statistical difference could be detected and KNO_3 actually provided inferior results to the control.

Although priming has been effectively used in numerous other field crops (Frett and Pill, 1995; Parera and Cantliffe, 1994) its applicability is apparently dependent on the species and possibly even the cultivar being studied. Some grasses such as fescue (*Festuca*) species (Frett and Pill, 1995), Kentucky bluegrass (*Poa pratensis*) (Phaneendranath and Funk, 1978), carpetgrass and centipedegrass (Bush, et al., 2000) and bahiagrass (Gates and Mullahey, 1997) have responded positively to various priming techniques, including those tested in this study. In addition, previous studies with other cultivars of bermudagrass have also yielded positive results (Young et al. 1977; Brede and Brede, 1986). A replicate study was also conducted as part of this project using a hulled, untreated bermudagrass seed with the same techniques and osmotic solutions. The second study yielded even more unfavorable results than that of the first due to poor overall germination of the seed (data not shown).

Considering the success of some previous researchers, further research in the area of osmopriming bermudagrass seed should be examined even though the current techniques were ineffective. Future studies might consider solutions that not only contain an osmotic agent, but also a plant hormone such as gibberrelic acid, as this approach has been successful in other studies on grasses.

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Table 1. Effects of various osmotic priming solutions and osmotic potentials on the establishment of 'Jackpot' seeded bermudagrass.

Solution	DAP[z] 10	DAP 16	DAP 21	DAP 27	DAP 36	AVG.
	% cover					
Control	2.25	11.20	17.43	25.13	33.19	17.34
PEG 10000	2.29	10.90	16.58	23.26	32.54	17.11
KNO_3	1.95	9.06	14.34	19.31	26.28	14.19
LSD (0.05)	ns[y]	2.05	2.92	3.84	5.53	2.72
Osmotic potential (-MPa)						
	% cover					
Control	2.25	11.20	17.43	25.13	33.19	17.34
0.20	2.43	10.17	16.78	22.99	30.90	16.65
0.25	2.06	10.03	15.70	21.20	28.98	16.48
0.30	1.92	9.49	14.71	19.75	28.71	15.86
0.35	2.06	10.97	16.11	22.76	30.50	15.94
0.40	2.25	10.09	15.28	21.49	30.20	14.92
0.50	2.04	9.14	14.18	19.53	27.17	14.41
LSD (0.05)	ns	ns	ns	ns	ns	ns

[z] DAP = days after planting

[y] ns = not significant at the 0.05 level of probability, according to analysis of variance

Growth Response of Five Perennial Ornamental Grasses to Three Light Intensities

Cynthia R. Stewart[1]*, and James T. Cole*[1]

Additional index words. sideoats, switchgrass, feathermoor grass, Chinese fountain grass

Summary. There is an increasing demand for ornamentals that can perform well in shady areas of the landscape. Additionally there has been increased interest in growing grass species for ornamental purposes. Five species of perennial, ornamental grasses were studied to examine the effect of different levels of shade on plant growth, as measured by a variety of parameters including plant height and number of inflorescences. Several species showed no significant differences due to shade for at least some of the parameters measured. This supports earlier studies that suggest some of the grass species tested are capable of performing well in sub-optimal environments.

Managed landscapes in Arkansas and elsewhere in the United States often include difficult to landscape areas under heavy shade. Light intensity may decrease as much as 90% to 95% with extensive cloud or tree cover (Barrios et al., 1986). Ornamental grasses that can survive and retain their visual qualities in densely shaded environments would be a useful landscape alternative to other herbaceous perennials. It has been demonstrated that some grass species can perform well outside their optimum environment (Cole and Cole, 2000).

Determining the shade tolerance of ornamental grasses will allow their incorporation into hard-to-fill landscape niches. Plants typically respond to dense shade in several ways. Commonly, leaf-area ratio, leaf-to-stem mass ratio, and stem length increase (Boardman, 1977). Specific leaf weight, plant dry weight, leaf-bald thickness, and root growth relative to shoot growth frequently decrease (Boardman, 1977). Reduced light intensities can produce enlarged stems as a result of the partitioning of photosynthates by the plant. However, in dense shade, reduced photosynthate production limits all plant development. In a turfgrass study with bermudagrass (*Cynodon dactylon*), phenotypically diverse clones responded to reduced light intensity with shorter leaves, shorter internodes, and reduced dry weights (Gaussoin et al., 1988). In this experiment five perennial ornamental grasses and their growth responses under three light intensities were studied.

Material and methods

Growth of sideoats grama (*Bouteloua curtipendula*), red rays switch grass (*Panicum virgatum* 'Rotstrahlbusch'), Karl Foerster feather reed grass (*Calamagrostis acutiflora* 'Karl Foerster') Strahlenquelle moor grass (*Molinia caerulea* 'Strahlenquelle') and Chinese fountain grass (*Pennisetum orientale*) were evaluated in field experiments under 0%, 30%, and 60% shade conducted over multiple growing seasons in Fayetteville, Ark. Plants were transferred from one-gallon containers to the field planting in spring 2001. The shade levels were created by using woven shade cloth on rebar and t-post frames. The plants were irrigated to keep moisture levels equal in all light treatments, which were monitored throughout the growing season. Recorded measurements include plant height, leaf area, number of inflorescences, and shoot dry weight. The field design was a split plot in which the whole plot was shade level arranged in a completely randomized design. Species served as the split plot factor. For all variables measured in more than one year, year was treated as a split-split plot factor. Means were separated using a protected least significant difference (LSD) procedure. Results were considered statistically significant at the $P<0.05$ level. All analyses were carried out using SAS Version 8.2 (SAS Institute Inc., Cary, NC).

Results and discussion

Plant height significantly increased from the first year (2001) to the second (2002) for feather reed grass, moor grass and switch grass independent of shade (Table 1). Height increased significantly between the two years across all levels of shade, independent of species. The level of shade did affect plant height in 2001 but not in 2002 (Table 2). Shoot dry weight significantly decreased in 30% and 60% shade, as compared to non-shaded grasses in both years. In 2002, a decrease in shoot dry weight was also observed between the 30% and 60% shade (Table 3). Shoot dry weight increased significantly between years for feather reed grass feather reed grass, sideoats grama, and switch grass (Table 4). Additionally, dry weights decreased significantly between 0% and 30% shade, as well as between 0% and 60% shade for Chinese fountain grass, sideoats grama, and switch grass, regardless of year. No differences were seen between 30% and 60% shade (Table 5).

There was a significant increase in leaf surface area between 2001 and 2002 in feather reed grass, sideoats grama, and switch grass (Table

The authors thank Jimmy Moore, Brian Hamilton, and Jason Collins for assisting in building and setting up the shade structures and Greenleaf Nursery for the donation of plant materials. Thanks also to Dr. Edward Gbur for help with statistical analysis.

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6). A decrease in leaf area was seen between 0% and 30%, and 0% and 60% percent shade in Chinese fountain grass, sideoats grama, and switch grass. No difference was observed between 30% and 60% percent shade (Table 7). Number of inflorescences per plant was the only factor to have a three-way interaction between shade level, species, and year (Figure 1). Overall, inflorescence number decreased as shade level increased.

Conclusions

In general, across shade levels, the differences in height in the second year were much smaller than those measured in the first year. In terms of shoot dry weight, however, there was no difference observed between years. The year and species, for the most part, seemed to have more of an effect on many factors than did level of shade. It seems plausible that some of the differences seen in measured parameters between years are due to differences in plant maturity or weather. We will be better able to establish next year how important these factors are. Some of the grass species tested may perform well in low light environments.

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Table 1. Mean plant height (cm)

Species	Year	
	2001	2002
Pennisetum orientale	86.8	82.6
Calamagrostis acutiflora	67.6	145.2
Molinia caerulea	72.3	109.1
Bouteloua curtipendula	99.8	95.0
Panicum virgatum	96.7	148.3

LSD to compare years within same species = 9.6
LSD to compare different species = 10.2

Table 2. Mean plant height (cm)

Shade Level	Year	
	2001	2002
0%	75.3	117.3
30%	86.4	117.2
60%	92.4	117.7

LSD to compare years within same shade level = 7.5
LSD to compare different shade levels = 9.6

Table 3. Mean Shoot Dry Weight (g)

Shade Level	Year	
	2001	2002
0%	217.6	475.2
30%	151.4	369.1
60%	120.6	269.0

LSD to compare years within same shade level = 53.66
LSD to compare different shade levels = 64.61

Table 4. Mean Shoot Dry Weight (g)

Species	Year	
	2001	2002
Pennisetum orientale	244.8	185.1
Calamagrostis acutiflora	113.0	408.4
Molinia caerulea	8.5	26.2
Bouteloua curtipendula	149.3	285.2
Panicum virgatum	285.9	842.1

LSD to compare years within same species = 69.28
LSD to compare different species = 74.37

Table 5. Mean Shoot Dry Weight (g)

Species	Shade Level (%)		
	0	30	60
Pennisetum orientale	331.9	180.0	132.3
Calamagrostis acutiflora	309.5	265.8	231.4
Molinia caerulea	15.7	6.7	23.9
Bouteloua curtipendula	319.6	186.7	149.8
Panicum virgatum	772.5	547.8	421.7

LSD to compare species within same shade level = 96.93
LSD to compare shade levels within a single species = 101.19

Table 6. Mean Leaf Area (cm^2)

Species	Year	
	2001	2002
Pennisetum orientale	8816.7	6744.4
Calamagrostis acutiflora	4221.4	14995.0
Molinia caerulea	181.8	942.7
Bouteloua curtipendula	5703.7	11632.2
Panicum virgatum	9291.8	13857.3

LSD to compare years within same species = 2511.0
LSD to compare different species = 2486.0

Table 7. Mean Leaf Area (cm^2)

Species	Shade Level (%)		
	0	30	60
Pennisetum orientale	11700.6	6743.1	4897.7
Calamagrostis acutiflora	8472.0	9937.2	10415.3
Molinia caerulea	464.0	349.6	665.0
Bouteloua curtipendula	10903.7	7647.5	6855.5
Panicum virgatum	15690.5	10669.4	8363.9

LSD to compare species within same shade level = 3013.8
LSD to compare shade levels within a single species = 3215.2

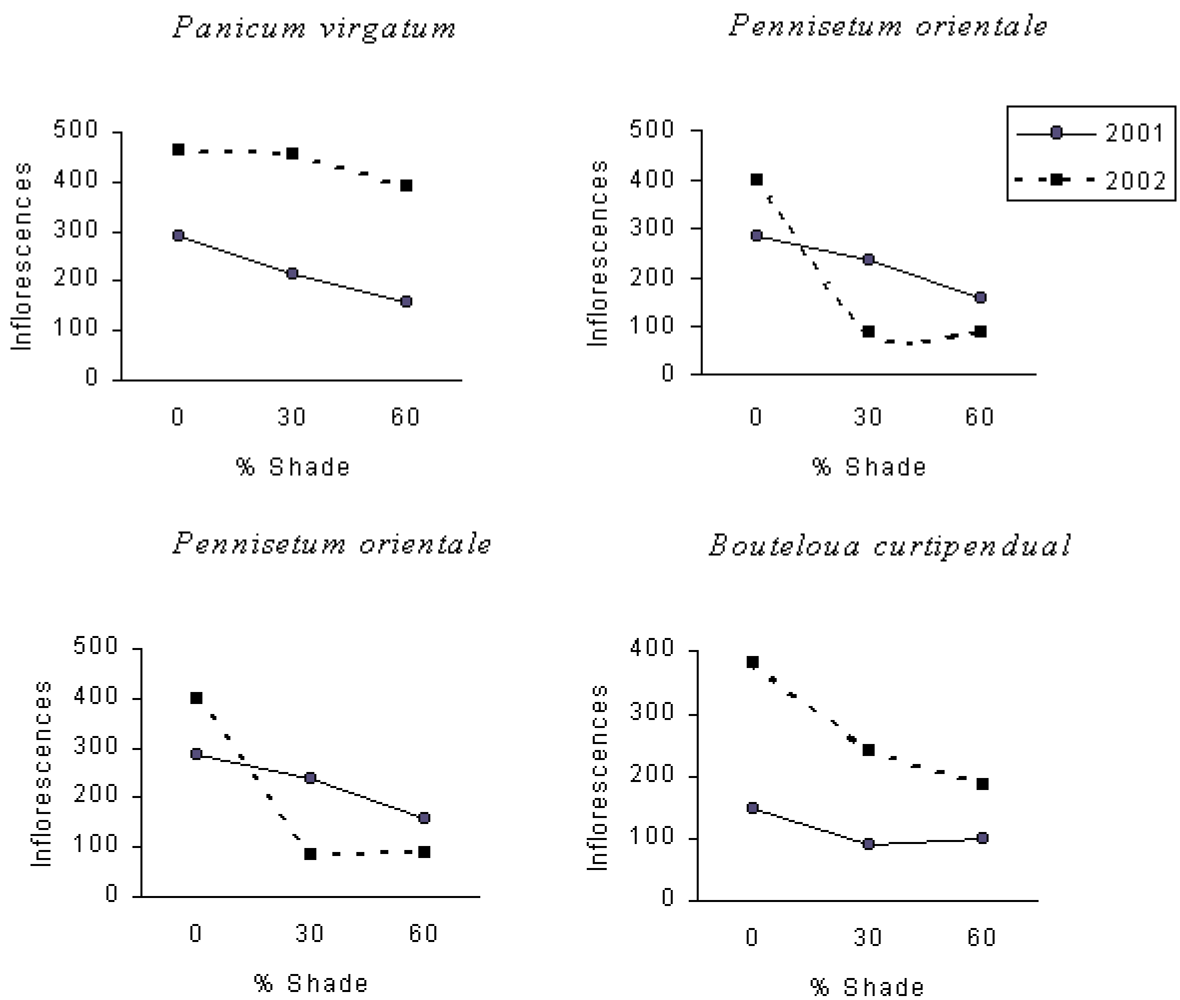

Fig. 1. Number of inflorescences per plant
LSD to compare years within same shade level and species = 94.3
LSD to compare years within same shade level but different species = 99.7
LSD to compare between different shade levels = 101.0

Using Composts to Re-establish Bermudagrass on Compacted Bermudagrass Turf

Chris Weight[1], Doug Karcher[1], Michael Richardson[1], and John McCalla Jr.[1]

Additional index words: *Cynodon dactylon, fertilizer*

Summary. Re-establishment of golf course turf is often necessary due to the stress of wear and compaction from intense traffic. The objective of the following study was to determine the effects of amending compacted golf course soils with various sand-compost-fertilizer combinations on the recovery of damaged turf areas. Three compost sources were compared to sand as amending agents on core-cultivated plots at two different golf courses where re-establishment of bermudagrass (*Cynodon dactylon*) was desired. Humalfa, poultry compost, and lawn compost all marginally increased turf recovery when compared to sand alone.

Soil compaction is a common problem on golf courses as a result of excessive wear, primarily from foot and golf cart traffic (Vavrek 2002). This often results in areas of thin turf and in extreme cases, exposed soil, which can be difficult to re-establish with turf. A typical management program for turf re-establishment might include practices such as core-cultivation, topdressing, reseeding, sprigging, or sodding. Some golf course superintendents have also experimented with using various forms of compost as topdressing material to aid in the re-establishment of damaged turf .

Studies on the use of compost as a soil amendment have shown that the increase in organic matter content from the addition of organic composts has several positive attributes. These include increased water holding capacity and higher nutrient retention, which might aid in the turf re-establishment process (McCarty 2001).

The objective of this study was to determine the impact of composts on turf recovery when applied with or without synthetic or organic fertilizer and either in combination with sand or alone when amending compacted soil.

Materials and methods

A study was initiated on 20 May 2002 on two Fayetteville, Ark. golf courses: Fayetteville Country Club and Stonebridge Meadows Golf Club. Experimental areas at each golf course were selected based on compacted soil conditions and had minimal turf coverage. The experimental area at Fayetteville Country Club was in play at the edge of a fairway. It was core-cultivated with 0.5 in. (1.3 cm) diameter hollow tines spaced 3 x 3 in. (7.5 x 7.5 cm) to a 4 in. (10 cm) depth. The experimental area at Stonebridge Meadows was out of play and was core cultivated with 0.5 in. (1.3 cm) diameter tines spaced 6 x 6 in. (15 x 15 cm) to a depth of 4 in. (10 cm). At both experimental areas, 27 plots measuring 2 x 2 ft (0.6 x 0.6 m) were created. In the center of each plot, a 2 in. (5 cm) diameter bermudagrass (*Cynodon dactylon*) plug was planted.

Nine soil amendment treatments consisting of lawn compost, poultry compost, Humalfa, sand, lawn compost + 1 lb N / 1000 ft^2 (48 kg N / ha) of synthetic fertilizer (Anderson's 18-6-15), lawn compost + 1 lb N / 1000 ft^2 (48 kg N / ha) of organic fertilizer (Honey Crest 4-2-2), sand + lawn compost (1:1 by volume), sand + poultry compost (1:1 by volume), and sand + Humalfa (1:1 by volume). Treatments were applied to each plot sufficient to fill the aeration holes and completely cover the plot with 0.25 in. (0.6 cm) of topdressing material. At both golf courses, treatments were arranged in a randomized complete block design with three replications.

Following treatment application, the area at Fayetteville Country Club received 0.25 in. (0.6 cm) irrigation every 2 days and a total of 2.75 lb N / 1000 ft^2 (134 kg N / ha) during the study using a 24-8-16 fertilizer. The area at Stonebridge Meadows received 0.2 in (0.5 cm) irrigation every 3 days and a total of 1.0 lb N / 1000 ft^2 (48 kg N / ha) from a 18-4-12 fertilizer and 1.5 N / 1000 ft^2 (73 kg N / ha) from a 34-0-0 fertilizer throughout the study.

Digital pictures were taken once a week for 10 weeks beginning at plot establishment on 20 May 2002. The pictures allowed for a consistent, quantifiable measurement on the progression of turf coverage in the plots from the initial 2 in. (5 cm) plug. Data were analyzed separately for each golf course using ANOVA techniques. When treatment effects were significant ($P < 0.05$), means were separated using Fisher's Least Significant Difference procedure.

Results and discussion

Re-establishment of bermudagrass in the plots at Fayetteville Country Club was minimal (Fig. 1). Plots in the primary rough replica-

The authors thank Brandon Nichols (Fayetteville Country Club) and John Streachek (Stonebridge Meadows Golf Club) for their assistance in providing area for research plots as well as general plot maintenance throughout the course of this study.

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tion (open sun) recovered the most after 10 weeks (approximately 20% turf coverage), but recovery at this golf course was limited due to continued traffic over the plots throughout the study period. This demonstrated the negative impact of traffic on turfgrass recovery and re-establishment.

Plots at Stonebridge Meadows were out of play and no traffic occurred on the plots throughout this study. This lack of traffic greatly increased the percent turf coverage on these plots. By the end of the study, the overall treatment average was 86% with treatment averages ranging from 73% turf coverage for the sand + lawn compost mix to 92% coverage for both the Humalfa and the poultry compost treatments.

Differences in turf coverage among the composts (when applied alone) were noted (Fig. 2). The poultry compost plot means were significantly higher than Humalfa on 8 July and 15 July. The poultry compost plot means were significantly higher than the lawn compost from 23 June through the end of the study on 22 July. Although these differences in means were statistically significant, the actual percentage difference in turf coverage between these treatments (9-16%) would be considered negligible by most superintendents.

When compost was blended with sand (1:1 by volume) the percent turf cover was lower when compared to compost alone (Fig. 3). This difference in turf coverage became significant on 1 July.

Turf coverage was highest when the lawn compost was used in conjunction with the organic fertilizer (Fig. 4), but was only significantly higher on 8 July. This indicates that mixing fertilizer into a topdressing mix may be only slightly beneficial.

Conclusions

Limiting traffic in areas being re-established is not always practical on a golf course. When it can be done, quicker recovery and more complete coverage can be expected, as demonstrated by the differences in turf recovery among the replications at Fayetteville Country Club. When limiting traffic is difficult, possible solutions might be either closer spacing of plugs or sodding damaged areas.

In this study, plots topdressed with sand had the lowest recovery compared to topdressing with any of the composts. Plots topdressed with either Humalfa or poultry compost had the highest turf coverage by the end of this study. Although this difference was statistically significant in some instances, the actual increase in percent recovery from using composts was minimal. The additional cost of the compost might not be justified based on a small gain in recovery of the turf. Addition of fertilizer to the topdressing mix appeared to have only a minimal impact on turf recovery.

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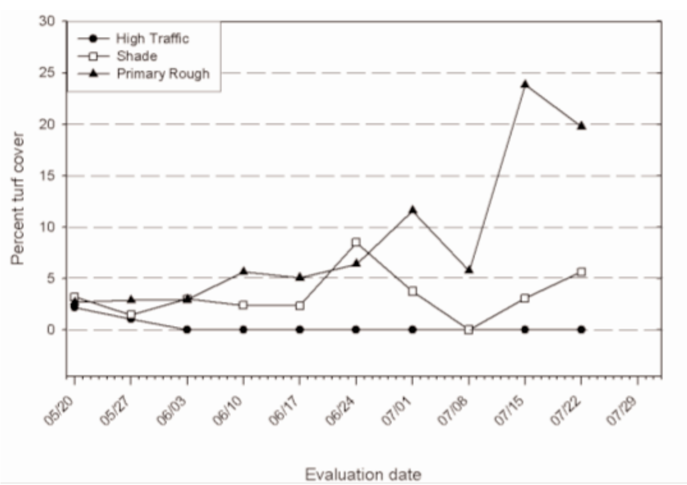

Fig. 1. Turf recovery of three treatment replications at Fayetteville Country Club.

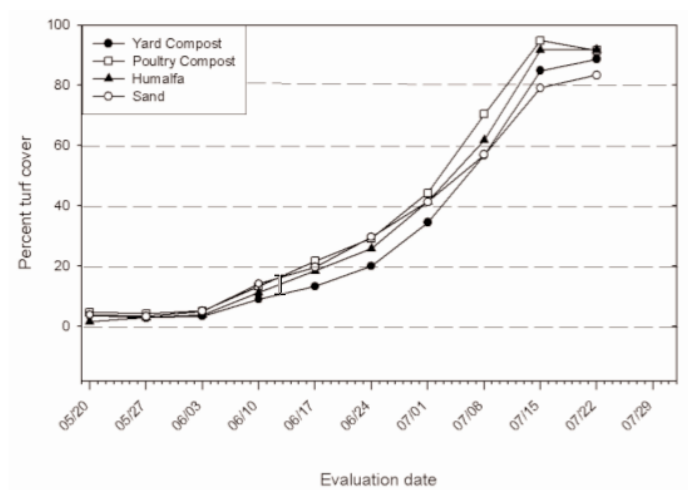

Fig. 2. Compost source effects on turf recovery at Stonebridge Meadows Golf Club. Fisher's least significant difference value (*P* = 0.05) equals 9.7.

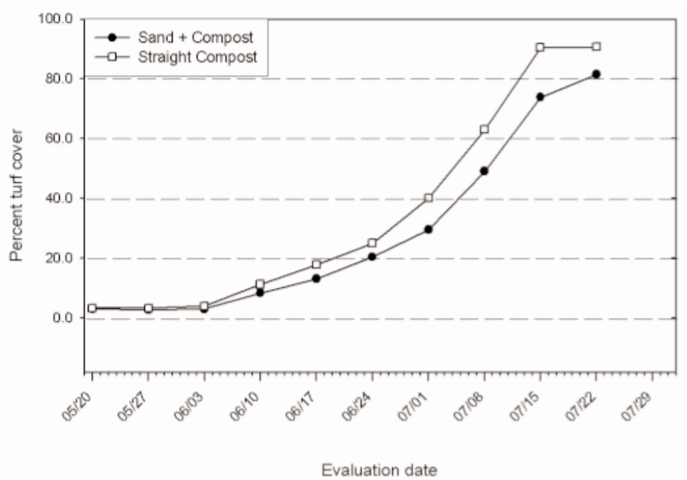

Fig. 3. Effects of blending sand with compost on turf recovery at Stonebridge Meadows Golf Club. Fisher's least significant difference value (*P* = 0.05) equals 9.1.

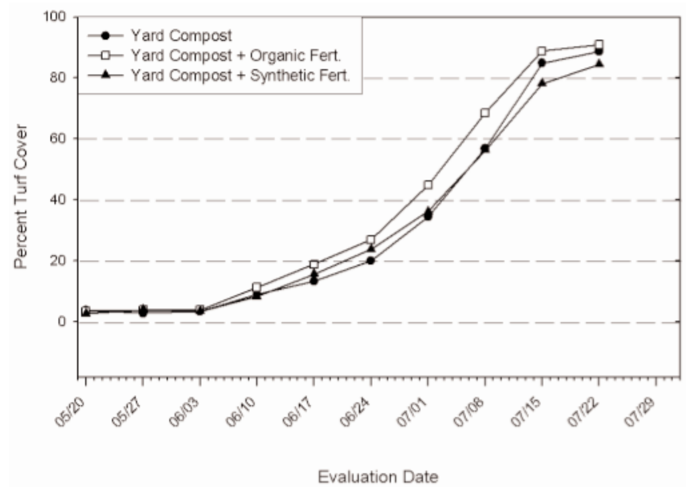

Fig. 4. Effects of blending fertilizer with compost on turf recovery at Stonebridge Meadows Golf Club. Fisher's least significant difference value (*P* = 0.05) equals 9.7.

VEGETABLES

Effect of Harvest Interval on Yield of Okra

P.E. Cooper[1]

Additional index words: vegetables, quality

Summary. Different harvest intervals of 'Jefferson' okra were evaluated as to their effect on yield and quality. It was found that okra yields can be greatly manipulated by various harvesting procedures.

Okra is a very popular vegetable sold at farmer's markets and roadside stands in Arkansas. As with all vegetables, quality is important to the consumer. Quality of okra refers primarily to age of the pod or pod length. The immature pod is the edible part of the okra plant. Sistrunk et al. (1960) found that fiber content of okra pods increases the longer the pods remain on the plant, which eventually renders them unsuitable for human consumption. Likewise, Iremiren et al. (1991) found that pods harvested more than seven days after pod set were of poorer quality. The reduction in pod quality was due mainly to an increase in crude fiber and a decrease in moisture. In a more recent study, Cooper (2002) concluded that 'Clemson Spineless' okra pods reached their optimum size for harvest about 5 days after full bloom. It was also concluded that a harvesting scenario of at least every other day produced the highest yields of okra, while maintaining quality. Treatments harvested every other day once the pods had reached 2 inches (5 cm) in length yielded 23.8% more than treatments harvested on a daily basis. Harvesting pods on a daily basis, but at a length of 2 1/2 to 3 inches (6.3 to 7.5 cm), resulted in a yield increase of 20.5%.

The purpose of this study was to continue the work begun in 2001, and to fine tune the various harvesting scenarios that might be used.

Materials and methods

This study was conducted in Bradley County on a silt loam soil. The cultivar 'Jefferson' was grown on raised beds covered with black plastic mulch and utilizing drip irrigation. Beds were 2 ft. (.6 m) wide and 6 ft. (1.8 m) center to center. Double rows of okra were planted 12 inches (30 cm) apart on the beds. Within each row, plants were spaced 12 inches (30 cm) apart. Plot length was 25 ft. (7.5 m).

In Part 1 of the study, okra pod length was examined. Individual flowers were tagged and dated on the day of flowering. Beginning the following day, pod measurements were made on a daily basis to chart the growth of individual pods. Measurements were taken for 6 days.

In Part 2 of the study, four harvest scenarios were used to collect data on yield and quality of the pods. The 4 treatments were: 1) daily harvest of every pod more than 2 inches (5 cm) long, 2) harvest every other day all pods more than 2 inches (5 cm) long, 3) harvest every third day all pods more than 2 inches (5 cm) long, and 4) daily harvest of all pods more than 3 inches (7.5 cm) long. Pods were measured to the nearest 1/8 inch (0.3 cm) and weighed to the nearest 1/10 gram (0.00402).

The harvest period of this study lasted from 30 July through 4 August 2002.

Results and discussion

Okra pods grew rapidly in this study as indicated by the results in Table 1. One day after flowering, the pods were slightly more than 0.5 inch (1.3 cm) long. On day 2, the pods averaged almost a full inch (2.5 cm) in length. By day 4, they averaged more than 2 inches (5.0 cm); they were now at the marketable stage. In two more days (day 6), the pods were almost 4 inches (10 cm) long. They had then reached the maximum length that is recommended by most experts. These pod growth data seem to concur with most recommendations that okra pods should be harvested 4-6 days after flowering. It also agrees with the results Cooper (2002).

Harvest interval had a significant effect on yield of okra (Table 2). Harvesting on a daily basis of pods that had reached at least 2 inches (5 cm) in length produced pods that had an average weight of 7.24 g (0.26 oz) (Table 2). Harvesting every other day of pods that had reached at least 2 inches (5.0 cm) in length (Treatment B) produced pods that had an average weight of 9.69 g (0.34 oz). This was an increase of 33.8%. Treatment C, the harvesting of 2-inch and longer pods every third day, produced pods that had an average weight of 10.67 g (0.38 oz). This was an increase of 47.4%, compared to the daily harvest. The treatment that produced the greatest yield was Treatment D, the daily harvest of all pods that had reached a length of 3 inches. Pods from this treatment

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averaged 11.68 g (0.41 oz) in weight, which was an increase of 61.3%.

Again, as in the 2001 study, total yields were not collected. It was assumed that all treatments produced the same number of pods. Therefore, the focus was on manipulating individual pod size by various harvest intervals. The data could then be easily converted to yield increases or decreases.

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Table 1. Length of 'Jefferson' okra pod 1-6 days after flowering, 2002.

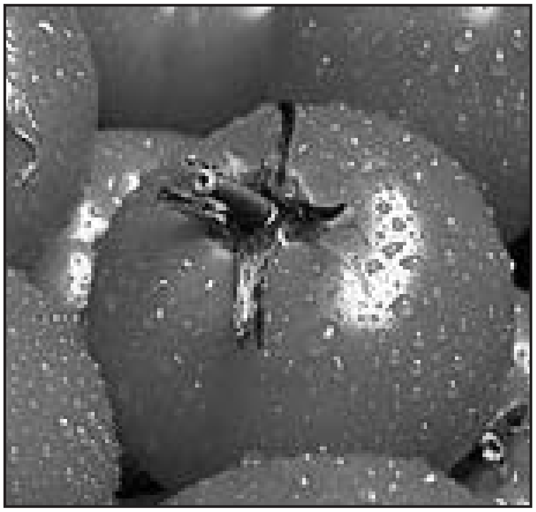
Days after flowering	Pod length (in.)
1	0.57 a
2	0.99 b
3	1.48 c
4	2.12 d
5	3.07 e
6	3.93 f

Means within a column followed by a different letter are significantly different as determined by Duncan's multiple range test (P<0.05)
1 inch = 2.54 cm.

Table 2. Average weight of 'Jefferson' okra pods as affected by harvest interval, 2002.

Harvest Interval	Avg. fresh wt. (g)	% Increase
A	7.24 c	------
B	9.69 b	33.8
C	10.67 ab	47.4
D	11.68 a	61.3

Means within a column followed by a different letter are significantly different as determined by Duncan's multiple range test (P<0.05)
1 g = 0.035 oz.
A = Daily harvest of pods 2" and longer
B = Harvest every other day of pods 2" and longer
C = Harvest every 3rd day of pods 2" and longer
D = Daily harvest of pods 3" and longer



Tomato Cultivar Trial Results, 2002

P.E. Cooper[1], C.R. Stark[1], and P.B. Francis[1]

Additional index words: *Lycopersicum esculentum*

Summary. Eight tomato cultivars and advanced breeding lines were evaluated in 2002. 'Mountain Spring', the industry standard in southeast Arkansas, was compared with 2 cultivars recently introduced to the area, along with 5 cultivars/breeding lines that possessed resistance/tolerance to tomato spotted wilt (TSWV). In the absence of a severe outbreak of TSWV, 'Mountain Spring' continued to perform well, as did the resistant cultivar, 'BHN-444'.

Cultivar selection is very important to the fresh-market tomato industry in southeast Arkansas. To remain competitive, the industry relies on the use of well-adapted cultivars that produce high yields of superior-quality fruit. In 1992, 'Mountain Spring' was released by North Carolina State University and quickly became the industry standard because of its yields of high-quality fruit (Gardner, 1992). In recent years, TSWV has become a severe problem, forcing many growers to search for new cultivars that possess resistance/tolerance to the disease. One such cultivar is 'BHN-444' which has shown good resistance, and has performed fairly well compared to 'Mountain Spring', although it has not graded as well (Cooper and Stark, 2001).

The purpose of this study was to evaluate 4 advanced breeding lines from the North Carolina State University program for yield and horticultural qualities as compared to 'Mountain Spring' and 'BHN-444'. Also, two cultivars recently introduced in the area, 'R-440' and 'R-449', were included in the study. They are extended shelf-life cultivars, but do not possess resistance to TSWV.

Materials and methods

This study was conducted at the Southeast Research & Extension Center (SEREC) at Monticello. Basic cultural practices used by tomato producers in the area were followed. Eight cultivars and breeding lines were compared in the test, including the standard, 'Mountain Spring' and five cultivars/breeding lines reputed to be resistant to TSWV (Table 1). Tomato seeds were planted on 27 February 2002 and plants were transplanted from seedling flats on 14 March, and transplants were set in the field on 12 April.

Black plastic mulch and drip irrigation were used on beds 2 ft wide and 8 in. high. Plants were spaced 22 in. apart in the rows, which were 6 ft from center to center. Insects, diseases, and weeds were controlled using recommended practices, and plants were staked, tied, and pruned in a manner consistent with the area.

Fruits were harvested from 18 June through 8 July and graded into the following categories: 1) extra large #1 (XL#1); 2) large #1 (L#1); 3) #2, and 4) #3/unclassified. Marketable fruit was composed of the first three grades. The experimental design was a randomized complete block containing four replications, and plots consisted of six plants.

Results and discussion

Total marketable yields ranged from 9.72 lb/plant to 5.10 lb/plant. 'BHN-444' produced the most marketable fruit followed by 'Mountain Spring' and 'R-440'. 'Mountain Spring' yielded the most XL#1 fruit (5.39 lb/plant) followed by 'R-440' (4.13 lb/plant). Average fruit weight ranged from 9.32 oz ('R-449') to 7.49 oz ('BHN-444') (Table 1).

Overall, yields in this study were less than in previous years. The standard 'Mountain Spring' continued to perform very well in comparison to the other cultivars/lines. It graded a higher percentage of #1 fruit than the others (81% of the marketable fruit).

Three of the breeding lines from North Carolina State University did exhibit resistance to TSWV (it was found in this study and others that NC-0253 is not resistant to TSWV). If TSWV continues to be a problem, resistance from these lines could prove to be very beneficial in the years ahead. Additional studies involving these and other lines are planned for 2003.

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Table 1. Yield and quality of tomato cultivars, 2002.

Cultivar	Total Mkt. (lb/plant)	XL#1 (lb/plant)	Avg. Wt. (oz)
BHN-444	9.72 a	2.38 bc	7.49 c
Mountain Spring	8.98 a	5.39 a	7.92 bc
R-440	8.05 ab	4.13 a	8.05 bc
NC 023 *	6.83 bc	1.64 bc	8.62 ab
NC 0253	6.11 bc	2.18 bc	8.24 bc
NC 0256 *	6.07 bc	1.20 c	7.92 bc
R-449	5.54 c	1.91 bc	9.32 a
NC 0230 *	5.10 c	2.74 b	7.96 bc

Means within a column followed by a different letter are significantly different as determined by Duncan=s multiple range test (P<0.05).

* Cultivars resistant/tolerant to TSWV.

Lutein and beta-Carotene levels in Selections of Spinach and Edible Greens

Margaret E. Secks[1], J. Brad Murphy[1], and Teddy E. Morelock[1]

Summary. Plant pigments serve several functions within plants, including harvesting light energy for photosynthesis, protecting chlorophyll from photooxidation, free radical and singlet oxygen scavenging, as well as attracting pollinators and herbivores. In addition, plant pigments retain their antioxidant characteristics when ingested by humans. The carotenoids, pigments found in both chloroplasts and chromoplasts, have antioxidant activity, and some have provitamin A activity. Edible leafy greens, such as spinach and kale, contain high levels of carotenoids, however, American consumption of these greens is not sufficient to meet dietary needs. Increasing carotenoid level, specifically lutein, in leafy green crops will improve quality without necessarily increasing the quantity of greens consumed. In these studies, lutein, β-carotene, and chlorophyll *a* levels where analyzed to provide information on carotenoid levels which will be used in the breeding program to improve lutein levels in spinach and other leafy greens. Considerable variability in lutein and β-carotene content, both plant-to-plant and among cultigens, was found to exist. In particular, three Italian kale varieties stood out with exceptionally high lutein levels.

Plant pigments are responsible for the variety of colors seen in fruits, vegetables, flowers, and foliage. Some plant pigments function to harvest light energy for photosynthesis and/or to protect chlorophyll from photooxidation, while others serve in other plant functions including free radical and singlet oxygen scavenging. Discovery of antioxidant characteristics of plant pigments and of their antioxidant behaviors in the human body when consumed has become an important part of the study of functional foods or nutraceuticals, foods that provide medical or health benefits (Biesalski, 2001).

Chlorophylls *a* and *b* are pigments that we perceive as green and are the most prevalent and important molecule involved in capturing of light energy for photosynthesis. Accessory pigments, the carotenoids, also capture light for photosynthesis as well as protect chlorophyll from photooxidation and serve in other non-photosynthetic functions. Carotenoids are visually perceived as the orange, red, and yellow colors and include carotenes, such as α- and β-carotene and lycopene, and xanthophylls, such as lutein, violaxanthin, neoxanthin, and zeaxanthin. Light-harvesting pigments (chlorophylls and carotenoids) are organized in pigment-protein complexes within chloroplasts and act as antenna to capture light energy for photosynthesis. This organization and containment within chloroplasts enables the hydrophobic carotenoid molecules to exist in an aqueous environment.

There are many plant pigments, independent of photosynthesis activities, which not only serve as visual attractants for pollinators and herbivores but also have anti-oxidative properties. They include carotenoids, betalains, such as red-violet betacyanin, and flavinoids, such as blue and red anthocyanins. Because these molecules are hydrophobic and lipophilic, they are contained within plastids called chromoplasts.

Some carotenoids are vitamin A precursors that are enzymatically converted to vitamin A in the intestines (Thompson et al., 1949), while others are powerful antioxidants. Carotenoids have recently become well known for their association with prevention of many diseases, such as age-related macular degeneration, cataract formation, cardiovascular disease, and cancer development and/or have immuno-enhancement capabilities (Takyi, 2001).

Consumption of provitamin A carotenoids, rather than vitamin A directly from animal tissue, prevents toxicity from hypervitaminosis. This is because the body regulates enzymatic reactions that convert precursors to vitamin A. In order for carotenoids to be assimilated and bioavailable, they must be released from pigment matrixes in chloroplasts and chromoplasts either mechanically or by cooking and in the presence of fat, since carotenoids are lipophilic.

β-Carotene (β,β,-carotene) is non-hydroxylated, and it is the most important carotenoid with provitamin A characteristics (Bauernfeind, 1972). Vitamin A, an essential vitamin, is important for maintaining healthy eyes and skin and an efficient immune system. (Ganguly, 1989; Olson, 1992). Much research has been conducted on β–carotene and its role in promoting health; however, there is growing interest in other carotenoids (Russell, 2001). Lutein is the most prevalent xanthophyll pigment found in yellow vegetables and dark, leafy greens, and it is also found in highest amounts in human blood serum levels. Lutein is a dihydroxlated carotenoid (β,ε,-carotene-3,3'-diol) and is involved in prevention of age-related macular degeneration (Seddon et al., 1994). Lutein, along with zeaxanthin, another xanthopyll, accumulates in the macula, the central portion of the retina responsible for detailed central vision. These xanthophylls act to prevent photooxidation in the retina (Bone et al., 1992) as well as act to prevent mutagenic and carcinogenic activity throughout the body (Landrum et al., 2002). Carotenoids' antioxidant characteristics are associated with their ability to quench free radicals and singlet oxygen molecules, both of which cause random damage within cells. The more numerous the conjugated double bonds of a carotenoid molecule, the greater its antioxidant behavior (Foote et al., 1970).

Consumption of carotenoid-rich foods has many health benefits, however, substantial quantities of these foods are not consumed in the Standard American Diet. By increasing carotenoid levels in dark leafy

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greens, through traditional breeding efforts, the diet can be improved without increasing consumption. Only recently, has there been interest in improving nutritional value of crops through breeding. This may have been due to growers' interest in other concerns such as higher yield and disease resistance (Munger, 1987).

With greater commercial interest in higher-nutrition foods, research and breeding efforts are now focusing on quantifying and improving nutritional quality of horticultural crops (Still, 2002). Spinach (*Spinacia oleracea*) and kale (*Brassica oleracea*) are leafy greens ranked highest in nutritional value (Stevens, 1974; USDA National Nutrient Database for Standard Reference, Release 15, Aug, 2002). Among cultivars of horticultural crops, there are considerable differences in vitamin and mineral contents (Stevens, 1974), and carotenoid profiles have been shown to vary with season and location (Russell, 2001). Analysis of carotenoids levels in breeding lines of spinach and other various edible leafy greens is being conducted at the University of Arkansas. The goal of improving nutritive, antioxidant value of these crops, specifically, lutein levels, is currently being investigated.

Materials and methods

Samples of commercial cultivars and breeding selections of spinach and edible greens were harvested during the winter of 2001 from fall-planted breeding nurseries for analysis of carotenoids, in particular, lutein and β-carotene. Composite samples of spinach consisting of five, fully expanded leaves from five different plants were collected from 32 spinach selections at the University of Arkansas Vegetable Substation, Kibler, Ark., and three subsamples of each selection were analyzed for carotenoid levels. Composite samples of assorted greens, consisting of five, fully expanded leaves from five different plants were also collected from selections of greens at the University of Arkansas Vegetable Substation, Kibler, Ark. There were ten cultigens of collard greens, ten of kale, six of mustard greens, and six of turnip greens. Three subsamples of each selection were analyzed for carotenoid content.

Upon harvest, samples were immediately sealed in plastic bags, and placed on ice for transportation to the University of Arkansas, Fayetteville, Ark., for carotenoid analysis. Samples were stored in a -20 ºC freezer until freeze-dried and ground to a powder in a Waring blender. Carotenoids were extracted from 10 mg of dry sample with 2.5 mL acetone:ethyl acetate (3:2 with 0.25 BHT). Two mL of water was added to the sample, vortex mixed, and centrifuged at 6,000 g for 5 mins. The ethyl acetate layer was collected, and the mixture was rinsed and centrifuged twice with additional ethyl acetate (totaling three mL). The collected ethyl acetate phase was dried under a gentle stream of nitrogen gas and brought to a final volume of two mL. A one mL aliquot was filtered through a 0.45 µm nylon filter (Phenomenex) before injection into the HPLC.

A 10 uL sample was separated with a Waters 2690 HPLC using a Spherisorb ODS1 column (Waters, Inc.). A mobile phase gradient was run from (A) 100% methanol:0.2 mM ammonium acetate pH 4.4 (90:10) to (B) 80% methanol:n-propanol:1.0 mM ammonium acetate (78:20:2) in 15 min, then to 100% B in 10 min, and held in B for 5 min before returning to A (ESA Applications 10-1176, 1996). Carotenoids (lutein, Sigma X-6250 and β-carotene, Sigma C-4582) and chlorophyll *a* (Sigma C-5753) were detected using a Waters 996 Photodiode Array Detector at 440 nm and were identified and quantified against standards.

Results and discussion

In the spinach study, there was considerable genetic diversity among cultigens with lutein levels ranging from 0.58 to 0.36 mg/g dry weight (Fig. 1a). Breeding lines, 97-154 and 91-415, had highest lutein content, 0.58 and 0.57 mg/g dry weight, respectively, while DM 07 had lowest lutein content, 0.36 mg/g dry weight. β-carotene levels for spinach selections ranged from 0.53 to 0.34 mg/g dry weight (Fig. 1b). Similar to lutein, 97-154 and 91-415 ranked highest in β-carotene levels, 0.53 and 0.52 mg/g dry weight, respectively, while DM 07 had lowest β-carotene content, 0.34 mg/g dry weight (Fig. 1b). Interestingly, chlorophyll levels for the same selections, 91-415 and 97-154, were highest (8.0 and 7.1 mg/g dry weight, respectively, data not shown), and DM 07 had the second lowest chlorophyll content next to 'Vancouver', 4.6 and 3.9 mg/g dry weight, respectively.

Since spinach is an open pollinated crop, each selection is a population with considerable genetic variability. In these experiments, a composite sample of five leaves from five plants was tested as a representative for the entire selection/population. Further studies might be considered to investigate the extent of genetic variability within a population. Additionally, results may vary with location, growing season, etc.; therefore, further investigation into what conditions control the accumulation of carotenoids in edible leaves and other plant parts may be necessary to make conclusions regarding the carotenoid levels of a particular selection or species.

In the edible greens study at Kibler, lutein levels of kale outranked all other greens with 'Green Curled', 'Tuscan', and 'Toscano' having lutein levels of 0.76, 0.70, and 0.63 mg/g dry weight, respectively (Fig. 2a). These three cultivars are Italian kale types having a very dark bluish-green color. The turnip green 'Topper' (0.55 mg/g dry weight) and the dark green mustard 'Savannah' (0.57 mg/g dry weight) also had high levels of lutein (Fig. 2a), whereas the paler green-colored mustard, 'Southern Giant Curled' (0.35 mg/g dry weight) and 'Vates' collard (0.34 mg/g dry weight) had lower lutein levels. Similar to lutein, β-carotene levels in 'Green Curled', 'Tuscan' and 'Toscano' kale (0.53, 0.46, and 0.42 mg/g dry weight, respectively); 'Topper' turnip (0.44 mg/g dry weight); and 'Savannah' mustard (0.46 mg/g dry weight) were highest among all selections tested. In this study, collards, as a species, appeared to be a poor source of lutein and β-carotene while kale was an excellent source of these carotenoids. However, this may be due to the three very dark green Italian kales included in this study.

There was much variation in pigment ratios among cultigens tested from these nurseries. However, there was an overall strong, positive correlation between lutein versus chlorophyll *a* levels for spinach and for all greens, except collards (Table 1). This trend was not observed for β–carotene versus chlorophyll *a* comparisons. Among lutein versus β–carotene comparisons, there was a strong positive correlation observed for spinach and kale, 0.855 and 0.756, respectively (Table 1), but not for any other greens tested. Since chlorophyll and lutein levels are positively correlated, visual selection for a darker green color may be helpful for choosing breeding lines for higher lutein levels. In addition, this indicates that in addition to selection for populations with higher lutein levels, cultural practices, such as fertilization, might be implemented to increase the chlorophyll *a* and thus lutein levels.

Conclusions

It was determined that considerable genetic variability exists in levels of lutein and β-carotene within several edible greens species, indicating the potential for increasing carotenoid levels through traditional breeding efforts. Additionally, a positive correlation between chlorophyll *a* and lutein indicates that darker green color may be an indicator of higher lutein and possibly other carotenoid levels. Other factors might also be considered for further studies, including influences of environmental conditions and location, growing season (fall versus overwintering crops), variability within populations, and cultural practices on the accumulation of carotenoids in plant tissues.

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Table 1. Leafy green species average ± standard deviation and correlations among carotenoids and chlorophyll.

	mg/g dry wt.			Correlations		
Crop species	Lutein	β-carotene	Chlorophyll *a*	Lutein vs. Chlorophyll *a*	Lutein vs. β-carotene	β-carotene vs. Chlorophyll *a*
Spinach	0.48 ± 0.06	0.44 ± 0.05	5.78 ± 1.45	0.721	0.855	0.584
Kale	0.52 ± 0.13	0.38 ± 0.13	5.95 ± 1.87	0.847	0.756	0.638
Turnip	0.45 ± 0.07	0.42 ± 0.12	5.55 ± 1.13	0.923	0.301	0.226
Mustard	0.42 ± 0.08	0.40 ± 0.10	4.10 ± 1.40	0.624	0.224	-0.137
Collard	0.39 ± 0.04	0.34 ± 0.11	4.63 ± 0.74	0.152	0.401	-0.017

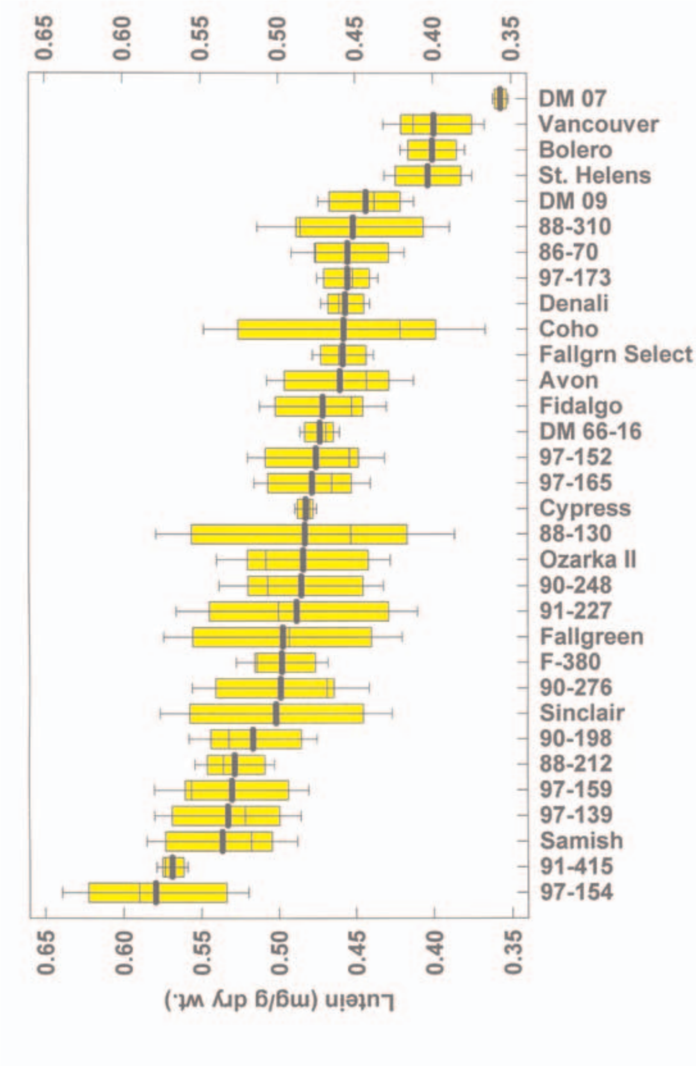

Fig. 1a. Lutein in composite samples (5 leaves from 5 plants) of spinach selections harvested at Kibler, Ark., on Nov. 27, 2001. Tukey box plots indicate the 25th, 75th, and 50th percentiles. The bolded line shows the selection mean, and the capped bars indicate the standard error.

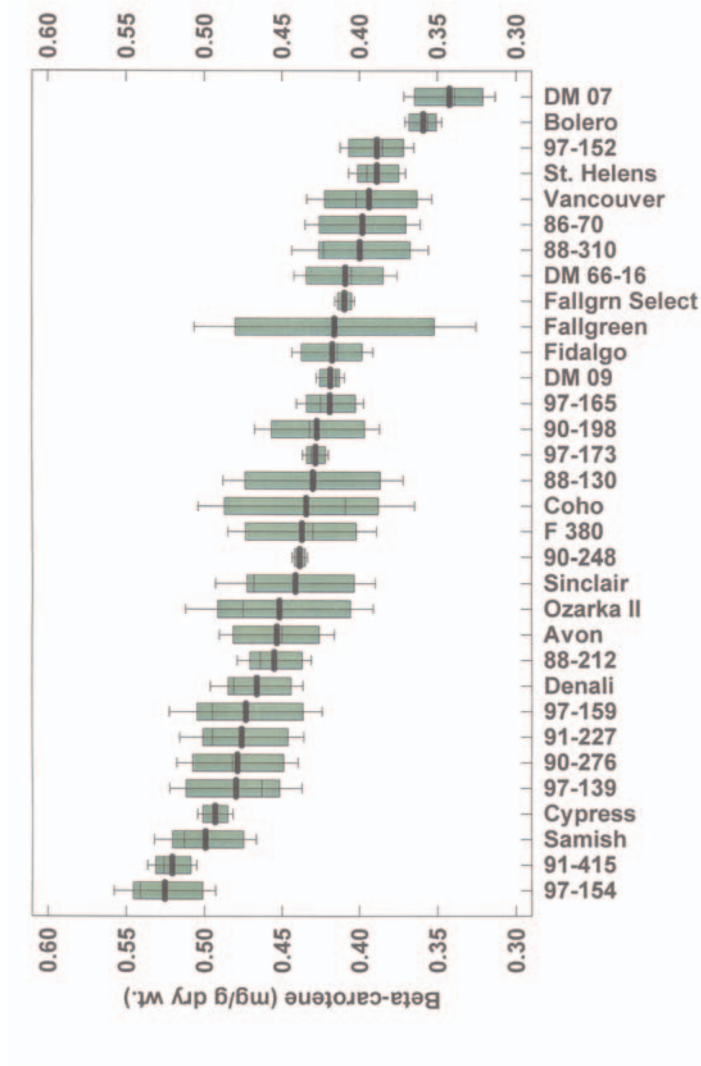

Fig. 1b. Beta-carotene in composite samples (5 leaves from 5 plants) of spinach selections harvested at Kibler, Ark., on Nov. 27, 2001. Tukey box plots indicate the 25th, 75th, and 50th percentiles. The bolded line shows the selection mean, and the capped bars indicate the standard error.

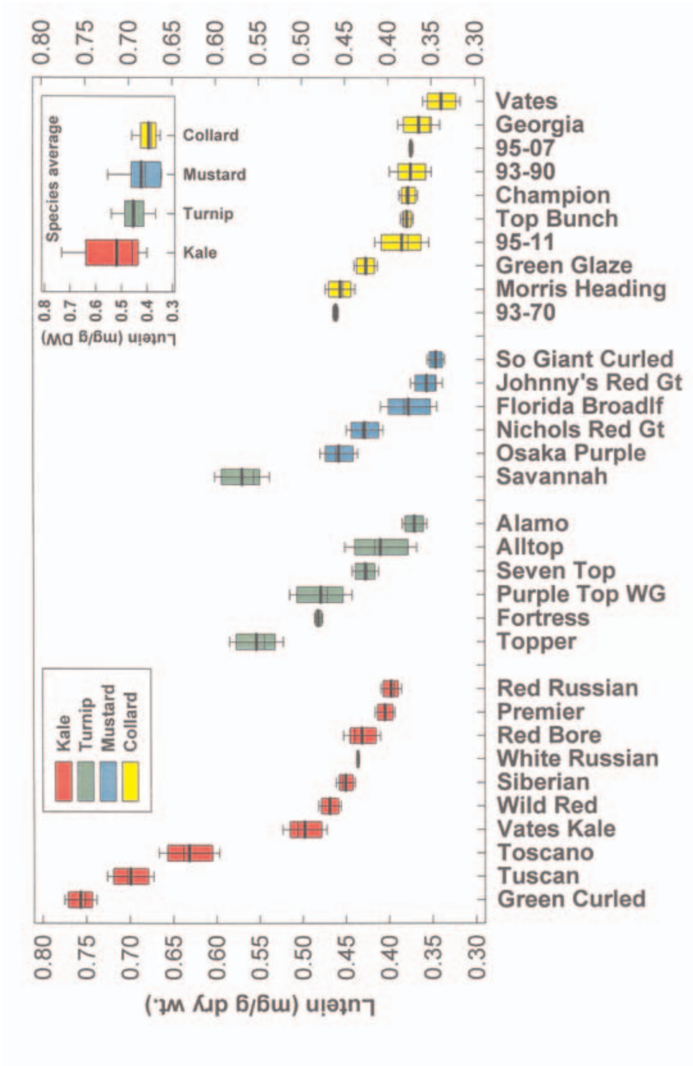

Fig. 2a. Lutein in composite samples (5 leaves from 5 plants) of various edible greens harvested at Kibler, Ark., on Nov. 27, 2001. Tukey box plots indicate the 25th, 75th, and 50th percentiles, with capped bars indicating the standard error. The bolded line is the mean for each selection. The small insert graph shows the average for all selections within a species.

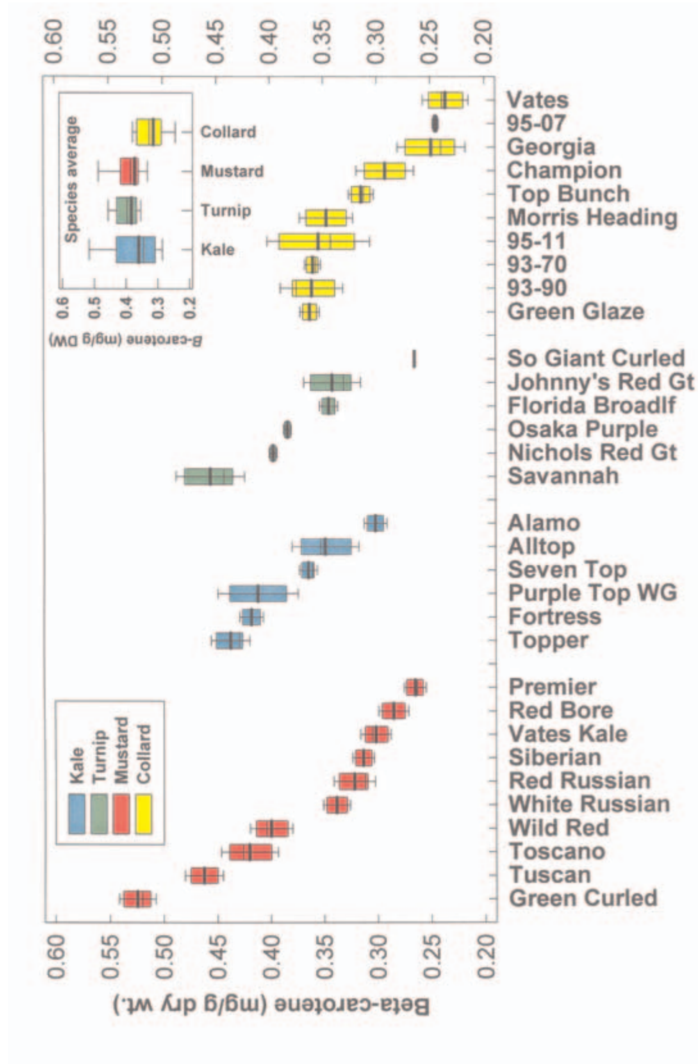

Fig. 2b. Beta-carotene in composite samples (5 leaves from 5 plants) of various edible greens harvested at Kibler, Ark., on Nov. 27, 2001. Tukey box plots indicate the 25th, 75th, and 50th percentiles, with capped bars indicating the standard error. The bolded line is the mean for each selection. The small insert graph shows the average for all selections within a species.

Evaluation of Advanced Cowpea Breeding Lines to Acifluorfen and Bentazon Herbicides

V.K. Shivrain, N.R. Burgos, E.N. Stiers[1], and T.E. Morelock[2]

Additional index words: Herbicide tolerance, *Vigna ungiculata*

Summary. In an effort to develop herbicide-tolerant cowpea cultivars, seven breeding lines and two cowpea (*Vigna ungiculata)* cultivars were evaluated in the field for tolerance to two herbicides. acifluorfen (Blazer®) and bentazon (Basagran®) were applied at the 4 to 5 trifoliate stage of cowpea at 0, 1.1 kg ha^{-1} (1 lb/ac), and 2.2 kg ha^{-1} (2 lb/ac) respectively. The acifluorfen rate was four times the commercial use rate in soybean. Tolerance was evaluated by rating injury at 2 and 4 WAT, moisture level at harvest, and yield reduction due to herbicide application. Lines 92-552, 00-855, and 00-178 were the most promising advanced breeding lines. These lines showed no yield reduction from herbicide treatment and had high yield potential. All lines tolerant to acifluorfen also showed excellent tolerance to bentazon. Use of commercial rates of both herbicides will most likely result in negligible injuries and no yield reduction. Registration of acifluorfen for cowpea will broaden the option for weed control in this crop. Bentazon is already registered for use in cowpea, but some cultivars show high sensitivity to this herbicide.

Cowpea is a widely adapted nutritious legume vegetable and fodder crop (Ehlers and Hall, 1997). Food and Agriculture Organization (FAO) estimates that 3.3 million tons of cowpea dry grains were produced worldwide in 2000. Total area grown to cowpea was 9.8 million hectares, about 9.3 million hectares of this was in West Africa. Cowpea is also grown in Latin America and Southeast Asia (Singh et al., 1997). Cowpea is a protein source for more than half the population of Africa, Brazil, and India (Rachie, 1985). Cowpea is drought tolerant, suitable for semiarid climatic conditions and for less fertile soils. The United States is the only developed country, which grows cowpea. In the U.S, it is grown in Arkansas, California, Louisiana, Texas, Georgia, Mississippi, and Missouri (Kline et al., 2002). Weed control is a major concern in vegetable crop production because of limited herbicide options. This is especially important in the production of cowpea for processing. Due to mechanized harvesting, it is impossible to separate weed seeds or debris from the crop after harvest. Weeds affect the quantity and quality of production, and can serve as alternate hosts for diseases and insect pests. Without herbicides, yield was reduced (Bell, 2000) and hand-weeding expenses increased (Prather, 1996). The Food Quality Protection Act of 1996 required the Environmental Protection Agency (EPA) to review tolerances for all pesticides registered before 3 Aug. 1996, which resulted in the decrease of herbicide options for vegetable growers (Bell et al., 2000). The vegetable market is too small to encourage the industry to develop new herbicides for minor crops, and the potential liability for damage to high value vegetable crops discourages manufacturers from seeking registration of new herbicides. Herbicides, which are already registered for various agronomic crops can be tested for use in vegetable crops.

Problematic weeds in vegetable production in the U.S. include goosegrass (*Elusine indica*), southwestern cupgrass (*Eriochloa gracilis*), pigweeds (*Amaranthus* spp.), and eclipta (*Eclipta prostrata*). Imazethapyr (Pursuit®), bentazon (Basagran®), and sethoxydim (Poast Plus®) are the only herbicides labeled for postemergence weed control in cowpea in southern U.S. and some cowpea cultivars are injured by bentazon (Harrison and Fery, 1993). Development of resistance in weed biotypes due to continuous use of the same herbicides is also a concern. Imazethapyr persists in the soil and many rotational crops like spinach, small grain crops, and corn are sensitive to imazethapyr (Johnson and Talbert, 1993). For these reasons, testing alternative herbicides on cowpea is imperative. Acifluorfen is labeled in soybean for broadleaf weed control, but not labeled for cowpea because of lack of tolerance in commercial cultivars. The objective of this study was to evaluate the tolerance of seven-advanced cowpea breeding lines and two cowpea cultivars to acifluorfen and bentazon.

Materials and methods

Field studies were conducted at the Vegetable Substation located in the Arkansas River Valley in Kibler, Ark. An unreplicated experiment of fifty advanced breeding lines was conducted using acifluorfen and bentazon in 2001. Acifluorfen was applied at 0 and 1.1 kg ha^{-1} (1 lb/A) and bentazon at 0 and 2.23 kg ha^{-1} (2 lb/A) at 4 to 5 trifoliate stage of cowpea. From the preliminary screening, seven lines, which showed highest tolerance to both herbicides, were used for the replicated experiment in 2002. The advanced breeding lines were: 00-178, 00-198, 00-265, 00-561, 00-784, 00-855, and 92-552. The commercial cultivars: 'Erect set' and 'Early scarlet' were used as standards for comparison. The experiment was arranged in a split block design with four replications. Cultivars were planted in strips across replications and herbicide treatment was randomized within replication, this was done to facilitate harvesting. The plots were 6 m (20 ft) long with four rows 92 cm (36 inch) apart. Cowpea was planted at three to four seed per foot of row, which

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equates to 13.5 to 17 kg ha^{-1} (30 to 37.5 lb/A) seeding rate depending on seed size. The plots were fertilized before planting with 168 kg ha^{-1} (370 lb/A) of 15-30-15. Cowpea was planted on 18th June 2002. Acifluorfen and bentazon were applied at 1.1 kg ha^{-1} (1 lb/A) and 2.23 kg ha^{-1} (2 lb/A), respectively when cowpea had 4 to 5 trifoliate. Herbicides were applied in a spray volume of 186.9 L/ha (20 gallon/A) with CO_2 backpack sprayers using 11003VS flat fan nozzles. Irrigation was conducted as needed using overhead sprinkler irrigation. Stand counts, crop injury, pod count, moisture content, plot yield, and yield reduction due to herbicide application were recorded. Only crop injury, moisture content at harvest, adjusted yield, and yield reduction are discussed here. Visual crop injury ratings were made at 2 and 4 weeks after application, using a scale of 0 to 100% where 0% = no plant injury, and 100% = total plant necrosis. The plant population of each plot was counted in the middle two rows. Ten plants from the middle two rows were harvested on 5 September 2002, from each plot for pod counts and moisture determination. The remaining plants in these two rows were harvested using a combine. Plot yield was calculated as the sum of hand-harvested and combine-harvested plants adjusted to equal plant density of 120 plants per harvest area. Pods from each plant were counted and threshed manually. Seed moisture was taken using DICKY-JOHN® moisture meter immediately after threshing. Seeds were dried and dry weights were recorded. An analysis of variance was conducted to determine if significant difference occurred between treatments. Where significant differences occurred, Fisher's protected LSD (P = 0.05) test was used to determine significant differences between specific means.

Results and discussion

All lines and cultivars showed good tolerance to bentazon 2 WAT with foliar injury less than 10% (Table 1.). Injury ranged from 3 to 8% and lines 00-561, 00-855, 92-552 numerically showed lowest injury (3%). Line 00-178 was less tolerant to bentazon 2 WAT (8 % injury) compared to the lines previously mentioned as well as one of the commercial standards, 'Erect Set'. Injury declined ≤ 5% in all lines and cultivars 4 WAT. Line 00-855 recovered completely from bentazon damage 4 WAT. 'Erect Set' was numerically more tolerant to bentazon than 'Early Scarlet' at 2 and 4 WAT. Crop injury from acifluorfen was higher than that of bentazon regardless of lines at any rating period. Injury ranged from 35 to 52% 2 WAT. Line 00-178 had the least injury with acifluorfen (35%), whereas line 00-192 was injured the most (52%) 2 WAT. 'Early Scarlet', 'Erect Set' , 92-552 and 00-265 were equally tolerant to acifluorfen as 00-178. Injury due to acifluorfen declined to 21 to 34% 4 WAT. Line 00-784 maintained a higher injury level (34%), where as line 00-178 showed good recovery (21%) 4 WAT. 'Erect Set' showed less injury from acifluorfen than 'Early Scarlet'. The injury from acifluorfen was high in all lines and cultivars due to the high rate used. In soybean, acifluorfen is normally used at 0.27 kg ha-1 (0.24 lb/A). Acifluorfen is also more injurious to legumes than bentazon. Crop injury from double rate of bentazon was very low or negligible.

Moisture content at harvest varied from 7 to 15%. 'Erect Set', 'Early Scarlet', 00-784, 00-198, 00-561, and 00-855 had similar moisture content (7 to 11%), whereas line 00-178, 92-552 and 00-265 had higher moisture (13 to 15%). High seed moisture is an indication of delayed maturity. Line 92-552 produced the highest yield with 1042 g (2.2 lb) / plot, followed by 00-561 with 905 g (1.99 lb). Line 00-855, 00-178, 'Erect Set', and 'Early Scarlet' were equal in yield, ranging from 768 to 888 g (1.69 to 1.95 lb) / plot. Line 00-198 was lowest in yield with 584 g (1.2 lb) / plot. Yield reduction due to acifluorfen and bentazon was not significantly different in any of the lines or cultivars. Negative yield reduction in Table 1 indicates enhancement in yield when treated with herbicide, probably due to increased branching (more pod-bearing stalks) after recovery from herbicide injury. Acifluorfen reduced the yield of line 00-561 and 'Erect Set' nearly 25%. There is minor yield reduction in 'Early Scarlet', and 00-178. Acifluorfen did not reduce the yield of 00-198, 00-265, 00-784, 00-855, and 92-552. Although 00-265 and 00-784 numerically showed the least effect from acifluorfen treatment, potential yields of these lines were lower than others so these will be excluded from further trials. Most of the lines and cultivars showed enhancement in yield due to application of bentazon. Numerically, line 00-561 had the most yield reduction (12%) from bentazon treatment; thus, showing the most sensitivity to bentazon.

Conclusions

Line 92-552, and 00-561 had the highest yield potential of all tolerant advanced breeding lines. Numerically highest yield reduction was observed in line 00-561 from acifluorfen and bentazon applications. Lines 92-552, 00-855, and 00-178 are the most promising advanced breeding lines. All lines tolerant to acifluorfen also showed excellent tolerance to bentazon. However, it should be noted that rates used here were excessive. Use of commercial rates of both herbicides in future trials will show expected injury levels and yield response from normal application situations. The high tolerance levels observed in this experiment assures us that in case of misapplication there will be no severe yield penalty from the lines mentioned above. Verification of most promising lines in multiple locations is necessary to register new herbicides for tolerant varieties. The registration of acifluorfen for cowpea will broaden the spectrum of postemergence broadleaf weed control, and prevent the development of herbicide-resistant weeds. Tolerance is achieved by whole-plant selection and does not involve insertion of foreign gene in the plant. The herbicide-tolerant cultivars would be readily acceptable to the public.

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Table 1. The effect of acifluorfen and bentazon on cowpea injury, moisture content at harvest, yield reduction, and final yield Vegetable Substation, Kibler, Ark., 2002.

	Injury[a]							
	Acifluorfen		Bentazon		Moisture	Yield	Reduction	Yield[b]
Line/ Cultivar	2 WAT	4 WAT	2 WAT	4 WAT	content	Acifluorfen	Bentazon	g plot^{-1}
	%							
00-178	35	21	8	5	15	4	4	808
00-198	52	33	5	1	10	0	-19	584
00-265	36	31	6	5	13	-8	-3	709
00-561	40	33	3	3	11	23	12	905
00-784	42	34	7	4	8	-18	-21	720
00-855	44	31	3	0	11	-4	-16	860
92-552	39	25	3	3	14	1	-29	1042
Erect Set	36	23	3	1	8	25	-21	888
Early Scarlet	44	33	6	4	7	6	-4	768
$LSD_{(0.05)}$[c]	4.6	3.2	4.6	3.2	4.5	NS	NS	143

[a] Visually assessed crop injury at scale of 0 to 100; 0 = no injury and 100 = whole plant necrosis.
[b] Yield is adjusted yield of hand, and combine harvested middle two rows of individual plots.
[c] Least significant difference at the 5% level for comparing accession means within acifluorfen and bentazon rate.

Evaluation of Tolerance of Advanced Cowpea Breeding Lines to Fomesafen

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Summary. Advanced cowpea (*Vigna unguiculata*) breeding lines from the University of Arkansas cowpea breeding program were planted in a preliminary screen in 2001 to determine their tolerance to the herbicide fomesafen. The goal of this research is to develop a fomesafen-tolerant cowpea cultivar through whole plant selection. From that screen, six lines were entered in a replicated trial in 2002, and were compared to Early Scarlet, the commercial standard. Crop injury, yield, and seed moisture content were recorded. Overall, three lines showed good tolerance to fomesafen and yielded equal to or better than Early Scarlet: 00-582, 00-584, and 00-609. These lines will be placed in more extensive trials in 2003.

Cowpea [*Vigna unguiculata* (L.) Walp.] is a nutritious grain legume used as a vegetable and fodder (Ehlers and Hall, 1997). Cowpea is drought tolerant and suitable for marginal soils. Weed control is a major concern, as in any vegetable crop, because of limited herbicide options. Because the number of herbicides labeled in cowpea is limited, they have been extensively used, causing herbicide-resistant weeds. Without herbicides to control these weeds, yield can be reduced (Bell, 2000) or hand-weeding expenses may increase (Prather, 1996). In addition, the current chemical weed control options in cowpea, including imazethapyr, bentazon and sethoxydim, leave a large gap in post-emergence broadleaf control. Producers must also choose their cultivar wisely, as the cowpea exhibits differential tolerance to some of these herbicides, including bentazon (Harrison and Fery 1993). Unfortunately, most vegetable markets are too small to encourage companies to develop new herbicides specific to them, and the potential liability for damage to the high-value vegetable crops outweighs the potential profit and discourages them from seeking registration of new herbicides being released in other crops, such as soybean.

Today there are two options to introduce new tolerance into the cowpea system. The first is genetic modification. It is possible to genetically modify cowpeas with a herbicide-resistance gene to achieve tolerance and a new option for weed control. However, cowpea is a field-to-mouth crop, and the genetically modified technology that has simplified weed control in processed crops like soybean is unavailable due to negative public perception. The other option is to breed tolerant cultivars. By screening advanced breeding lines and using whole plant selection, we can, theoretically, create a non-transgenic herbicide-tolerant cultivar. Herbicides that are already registered for various agronomic crops, including the closely related soybean, can be alternatives for use in specialty legume crops like cowpea. Preliminary selection of advanced breeding lines from the University of Arkansas cowpea breeding program showed several lines with high tolerance to twice the recommended soybean rate of fomesafen (5-[2-chloro-4-(trifluoromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide). Fomesafen is a contact herbicide labeled in soybean effective in controlling some of the problem weeds in cowpea, such as pigweed (*Amaranthus* spp.) and morningglory (*Ipomoea* spp.).

The objective of this research was to evaluate the tolerance of advanced cowpea breeding lines to fomesafen and develop cowpea cultivars that are fomesafen-tolerant using whole plant selection to give cowpea producers more chemical weed-control options.

Materials and methods

An initial unreplicated screen of fifty advanced breeding lines, from the University of Arkansas cowpea breeding program, was done in 2001 at the Vegetable Substation in Kibler, Ark. Fomesafen was applied at 0 or 0.67 kg a.i./ha (commercial rate of soybean is 0.335 kg a.i./ha) to the 4 to 5 trifoliate stage of cowpea. The experiment was conducted using one 20-ft row per entry. The preliminary screen revealed six lines had substantial tolerance to fomesafen, and these lines, along with Early Scarlet, were used for a replicated trial in 2002. The six advanced breeding lines were: 00-337, 00-582, 00-584, 00-609, 95-105, and 95-356. The experiment was arranged in a split block design with four replications. Lines were planted in 4 rows on 92-cm spacing, and replications, each of 6 m, were placed perpendicular to the rows. Herbicide treatment was randomized within replication. Seeding rate was targeted at three to four seed per foot. The plots were fertilized before planting with 168 kg/ha of 15-30-15. The experiment was planted on June 19, 2002. Fomesafen was applied at 4 to 5 trifoliate @ 0 kg a.i./ha or 0.67 kg a.i./ha. Treatments were applied in a spray volume of 186.9 L/ha using a CO_2 backpack sprayer. Plots were irrigated as needed using an overhead sprinkler system. Plots were harvested September 5. Agronomic data such as 2-row stand count, crop injury, pod count, moisture content and yield were collected. Visual crop injury estimates were made at 2 and 4 weeks after application. Each treatment was rated for injury on a 0 to

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100% scale where 0% = no crop injury and 100% = total crop necrosis. Ten plants from the middle two rows of each plot were harvested on 5 September 2002. Pod count, grain weight, and moisture readings were taken from these subsamples. Seed moisture was measured by recording the grain weight at harvest, allowing the grain to dry down for 2 weeks, and recording the weight again. Data were analyzed using analysis of variance and means were separated using Fisher's protected LSD (*P*= 0.05 or 0.10).

Results and discussion

Visual injury ratings taken at 2 or 4 weeks after treatment (WAT) were initial indicators of tolerance level of the lines to fomesafen. Table 1 shows that there was still significant injury (>40%) to the lines 2 WAT, and that most lines were not different from Early Scarlet with the exception of 00-582 and 00-584. Recovery from herbicide injury occurred much faster in 00-582, 00-584, and 95-356 than in Early Scarlet or any other line. However, regardless of line, injury at this rating was still high (>30%).

Yield of most lines was adversely affected by fomesafen treatment (Table 2). The only lines that maintained yield potential when treated with fomesafen were 00-584, 00-609, and 95-105. Line 95-105, however, has very low yield potential to begin with, yielding almost 200 grams less than Early Scarlet. For that reason, 95-105 will be dropped from further investigation. Three lines, 00-582, 00-584, and 00-609, produced equal or higher yields than Early Scarlet, regardless of herbicide treatment. These trends are mimicked in the percent yield reductions, where 00-582, 00-584, 00-609, and 95-105 all had less yield reduction than Early Scarlet when fomesafen was applied. Considering that the rate of fomesafen used here was twice the recommended rate in soybean, the tolerant lines are expected to perform better at normal use rates.

Moisture content, a direct indicator of maturity, showed that while the herbicide treatment did not affect yields in some lines, it delayed time to maturity. Table 3 indicates that all lines tested had similar moisture contents when untreated. However, the only lines that maintained similar moisture levels when treated with fomesafen were 00-582, 00-584, and 95-356. All other lines tested had approximately 3 times more moisture in the grain from the treated plots versus the untreated.

Conclusions

Based on herbicide injury ratings, yield, and moisture content, we feel confident that 00-582 and 00-584 have good tolerance to fomesafen. Line 00-609 also showed tolerance to fomesafen, but the treatment delays the maturity of this line. This developmental problem may be resolved when the herbicide is applied at the 1X rate (0.335 kg a.i./ha) rather than the 2X rate used here. We plan to take these selected lines into more extensive trials, including multiple locations and rates.

The registration of fomesafen for cowpea can help broaden the herbicide options for weed control and help prevent the development of herbicide-resistant weeds; and because tolerance is achieved by whole plant selection, there should be no negative reaction from the public.

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Table 1. Crop injury of advanced cowpea breeding lines and Early Scarlet, when treated at 4 to 5 trifoliate with 0.67 kg a.i./ha fomesafen. Vegetable Substation, Kibler, Ark., 2002.

Line	Injury 2 WAT	Injury 4 WAT
	----------------------%	----------------------
Early Scarlet	50	38
00-337	51	38
00-582	36	30
00-584	35	34
00-609	55	35
95-105	49	40
95-356	46	24
LSD (0.05)	7	3

Table 2. Yield and yield reduction of advanced cowpea breeding lines and Early Scarlet treated with fomesafen. Vegetable Substation, Kibler, Ark., 2002.

Line	Fomesafen Rate	Adjusted Yield†	Yield reduction‡
	(kg a.i./ha)	(g/120 plants)	(% of Untreated)
Early Scarlet	0	568.1	--
	0.67	304.8	47.6
00-337	0	414.7	--
	0.67	157.2	61.8
00-582	0	798.2	--
	0.67	591.8	22.2
00-584	0	655.9	--
	0.67	598.4	7.7
00-609	0	695.4	--
	0.67	606.7	-0.4
95-105	0	372.9	--
	0.67	261.9	16.7
95-356	0	387.8	--
	0.67	206.4	48.8
LSD (0.10)	†Different line, same rate = 179.75		‡45.1
	Different rate, same line = 178.84		
	Different line, different rate = 246.86		

Table 3. Effect of fomesafen treatment on maturity of advanced cowpea breeding lines and Early Scarlet. Vegetable Substation, Kibler, Ark., 2002.

Line	Fomesafen Rate	Moisture content
	(kg a.i./ha)	(%)
Early Scarlet	0	13.9
	0.67	40.3
00-337	0	12.9
	0.67	26.5
00-582	0	15.9
	0.67	20.3
00-584	0	16.1
	0.67	26.5
00-609	0	15.6
	0.67	49.1
95-105	0	13.1
	0.67	48.1
95-356	0	12.8
	0.67	12.6
LSD (0.05)	Same rate, different line =	11.5
	Same line, different rate =	13.1
	Different line, different rate =	13.7

FRUIT

Chilling Response of Arkansas Blackberry Cultivars

Manjula Carter[1] *and John R. Clark*[2]

Additional index words: Rubus, temperature

Summary. The chilling requirements of the University of Arkansas blackberry cultivars 'Apache', 'Arapaho', 'Chickasaw', 'Choctaw', 'Kiowa', and 'Shawnee' were determined using stem cuttings from field-grown plants. A biophenometer was used to measure chilling (hours below 7ºC) in the field and 12-node cuttings of lateral shoots were taken from the cultivars every 100 hours up to 1,000 hours below 7ºC. The cuttings were placed in a mist chamber in the greenhouse with a day length of 16 hours and air temperature of 26-29ºC. Percent budbreak was measured weekly. The cultivar x chilling interaction was significant (*P*<0.05). 'Kiowa' had substantial budbreak after only 200 h chilling. 'Arapaho' and 'Shawnee' required moderate chilling (400-500 h), and 'Choctaw' low to moderate chilling (300-600 h) for significant budbreak. 'Chickasaw' was a high-chill cultivar requiring about 700 h. The exact chilling requirement for 'Apache' could not be determined since budbreak was low at all chilling levels. However, it is likely to be a high-chill cultivar since budbreak was only 20% at 800 hours. The use of stem cuttings appears accurate for determining chilling requirement, especially of low-chill cultivars and could be used to evaluate new blackberry germplasm for chilling requirement.

Blackberries (*Rubus* subgenus *Rubus*) require a period of chilling during the dormant season in order to resume growth in the spring. Chilling is defined as hours below 7ºC(45ºF) (Darrow, 1942). The number of chilling hours necessary to fully break dormancy (chilling requirement) is cultivar dependent (Fear and Meyer, 1993). Symptoms of insufficient winter chilling such as delayed or sporadic budbreak and bud abortion (Jennings et al., 1986) have been observed in some blackberry cultivars in warm climates, for example, 'Chester' blackberry in California (Fear and Meyer, 1993). In Arkansas, the blackberry breeding program has begun to focus on releasing cultivars better adapted to lower-chill climates. Reports of sporadic budbreak in 'Navaho' in southern Arkansas (John R. Clark, personal communication) and Mississippi (Creighton Gupton, personal communication) substantiate the need to test this and other cultivars for their chilling requirement so that hardiness recommendations can be made. Previous work by Yazzetti and Clark (2001) demonstrated cultivar differences in chilling requirement in stem cuttings. Our objectives were to use stem cuttings to define the chilling requirements of some currently available blackberry cultivars and the Arkansas primocane fruiting selection number 12 (APF 12).

Materials and methods

This trial was conducted at the University of Arkansas Southwest Research and Extension Center, Hope, Ark. The cultivars 'Apache', 'Arapaho', 'Chickasaw', 'Choctaw', 'Shawnee', and APF 12 were planted in the field in a randomized complete block design with four replications in mid April 1999. The primocanes were tipped to 1.07 m (3.5 ft) height during the summer, and in winter any dead growth was removed. Sampling began in the fall of 2001 when the plants were 2 years old.

On 22 Nov. 2001 an overnight air temperature of –3.3ºC(26ºF) was recorded. This temperature was considered low enough to trigger the onset of dormancy in the blackberry cultivars. A biophenometer (Wescor Environmental Products, Logan, UT) was placed in the field on Nov. 23 to record hours below 7ºC. Samples were taken at every 100 hours up to 1,000 hours below 7ºC(45ºF). One thousand hours were reached on 11 Feb. 2002. 'APF 12' was only sampled up to 800 hours chilling due to a shortage of plant material. For each sampling time, eight 12-node, lateral-branch cuttings were taken from each cultivar (two from each of the four plots of the cultivar). Following sampling, the cuttings were arranged in a mist chamber in a randomized complete block design with eight replications. The mist chamber was located in a heated greenhouse with a maximum daytime air temperature of 26 –29ºC(80 – 85ºF) and a minimum of 21ºC(70ºF) at night. Day length was maintained at 16 hours with incandescent lighting. The mist chamber bed was filled with perlite. The bottom two nodes of each cutting were submerged in the perlite to anchor the cutting so that 10 nodes remained exposed. Cuttings were placed 4.8 cm (2 inch) apart within a row with 7.2 cm (3 inch) between rows. Each cutting remained in the chamber for 10 weeks. Percent budbreak in the cuttings was recorded weekly. Since there were 10 nodes on each cutting, budbreak for each node represented 10% of the total. The data were analyzed as a randomized complete block design with a split-plot in time and means were separated using least significant difference (*P*<0.05) (SAS Institute, Cary, N.C.). Dormancy was considered broken at the first significant increase in budbreak, and this was taken to be the chilling requirement for the cultivar.

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Results and discussion

Although budbreak was rated for 10 weeks, budbreak reached a maximum at week five and no new buds were broken after week five. Therefore only week five data are considered in this discussion. Percent budbreak at different chilling hours ranged from 10% to as high as 90%. The cultivar x chilling hours interaction was significant.

'APF 12' appeared to have a low chilling requirement (Fig. 1). Significant increases in budbreak were between 100 h and 200 h (30%) and between 300h and 400 h (43%). Maximum budbreak occurred at 800 h (67%). New leaves and flowers were present throughout the winter indicating that 'APF 12' never became fully dormant. The chilling requirement of 'APF 12' seems to be between 100 and 200 hours.

'Kiowa', like 'APF 12', showed budbreak even at 200 chilling hours (Fig. 2) and this is consistent with Yazzetti and Clark (2001). Budbreak remained constant at approximately 30% until 800 h when there was a significant increase to 79%. Although no significant increases in budbreak were observed before 800 h, field observations at Hope suggest that 'Kiowa' has a chilling requirement of 200-300h.

'Arapaho' had budbreak of approximately 30-35% between 100 and 400 h (data not shown). Budbreak increased significantly at 500 h to 53% corroborating findings by Yazzetti and Clark (2001). We conclude the chilling requirement for this cultivar is 400-500 h.

'Shawnee' showed significant increases in budbreak between 400-500 h, 500-600 h and 600-700 h (data not shown). Maximum budbreak was at 700 h (84%). These results closely match the findings of Yazzetti and Clark (2001) and suggest that the chilling requirement of 'Shawnee' is 400-500 h.

'Choctaw' showed little budbreak until 300 h when budbreak increased significantly to 19% (data not shown). Another significant increase to 28% budbreak occurred at 600 h. The results for 'Choctaw' are inconclusive. However, it is likely that the chilling requirement of 'Choctaw' is between 300 - 600 h. In our study there was also a significant increase in budbreak at 800 h to 62%. 'Choctaw' has been grown successfully in Central Mexico, an area of no chill, by the use of several cultural manipulations (Jorge Rodriguez, personal communication).

The response of 'Apache' to chilling hours was difficult to determine. Little or no budbreak was seen between 100 and 400 h suggesting a higher chilling requirement. However, even at 800 h, maximum budbreak was only 20% (Fig. 3). The exact requirement for 'Apache' is not clear from our data, although 'Apache' appears likely to be a high-chill cultivar. Observations of sporadic budbreak in a year of approximately 600 h chilling at Hope, Ark., (unpublished data) indicate that 'Apache' indeed requires higher chilling.

'Chickasaw', like 'Apache', had relatively low budbreak at low chilling hours with an increase to 21% at 700 h (data not shown). Maximum budbreak was only 27% at 1000 h. It is difficult to pinpoint the chilling requirement of 'Chickasaw' since overall budbreak was so low. Our results, like those of Yazzetti and Clark (2001), suggest that 'Chickasaw' requires 700 or more chilling hours for significant budbreak.

Conclusions

In reviewing the data from our experiment, it is apparent that the genotypes evaluated had differences in chilling requirement. However, the percent budbreak attained varied substantially, raising questions as to what might be considered "fulfillment" of chilling and whether chilling requirement was well measured for cultivars such as 'Apache' and possibly 'Chickasaw', which showed low budbreak even at high chill levels. Despite variability in the study, overall we did have findings that we feel were reflective of chilling requirement for several cultivars. For instance, 'Arapaho' had significant increases in budbreak at 400 -500 h, and this parallels the field observations that it breaks buds more evenly in areas receiving less chilling than northwest Arkansas, namely Poplarville, Miss., (Creighton Gupton, personal communication), and Monticello, Fla., (Peter Andersen, personal communication). 'Choctaw' has also been reported to be lower in chilling requirement in Mexico (Jorge Rodriguez, personal communication), although a low chilling requirement could not always be discerned from our data. The reasons for this variability in chilling response are not clear. 'Kiowa' is a newer cultivar. In recent years, field observations of 'Kiowa' have indicated good budbreak in southern Georgia (Gerard Krewer, personal communication) where chilling is usually 400-600 h. Reliable fruiting has also been observed in an area of very little to no chill in Guatemala (Roberto Castaneda, personal communication). 'Kiowa' has also consistently broken buds evenly at Hope, Ark., in many trials there. Our data reflect a lower chilling requirement for 'Kiowa' compared to most other genotypes in our studies, which parallels field observations.

We are encouraged that the forced-stem approach generally gave positive results. Although this system did not work as well for a few genotypes, it did appear to give general chilling responses for a range of genotypes. We will use this technique for further screening of cultivars and breeding selections with the goal to have earlier information on chilling requirement for blackberry cultivars to provide for growers in a wider range of climates.

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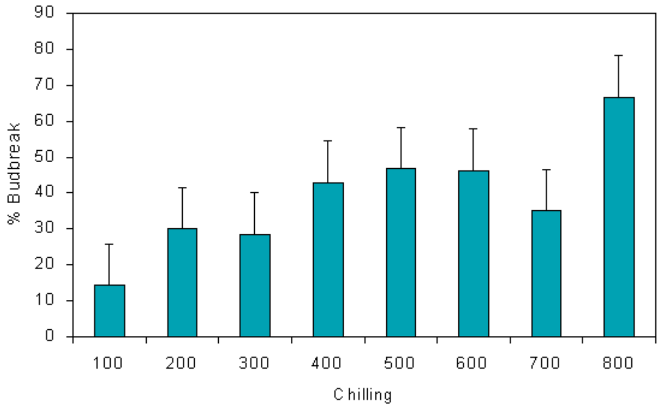

Fig. 1. Budbreak in stem cuttings of APF 12 blackberry at 100-800 chilling hours below 7ºC, Hope, Ark., 2001. Bars represent LSD.

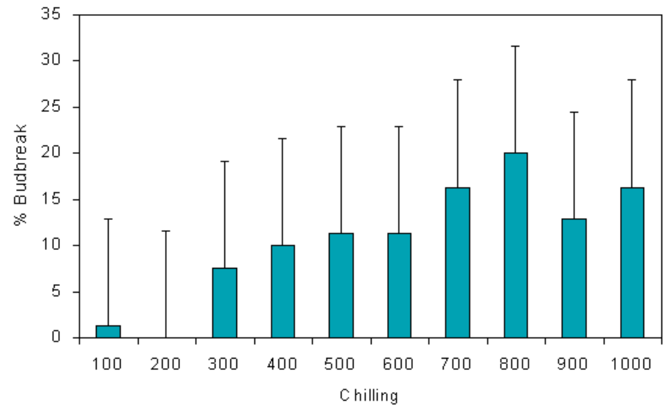

Fig. 3. Budbreak in stem cuttings of 'Apache' thornless blackberry at 100-1000 chilling hours below 7ºC, Hope, Ark., 2001. Bars represent LSD.

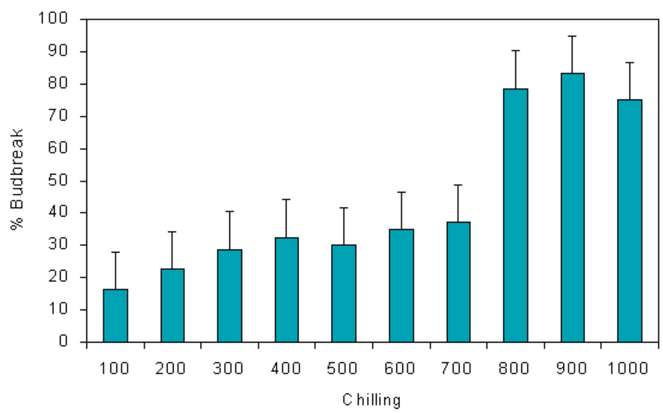

Fig. 2. Budbreak in stem cuttings of 'Kiowa' blackberry after 100 to 1000 hours below 7ºC, Hope, Ark., 2001. Bars represent LSD.

'Ouachita' Thornless Blackberry

John R. Clark and James N. Moore[1]

Additional Index Words. *Rubus*, fruit breeding

Summary. 'Ouachita' is the eleventh release in a series of erect-growing, high-quality, productive, floricane-fruiting blackberry cultivars developed by the University of Arkansas. It is the fourth thornless, erect cultivar released. 'Ouachita' ripens between the Arkansas thornless cultivars 'Arapaho' and 'Navaho', produces larger fruit than these cultivars, and yields as high as or higher than these cultivars and 'Apache'.

Materials and methods

'Ouachita' resulted from a cross of 'Navaho' x A-1506 made in 1990. The original plant was selected in 1993 from a seedling field at the University of Arkansas Fruit Substation, Clarksville, and tested as selection A-1905. A single plot was established at Clarksville in 1993 and observational data were taken on 'Ouachita' on this plot after fruiting began in 1995 and continued through 2002. Plots of comparative cultivars 'Arapaho', 'Navaho', and 'Apache' were also present in this planting and observational data were collected on these during this evaluation period. In all plantings, standard cultural practices for erect blackberry production were used including annual preemergence and postemergence herbicide applications, annual spring nitrogen fertilization (56 kg at ha^{-1} N or 50 lb/acre) using ammonium nitrate, summer tipping of primocanes at 1.1 m (45 in.), and dormant pruning. All plantings received a single application of liquid lime sulfur at budbreak for control of anthracnose. The data collected included fruit and plant ratings and also fruit soluble solids concentration. Winter injury was observed each year, if it occurred, at the time of fruiting. Additionally, replicated trials were established at research stations in Clarksville (Fruit Substation), Hope (Southwest Research and Extension Center), and Fayetteville (Arkansas Agricultural Research and Extension Center), in 1996 and 1999. The comparative cultivars 'Apache', 'Arapaho', and 'Navaho' were included in the 1996 trial and all but 'Navaho' were included in the 1999 trial. Data for 10% and 50% bloom, and first, peak, and last harvest dates were recorded for 1997-1999 for the 1996 trial and for 2000-2002 for the 1999 trial and averaged for each trial at Clarksville. Also, 25 berry samples were collected from the two or four replications (depending on cultivar) at Clarksville on one harvest date in 1998. Seeds were extracted from the berries using a blender, and 100-seed samples were weighed. Berry weight (average for 25 berries/replicate on each harvest date at each location, with the average for each replicate for the season being used in the analysis) and total yield data from the replicated plantings for 1997-1999 and 2000-2002 for all locations were analyzed as a randomized complete block separately by year and location. Seed weight data from 1998 from Clarksville only were analyzed as a randomized complete block. All mean separation was by t test (P<0.05).

Description and performance

'Ouachita' produced yields comparable to or higher than 'Apache' or 'Navaho' in 13 of 15 mean comparisons from the two replicated trials (Tables 1 and 2). It exceeded the yield of 'Arapaho' in most comparisons. 'Ouachita' performed well at all three locations in Arkansas: Hope, Clarksville, and Fayetteville.

Average berry weight of 'Ouachita' ranged from a high of 6.8 g to a low of 4.5 g (Table 2). Across all locations and years the average fruit weight for 'Ouachita' was 5.8 g compared to an overall average of 4.7 g for 'Arapaho', 4.1 g for 'Navaho', and 8.1 g for 'Apache'. 'Ouachita' was observed to retain its fruit weight later into the harvest season than 'Navaho'(data not shown). Additionally, uneven drupelet set has often been observed in 'Navaho' and has been attributed to some degree of sterility. 'Ouachita' has excellent fruit fertility and full drupelet set (data not shown).

Fruit of 'Ouachita' are blocky and conical and very attractive with an exceptional glossy, black finish. Fruit firmness rated in the field at maturity of 'Ouachita' was slightly less than that of 'Navaho' but comparable to that of 'Apache' and 'Arapaho' (Table 3). Soluble solids concentration over 7 years averaged 9.9% for 'Ouachita', 11.9% for 'Navaho', 11.1% for 'Apache' and 8.2% for 'Arapaho' (Table 3). Flavor rating for 'Ouachita' averaged 8.4, near that of 'Apache' and 'Navaho', and exceeding that of 'Arapaho'. Postharvest evaluations indicated that 'Ouachita' stored comparably to 'Navaho' when held at 5ºC (41ºF) for 7 d (Penelope Perkins-Veazie, personal communication) (data not shown). This is a very noteworthy item of performance, as 'Navaho' is considered an exceptional shelf-life berry.'Ouachita' is expected to perform well in commercial shipping use also. Fresh seed weight of 'Ouachita' was significantly heavier than 'Arapaho', similar to 'Navaho', and less than that of 'Apache' (Table 3). Dry seed weights had similar trends.

'Ouachita' began bloom the same date as 'Apache', a day later than 'Arapaho', and two days earlier than 'Navaho' (Table 3). Fifty percent bloom was comparable to 'Navaho, 2 d later than 'Apache' and 0 to 3 d

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later than ‘Arapaho’ (Table 3). First harvest date for ‘Ouachita’ was June 12 or 13, 6 to 8 d after ‘Arapaho’, 7 d before ‘Navaho’, and 6 to 9 d before ‘Apache’. ‘Arapaho’ often has a shorter harvest period than the other cultivars, and this can result in a reduction in fruit available between ‘Arapaho’ and ‘Navaho’. ‘Ouachita’ ripens between these two cultivars and should contribute to a more steady and continuous supply of fruit for harvest, a key issue for labor and marketing management.

Canes of ‘Ouachita’ are thornless and are very erect. Average erectness rating for ‘Ouachita’ surpassed those of ‘Navaho’ and ‘Arapaho’ but not ‘Apache’ (Table 3). If primocanes are tipped at 1.1 m (45 in.) to control primocane length and encourage lateral branching, ‘Ouachita’ can be grown in a hedgerow without trellis support. However, support of the floricanes during fruiting is valuable since support can reduce canes from falling over due to wind or unusually heavy crop loads. Vigor rating of ‘Ouachita’ was higher than ‘Arapaho and ‘Navaho’ but not as high as ‘Apache’ (Table 3). Average health rating for ‘Ouachita’ was very good, surpassing that of ‘Arapaho’ but not ‘Apache’ or ‘Navaho’. In some years, health was rated lower due to some upward leaf curling of primocane leaves. This was noted during several years. The concern was that this could be a symptom of susceptibility to powdery mildew. However, no mycelial growth of the fungus or stunting of leaf growth was seen on ‘Ouachita’, even when seen on other genotypes in the selection evaluation planting. No orange rust has been observed on ‘Ouachita’ in any evaluations, even though infected plants have been seen within 30 m (98 ft) of plots of ‘Ouachita’. However, one of ‘Ouachita’s’ parents, ‘Navaho’, is susceptible to orange rust, so evaluators or growers of ‘Ouachita’ should be aware of this relationship and possible susceptibility. ‘Ouachita’ is mostly resistant to anthracnose, as only a small amount of anthracnose was noted on berries in 2 of 8 years in the selection observation planting in evaluations where a single spray of lime sulfur was applied. Fruit and cane anthracnose was observed only one time in the numerous replicated plantings. Reaction of ‘Ouachita’ to rosette/double blossom was evaluated at the Calhoun Research Station of Louisiana State University, Calhoun, La., by Dr. Blair Buckley, in a planting where the disease pressure was very high. ‘Ouachita’ had no incidence of this disease nor did ‘Apache and ‘Navaho’. By contrast, the disease incidence was 100% on canes of the thorny cultivars ‘Shawnee’ and ‘Kiowa’ (data not shown nor published). Therefore, ‘Ouachita’ holds promise for production in areas where this disease limits production. In recent years at test sites in Arkansas there has been observation of white drupelets on some blackberry genotypes near or at fruit maturity, and it has been most severe on ‘Apache’. It has been thought that this is due to insect damage from eastern flower thrips, brown stink bug, and/or green stink bug. In 2002 the incidence of this was quite severe. In repeated observations in the replicated trials, ‘Ouachita’ was observed to have no white drupes while incidence of this was very high for ‘Apache’ (these could be observed at the same time due to partial overlap in fruiting season for these two cultivars).

Plant hardiness has been observed to be good on ‘Ouachita’ and observations generally support the idea that ‘Ouachita’ is likely more hardy than ‘Arapaho’, comparable to ‘Apache’, and slightly less hardy than ‘Navaho’.

Root cutting sprouting of ‘Ouachita’ has consistently been about 60% on roots forced in a heated greenhouse in commercial potting soil. This compares with ‘Apache’, which had sprouting of 50-100%, ‘Arapaho’ 40-80%, and ‘Shawnee’ 80-100% (data not shown). Therefore, plantings utilizing root cuttings for establishment must be aware that a complete stand will likely not be achieved due to this sprouting percentage.

Chilling requirement of ‘Ouachita’ has not been measured. However, two occurrences of less than adequate chill (estimated to be approx. 700 hours below 7ºC; 45ºF) were experienced at Hope during its testing. In 1999, approximately 600 h of chilling were attained, and ‘Ouachita’ was observed to have full budbreak, as was ‘Arapaho’, while ‘Apache’ and ‘Navaho’ had poor budbreak. This likely accounted for the higher yields of ‘Ouachita’ over those for ‘Apache’ and ‘Navaho’ at Hope for 1999 (Table 1). In 2001 a similar level of chill occurred, and a range of cultivars were rated for budbreak. The ratings were on a scale of 1-5 with 5=full budbreak. ‘Ouachita’ had a rating of 5.0, while other cultivars were as follows: ‘Arapaho’ 4.5, ‘Apache’ 3.3, ‘Shawnee’ 4.0, ‘Kiowa’ 5.0. Yields for that year at Hope corresponded to these budbreak ratings (Table 2). The observations in these two years indicate that ‘Ouachita’ may have a chilling requirement similar to that of ‘Arapaho’, and lower than the other two thornless cultivars. This is a valuable trait since the higher chill cultivar ‘Navaho’ has been observed to break buds and yield poorly in some locations in the deep South of the U.S.

Availability

An application for a U.S. plant patent has been filed for ‘Ouachita’. A list of nurseries licensed to propagate and sell ‘Ouachita’ can be obtained from J.R.C., 316 Plant Science, Dept. of Horticulture, Univ. of Arkansas, Fayetteville, Ark. 72701 (jrclark@uark.edu).

Table 1. Yield and berry weight of four thornless blackberry cultivars in plantings established at three locations in Arkansas in 1996.

	Yield (kg•ha-1)[z]			Weight/berry (g)[y]		
Cultivar	1997	1998	1999	1997	1998	1999
			Clarksville			
Ouachita	10,119 a[x]	10,086 a	9,568 a	6.7 b	6.7 b	5.8 b
Apache	10,100 a	7,683 a	9,560 a	10.0 a	9.5 a	7.7 a
Arapaho	4,940 b	4,974 a	4,981 b	5.4 c	5.2 c	5.0 c
Navaho	15,066 a	4,764 a	10,060 a	5.1 c	4.6 c	4.6 d
	Hope					
Ouachita	4,292 a	16,994 a	9,866 a	6.8a	6.0 b	5.1 b
Apache	4,512 a	14,533 a	5,588 b	6.6 a	8.4 a	6.7 a
Arapaho	3,635 a	9,703 b	5,134 b	4.7 b	5.0 c	4.2 c
Navaho	3,024 a	11,115 ab	3,071 b	3.9 c	4.9 c	3.6 c
	Fayetteville					
Ouachita	6,376 a	8,588 a	-	6.4 a	4.5 b	-
Apache	7,481 a	8,349 a	-	8.9 a	7.4 a	-
Arapaho	2,047 b	4,996 b	-	4.7 b	3.5 c	-
Navaho	2,711 b	4,785 b	-	3.2 b	3.1 c	-

[z] 1.0 lb/acre=1.12 kg@ha-1. y 1 g=0.035 oz.
[y] 1 g=0.035 oz.
[x] Mean separation within columns and locations by t test (*P*<0.05).

Table 2. Yield and berry weight of three thornless blackberry cultivars in plantings established at three locations in Arkansas in 1999.

	Yield (kg•ha-1)[z]			Weight/berry (g)[y]		
Cultivar	2000	2001	2002	2000	2001	2002
			Clarksville			
Ouachita	5,886 a [x]	6,811 a	6,659 b	5.8 ab	6.4 b	4.7 b
Apache	3,859 ab	7,908 a	12,045 a	7.7 a	8.8 a	7.9 a
Arapaho	2,699 b	3,527 b	3,171 c	5.0 b	5.3 c	4.2 b
			Hope			
Ouachita	9,915 a	11,184 a	10,931 a	5.9 b	5.5 b	5.0 b
Apache	4,941 b	5,336 c	6,178 b	7.5 a	8.9 a	7.0 a
Arapaho	7,227 ab	7,365 b	9,516 a	5.6 b	4.6 c	4.0 c
			Fayetteville			
Ouachita	7,900 b	-	-	-	-	-
Apache	14,900 a	-	-	-	-	-
Arapaho	4,178 c	-	-	-	-	-

[z] 1.0 lb/acre=1.12 kg@ha-1.
[y] 1 g=0.035 oz.
[x] Mean separation within columns and locations by t test (*P*<0.05).

Table 3. Plant and fruit characteristics of four thornless blackberry cultivars at the University of Arkansas Fruit Substation, Clarksville.

	Cultivar			
Characteristic	Ouachita	Apache	Arapaho	Navaho
Bloom date[z]				
10% bloom	29 Apr.	29 Apr.	28 Apr.	1 May
50% bloom	7 May	5 May	4 May	7 May
Bloom date[y]				
10% bloom	26 Apr.	26 Apr.	25 Apr.	-
50% bloom	2 May	30 Apr.	2 May	-
Harvest date (1996-99) [z]				
First	12 June	21 June	6 June	19 June
Peak	19 June	30 June	11 June	1 July
Last	20 July	26 July	7 July	27 July
Harvest date (2000-02) [y]				
First	13 June	19 June	5 June	-
Peak	24 June	29 June	16 June	-
Last	16 July	25 July	2 July	-
Fruit:				
Firmness[xw]	8.1 ("0.4)	8.0 ("0.5)	8.1 ("0.4)	8.6 ("0.7)
Flavor[xw]	8.4 ("0.7)	8.3 ("0.7)	7.8 ("0.5)	8.5 ("0.8)
Seed fresh weight[v] (mg/seed)	11.4 bv	12.5 a	8.4 c	10.6 b
Seed dry weight[v] (mg/seed)	4.5 abv	4.8 a	3.3 c	4.2 b
Soluble solids (%)[u]	9.9 ("1.3)	11.1 ("1.8)	8.2 ("1.6)	11.9 ("3.0)
Plant[xw]:				
Vigor	8.4 ("0.5)	9.1 ("0.6)	7.3 ("1.0)	7.4 ("0.5)
Health	8.5 ("0.8)	9.4 ("0.5)	7.8 ("1.0)	8.9 ("0.4)
Erectness	8.5 ("0.5)	8.9 ("0.6)	8.0 ("0.9)	7.9 ("0.4)

[z] Means of 3 years, 1997-1998, with data collected from the 1996-established replicated plots.
[y] Means of 3 years, 2000-2002, with data collected from the 1999-established replicated plots.
[x] Means of 8 years, 1995 through 2002, with data collected from the observational plots; standard deviation in parentheses.
[w] Rating scale of 1 to 10 where 10=best.
[v] Mean separation within rows by t test (P<0.05); seeds were collected and weighed in 1998.
[u] Means of 7 years, 1995 and 1997 through 2002, with data collected from the observational plots.

‘White River’ Peach

John R. Clark and James N. Moore[1]

Additional index words: *Prunus persica*, fruit breeding, bacterial spot, *Xanthomonas campestris pv. pruni*

Summary. ‘White River’ is the first white-flesh peach released from the University of Arkansas peach [*Prunus persica* (L.) Batsch] breeding program. ‘White River’ is mid- to late-season maturity with melting flesh that is firm when ripe, with large fruits of excellent quality and attractive skin color. It is high yielding and has very good resistance to bacterial spot. This cultivar should provide a high-quality option for peach growers in areas where bacterial spot disease is a concern. It expands options for growers in Arkansas, the mid- to the upper-southern United States, and other areas of the world with similar climatic conditions.

Origin and evaluation

‘White River’ resulted from a cross of ‘Loring’ x NJ 257. The original seedling tree of ‘White River’ was selected in 1986 by James N. Moore and tested thereafter as Ark. 376. Primary testing of this selection and comparison cultivars was at the University of Arkansas Fruit Substation, Clarksville. It was also tested at the University of Arkansas Southwest Arkansas Research and Extension Center, Hope. In all tests, trees were spaced 5.5 m (18 ft.) between trees and rows and were trained to an open-center system and pruned annually. Trees were fertilized annually with either complete (13-13-13 for example) or nitrogen fertilizers (providing recommended N rates for peach trees of appropriate age) and irrigated as needed. Pests were managed using a pest management program typical for commercial orchards of the area. No bacteriacides were applied to evaluation plantings during testing of ‘White River’ or comparison cultivars. Fruits were thinned to a distance of 12 to 15 cm (5-6 in.) between fruit prior to pit hardening but after shuck split each year that a crop was present. Data that were collected included bloom and harvest dates, fruit and tree ratings (ratings on a 1-10 scale with 10=best), fruit sample analyses, and yields in replicated trials.

Description and performance

Average 10% bloom date for ‘White River’ was 16 Mar. for 1987 through 2001, which was within 1 d of the average for ‘Summer Pearl' and ‘Redhaven’ and 3 d later than ‘Carolina Belle’ (Table 1). Average full bloom date was 22 Mar. (Table 1). ‘White River’ also bloomed 2 to 9 d later than ‘Carolina Belle’in the replicated trial at Clarksville (data not shown) and with or near ‘Cresthaven’ and ‘Redhaven’ most years at Hope (data not shown). The most noteworthy exception was at Hope where in 1999 ‘White River’ bloomed 9 to13 d earlier than ‘Redhaven’ and ‘Cresthaven’, but this was caused by delayed and extended bloom due to insufficient chilling.

Tree vigor ratings on observational trees averaged 8.6 (data not shown), which is average to slightly above average vigor for trees at Clarksville. However, this cultivar has wider crotch angles of main scaffold branches than some cultivars and this should be an asset in tree training. Tree health ratings for ‘White River’ were exceptional, averaging 9.6 on a 10-point scale (data not shown). A major component of the tree health rating is resistance to bacterial spot, and ‘White River’ was observed to have only slight infections in any years in the observational plots or in the replicated trial at Clarksville. ‘White River’ has been among the most resistant genotypes to bacterial spot in the breeding program and no economic damage to the crop was observed in any year.

Diseases seen on ‘White River’ were occasional brown rot and peach scab (at Hope only). A commercial fungicide program is required for disease control for ‘White River’ in areas where these diseases are present. Chilling requirement of ‘White River’ was not measured but is probably near 800 h below 7ºC(45ºF) based on observations of budbreak and bloom in comparative plantings with test cultivars of known chill requirement. Although good budbreak and some crop was produced following 600-700 h of chilling at Hope in 1999, this amount of chilling did not appear adequate for full crop production as yield was low for that year at that location (data not shown).

On average ‘White River’ ripened 20 July at Clarksville in observational plots (Table 1) and ranged from 13 July to 24 July in 1997 to 2000 in the replicated trial (data not shown). At Hope, on average it ripened July 10 (data not shown). Ripening date was 25 d later than ‘Redhaven’, 8 d later than ‘Carolina Belle’and 8 d earlier than ‘Summer Pearl’at Clarksville. At Hope, ‘White River’ ripened closer to ‘Redhaven’, on average 13 d later, and 9 d earlier than ‘Cresthaven’.

Crop ratings on observation trees had a mean rating for 9 years of 9.3, among the highest for any genotypes in the program during this time (data not shown). Yields for ‘White River’ were usually very good in

We thank Kenda Woodburn, Curt Rom, Bryan Blackburn, Effie Gilmore, David Gilmore, Patrick Byers, Robert Bourne, Manjula Carter, and Jack Young for contributions in data collection and observations during the evaluation of ‘White River’.

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replicated trials. At Clarksville, 'White River' exceeded or equaled yield of 'Carolina Belle' while at Hope, 'White River' outyielded 'Cresthaven' and/or 'Redhaven' in 5 of 7 years (data not shown). Average fruit weight at Clarksville for 'White River' was 201 g (7.0 oz), similar to 'Carolina Belle' and heavier than 'Summer Pearl' and 'Redhaven' (Table 1). Split pits were never observed on any fruit of 'White River' at Clarksville, while in one year (1997) split pits were commonly seen at Hope. Fruit skin color and finish ratings were very good for 'White River', usually 8 or 9 (data not shown). Percent blush on the fruit skin averaged 68%, the same as 'Summer Pearl'(Table 1), although in many years was 80% or more. The background color at early maturity was usually observed to be a cream color rather than green as seen on some white-flesh peaches. Finish ratings reflect the uniformity of the surface of the fruit and higher ratings indicate smooth fruit surface free of cracking, freckling, and bacterial spot lesions. 'White River' had excellent finish ratings, averaging 8.7 on a 10-point scale (data not shown).

Fruit firmness rating for 'White River' averaged 7.7 over 9 years (data not shown). The flesh of 'White River' is melting and does soften at full maturity although it is very firm when early mature. However, shipping and storage evaluations have not been conducted on this cultivar. 'White River' is a freestone-type fruit. Flesh color of 'White River' is white with red in the flesh around the pit but not substantial red color throughout the flesh. Flavor has been consistently rated high by the authors for 'White River', averaging 7.7 over 9 years (data not shown). The aromatic fruit has a distinct white peach flavor and is considered a "standard acidity" flavored peach but maintains a good balance of acidity and sweetness. Soluble solids averaged 12.9% (Table 1).

Availability

Application for U.S. plant patent has been filed for 'White River' peach. A list of nurseries licensed to propagate and sell this cultivar will be available from John R. Clark, 316 Plant Science, Dept. of Horticulture, Univ. of Arkansas, Fayetteville, Ark. 72701, or jrclark@uark.edu.

Table 1. Fruit and plant characteristics of three white-flesh peach cultivars and 'Redhaven' (yellow-flesh) peach from two-tree observational plots, University of Arkansas Fruit Substation, Clarksville, 1987-88, 1990-95, and 1997-2000.

	White River[z]	Carolina Belle[y]	Summer Pearl[x]	Redhaven[w]
Fruit				
First harvest date	20 July ± 7[u]	12 July ± 7	28 July ± 6	24 June ± 5
Fruit weight (g)[v]	201 ± 43	205 ± 60	155 ± 43	149 ± 39
Soluble solids %	12.9 ± 1.0	12.9 ± 0.8	15.2 ± 1.9	12.4 ± 1.5
Plant				
10% bloom date	16 Mar. ± 9	13 Mar. ± 9	17 Mar. ± 7	15 Mar. ± 7
Full bloom date	22 Mar. ± 6	19 Mar. ± 8	24 Mar. ± 7	21 Mar. ± 7

[z] Means of 10-14 years.
[y] Means of 8-10 years.
[x] Means of 8-13 years.
[w] Means of 9-14 years.
[v] 1.0 oz=28.4 g.
[u] Standard deviation.

The Effects of Potential Organic Apple Fruit Thinners on Gas Exchange and Growth of Model Apple Trees: A Model Plant Study of Transient Photosynthetic Inhibitors and Their Effect on Physiology and Growth

J. D. McAfee and C. R. Rom[1]

Additional index words: photosynthesis, conductance, evapotranspiration, potassium bisulfate, potassium bicarbonate, sodium chloride, lime-sulfur, soybean oil

Summary. Few fruit thinners have been certified for organic fruit growers. Previous studies have shown that herbicides or shade are capable of reducing photosynthesis and are effective fruit thinning techniques, although impractical. This project evaluated use of a model plant system of vegetative apple trees grown under controlled conditions to study photosynthetic inhibitors, which could be used as potential organic thinning agents. Various concentrations of osmotics, salts, and oils (lime-sulfur, potassium bisulfite, potassium bicarbonate, sodium chloride, soybean oil) were applied to actively growing apple trees and showed a reduced trend on the rate of apple tree photosynthetic assimilation (Pn), evapotranspiration (Et), and stomatal conductance (gs). From a series of two studies, it was observed that treatments of 2% lime-sulfur (LS) + 2% soybean oil (SO), 4% SO, 8% LS, 5% potassium bicarbonate ($KHCO_3$), and 5% potassium bisulfite ($KHSO_4$) all significantly reduced Pn. The 4% LS + 2% SO, 4% LS + 4% SO, 0.5% sodium chloride (NaCl), and 2% NaCl did not significantly reduce Pn. The response of Et was significantly reduced by 2% LS + 2% SO, 5% $KHCO_3$, and 4% SO. In a second study, trees had reduced Pn, Et, and gs after the application of 4% LS + 4% SO, 2% NaCl, 5% $KHCO_3$, and 5% $KHSO_4$. Stem weight, total plant weight, average leaf weight, and leaf surface area of the treated plants although reduced were not significant when compared to the control 20 days after treatment.

Fruit thinning is a technique essential to fruit production that ensures fruit quality by maximizing fruit size and sustaining the apple tree's potential to annually bear marketable fruit. A number of chemical treatments are available to conventional apple growers but few are currently registered or recommended to certified organic growers. Organic growers typically rely on mechanical removal of excessive fruitlets by hand labor, which is very expensive. In order to test potential organic fruit thinning treatments and develop reliable, economic thinning technologies, it is necessary to create a model system to test naturally occurring and organically certifiable compounds.

Over the past four decades, research has demonstrated the value and appropriate timing of thinning techniques to maximize fruit size and for return bloom flower development for the following year's crop. Early studies showed the correlation between factors such as shade and the reduction in photosynthesis and how they affect fruit growth (Heinecke, 1966). Currently, fruit thinning is accomplished through synthetic plant growth regulators, herbicides, and caustic chemicals, or by mechanical means (hand removal of flowers or fruitlets). Due to the expense of hand removal of flowers and fruitlets, most fruit thinning research has focused on chemical methods of application. Past studies have shown that herbicides such as terbacil and increased shade are good fruit thinning techniques (Byers et al.,1990). Furthermore, the primary focus of research has been on chemical treatments for conventional orchards. Several of these chemical products have been registered for fruit thinning purposes. However, none of these chemicals are certified for organic fruit producers.

The present increase in market demand for organically grown food has increased the need for science-based technologies, which are certifiable organic alternatives to conventional methods and hand labors. It was proposed that some certified organic spray materials may cause a transient suppression or inhibition of photosynthesis. The reduction of carbohydrate supply caused by this suppression would result in strong inter-fruit competition for metabolites, whereby smaller or developmentally delayed fruit would not compete and therefore abort. A model plant test under a controlled environment of treatment effects on photosynthesis and vegetative growth may indicate the usefulness of such materials for fruit thinning in the field. The objective of this project was to study the effects of potential organic thinning agents on gas exchange and growth of vegetative apple trees as a model system.

Materials and methods

Study 1 (February – March, 2002). 'Golden Delicious'/M.7a nursery stock trees (approximately 0.5-0.75 cm (0.2-0.3 in.) diameter) were potted in 7.57 L (2 gal) pots with a soil media consisting of a SB500 mix (35-45% bark, Canadian sphagnum peat moss, vermiculite, perlite, dolomitic limestone, gypsum, starter nutrient charge, and wetting agent) (SunGro Horticulture, Bellevue, WA) at the farm of the University of Arkansas Agricultural Research and Extension Center, Fayetteville, in January, 2002. At potting, trees were cut 2.5 cm (1 in.) above the graft union and subsequently new growth was trained to single shoot and all lateral buds were removed. Plants were grown in a greenhouse with temperatures of 25-30/18-20ºC (77-86/64.4-68 degrees F) (day/night). Trees were watered as needed and fertilized with a Peters' soluble 10N-4.4P-8.3K fertilizer weekly. Pests were controlled by chemical treatments only if found present from scouting.

Trees were divided into six replications of ten single-tree experimental unit treatments. When shoots were approximately 20 cm (7.9 in.)

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in height (February, 2002) treatments were applied one time for the study. Treatments included: 1) 4% soybean oil (SO), 2) 2% lime-sulfur (LS) + 2% SO, 3) 4% LS + 2% SO, 4) 4% LS + 4% SO, 5) 0.5% sodium chloride (NaCl), 6) 2% NaCl, 7) 5% potassium bicarbonate ($KHCO_3$), 8) 5% potassium bisulfate ($KHSO_4$), 9) 8% LS and 10) untreated control. Trees were placed in a completely randomized design in the greenhouse.

Study 2 (November – December, 2002). M.111 EMLA, clonal apple rootstock liners (0.30-0.50 cm (0.11-0.2 in) diameter) were planted in 4.1 L (1.1 gal) pots with SB500 mix and grown in a greenhouse (as described previously) in late August, 2002. After planting, liners were cut 2.5 cm (1 in.) above the soil leaving two buds exposed. Plants were grown as single shoots and managed as described above.

Treatments were applied once with 1 L (0.26 gal) spray bottles until leaves were dripping. Treatments included: 1) LS 4% + SO 4%, 2) 2% NaCl, 3) 5% $KHCO_3$, 4) 5% ($KHSO_4$), and 5) untreated control. The trees were placed in a completely randomized design with five single-tree experimental unit replications of each treatment.

Measurement Variables. A CIRAS-1‘ differential CO_2/H_2O infrared gas analyzer with integral cuvette air supply unit and Parkinson leaf cuvette with an automatic light control was used for the measurements of photosynthetic assimilation (Pn), internal CO_2 (Ci), evapotranspiration (Et), conductance (gs), leaf temperature (T), relative humidity (RH), and photosynthetically active radiation (PAR) in each study. The chamber of the leaf cuvette measured a leaf surface area of 2.5 cm^2 (1 $in.^2$). The leaf chamber conditions were set for 50% RH, 350 ppm CO_2. Light saturation of PAR for all measurements averaged >1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and temperature of 25 to 32ºC (77 to 89.6ºF) (Table 1).

Each tree was labeled at the fifth and seventh leaf for continued measurement of the same leaves. In Study 1, leaves were measured on -1, 1, 4, 8, 15, and 22 days after treatment. In Study 2, leaves were measured on -1, 1, 3, 10, and 20 days after treatment. Following measurements, trees were cut off at the graft union. Leaves were divided between treated and newly emerged. Growth measurements were recorded for the stem dry weight (oven dried), total plant dry weight (oven dried), total leaf surface area, and average leaf area. The growth and treatment measurements were based on a previous, similar study using shade treatments (Barden, 1977). The various treatments used in the two studies represented a range of solution pH and electrical conductivity (EC) characteristics (Table 2).

The statistical analysis for this study was done using JMP-IN software using an LSD student's t test.

Results and discussion

Study 1. Treatments of the 5% $KHCO_3$, 5% $KHSO_4$, 4% SO, 8% LS, and 2% LS + 2% SO significantly decreased Pn. Three different treatment combinations of LS and SO treatments were introduced to compare differences in concentration. The lowest concentration (2% LS and 2% SO) was the only one to show a significant decrease in Pn when compared to the higher concentrations (Fig. 1A). Treatments of the 5% $KHCO_3$, 5% $KHSO_4$, 4% SO, 8% LS, and 2% LS + 2% SO significantly decreased Et (Fig. 1B). Treatments of the 5% $KHCO_3$, 5% $KHSO_4$, 4% SO, 8% LS, and 2% LS + 2% SO significantly decreased gs (Fig. 1C).

Study 2. Treatments of 5% $KHSO_4$, 5% $KHCO_3$ and 2% NaCl significantly reduced Pn (Fig. 2A). Treatments of 5% $KHSO_4$ and 5% $KHCO_3$ significantly reduced Et (Fig. 2B). Treatments of 5% $KHSO_4$ and 5% $KHCO_3$ significantly reduced gs (Fig. 2C). Stem weight, total plant weight, average leaf weight, and leaf surface area of the treated plants although reduced were not significant when compared to the control 20 days after treatment.

A treatment of $KHSO_4$ had the greatest decrease in Pn out of all treatments. The gs was reduced following treatment. As an acidic salt, this treatment potentially influenced the amount of stomates present on the leaf's surface, which resulted in a decrease of Pn, Et, and gs. The leave exhibited necrotic burn. This damage appeared as small burn lesions randomly distributed all over the leaves. A 5% concentration of $KHSO_4$ has a pH of 1.1 and a high EC of 333 mV (Table 2). This caustic nature is presumed to be the cause of the necrosis.

The LS treatments have the potential to act as a caustic agent for fruit thinning purposes. This compound has a pH in the range of 10-11 and a low EC measured at -246, acting as a strong base. When applied as a thinning agent, it is capable of stressing the leaves of the tree due to osmotic tension on stomatal and epidermal cells therefore lowering Pn, Et, gs.

A treatment of SO may potentially cover and plug of stomates. This can slow the Pn of the leaves and results in a lower Et. A SO application on the tree may cover stomatal pores on the leaf surface of the plant. This may decrease the plant's photosynthesis and transpiration and further decrease the amount of carbohydrates available for cell division resulting in fruit abortion (Weller et al., 1978).

Conclusion

The model plant study was a successful method for studying photosynthetic inhibitors under a controlled environment. In both studies, osmotics, salts, and oils reduced Pn, Et, and gs in model vegetative apple trees. Future studies will need an increase in replications to show more significance between treatments and control. The next step is to study each individual photosynthetic inhibitor for differential effects among various concentrations. Once concentration effects have been measured, it will be necessary to apply these photosynthetic inhibitors in the orchard during the post-bloom period. This will show the true potential of these inhibitors as fruit thinning agents.

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Table 1. Environmental parameters for gas exchange measurements of the effect of potential organic thinning chemicals on apple, Fayetteville, Ark., 2002.

Date (days after treatment)	Average cuvette light PAR (µmols•m^{-2}•s^{-1})	Average leaf temperature (oC)	Average cuvette relative humidity (%)
	Study 1: February - March 2002		
20 Feb (-1)	1273.1	30.0	-
22 Feb (1)	924.8	25.4	-
25 Feb (4)	945.1	23.6	-
1-Mar (8)	991.0	23.3	-
8-Mar (15)	998.1	24.3	-
15-Mar (22)	967.8	23.2	-
	Study 2: November - December 2002		
12-Nov (-1)	1323.5	24.2	7.0
13-Nov (1)	1274.9	24.4	6.1
15-Nov (3)	1295.1	25.2	5.5
22-Nov (10)	1178.2	24.2	5.4
2-Dec (20)	1203.4	25.8	4.5

Table 2. Characteristics of spray solutions used in studying effects on apple leaf gas exchange.

Treatment	pH	EC (mV)[z]
Control H20	6.90	15
Potassium bisulfate 5%	1.09	333
Potassium bicarbonate 5%	8.30	-71
Sodium chloride 0.5%	4.67	140
Sodium chloride 2%	4.85	124
Lime-sulfur 8%	11.25	-246
Soybean oil 4%	9.51	-145
Lime-sulfur 2% + soybean oil 2%	10.39	-198
Lime-sulfur 4% + soybean oil 2%	10.78	-219
Lime-sulfur 4% + soybean oil 4%	10.88	-224

[z] EC = electrical conductivity, mV = millivolts.

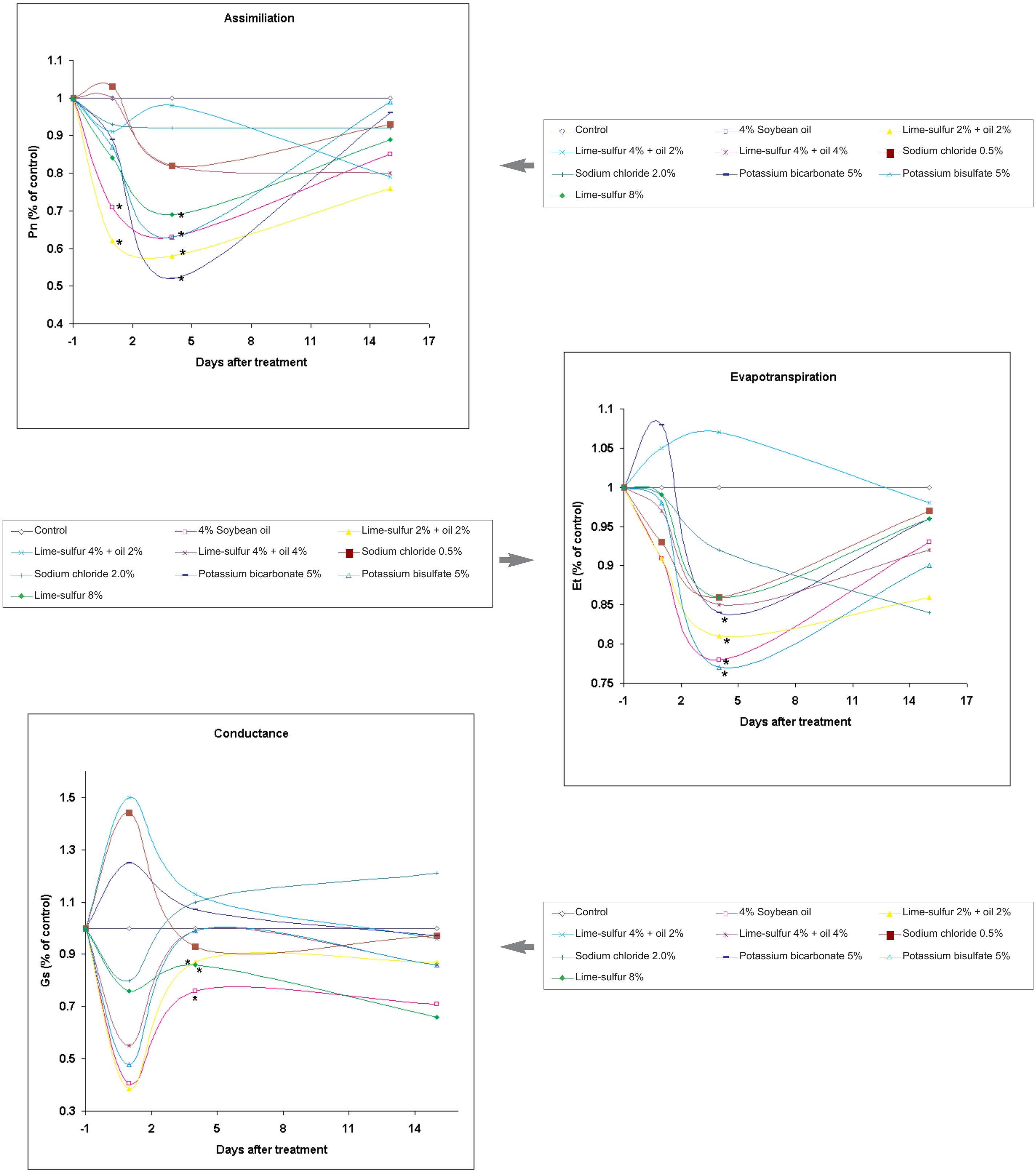

Fig. 1. Pn (A), Et (B), and gs (C) in response to various treatments of organic thinning chemicals, Fayetteville, Ark., February – March, 2002.*
*** Values are percent of control and mean separation by LSD (*P*<0.05, n = 10).**

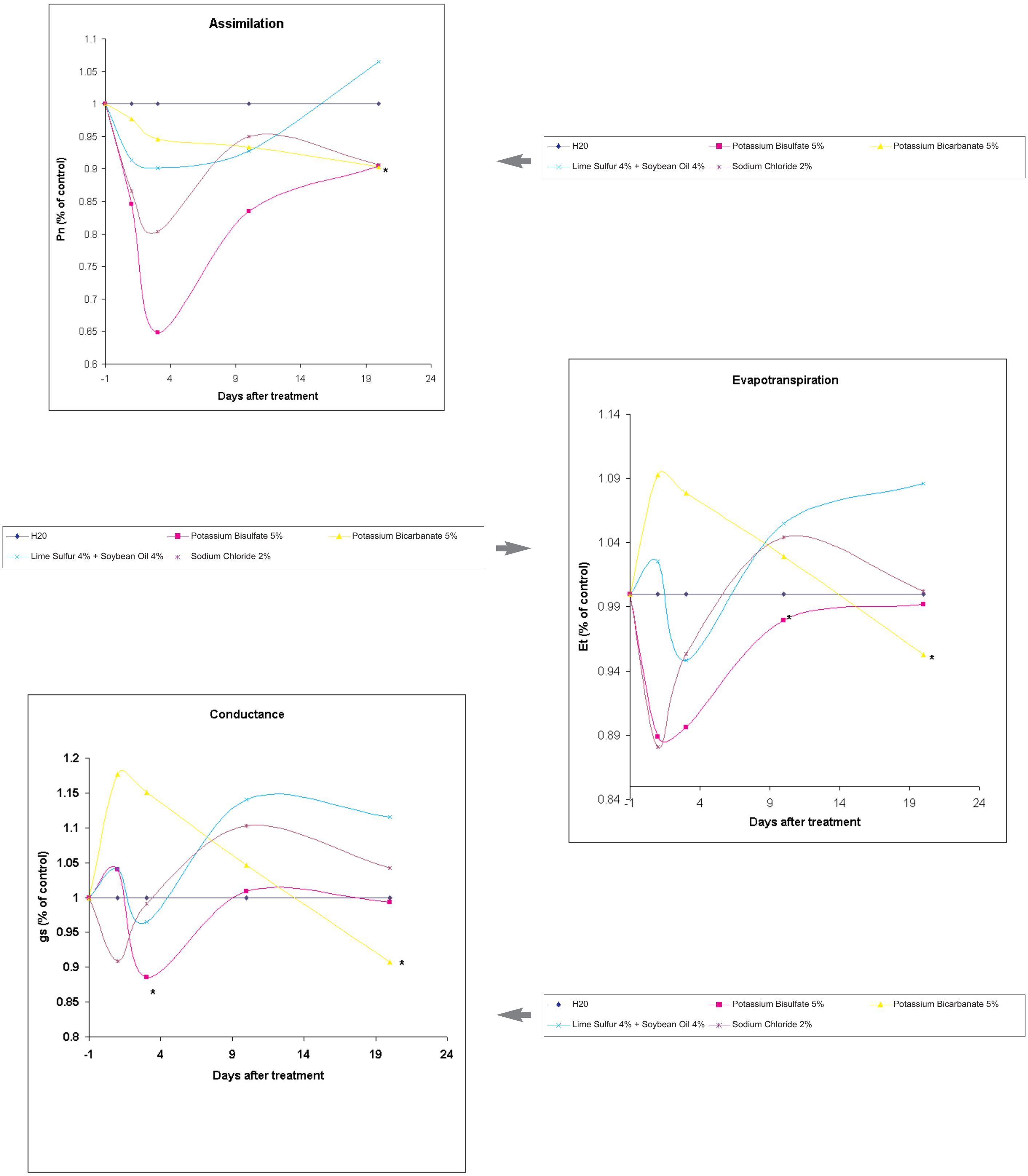

Fig. 2. Pn (A), Et (B), and gs (C) in response to various treatments of organic thinning chemicals, Fayetteville, Ark., November - December, 2002.*

*** Values are percent of control and mean separation by LSD (*P*<0.05, n = 10).**